SPOTTING THE SIGNS: SITUATION AWARENESS AT LEVEL CROSSINGS

Dan Basacik[1], Stephanie Cynk[1] and Toni Flint[2]

[1]TRL, [2]RSSB

SUMMARY

In 2009 RSSB commissioned a root and branch review of signing requirements at level crossings to determine, without the influence of the legacy of previous requirements and constraints, the types of signs, signals and markings that would be most effective in reducing road user errors at level crossings, and consequently whether improvements can be made on existing arrangements. As part of this study a laboratory experiment was conducted to evaluate road users' awareness of the possibility that another train might arrive at the crossing after the first train has passed, and also their awareness that they should not enter the crossing until the exit is clear. The study found that awareness of the possibility of a second train was low even where measures were present to inform road users. Awareness of the need to wait for the crossing exit to clear before driving onto the crossing was higher, but still one in five participants said that they would expect to enter the crossing despite a lorry blocking the exit. This paper concludes that alternative methods of raising awareness of these potential scenarios should be designed and tested with participants, and measures that are shown to be beneficial should be considered for implementation.

NOTATION

AHB: Automatic half barrier level crossings, with half barriers and light signals

AHB Max: Automatic half barrier level crossing scenario, in which signs are in place to warn road users of additional hazards such as the possibility of a second train passing through the crossing in one closure.

AOCL: Automatic open crossing locally monitored, with light signals but no barriers

Blocking back: Situations in which a road user enters a level crossing but can not leave the crossing on the other side due to an obstacle (such as queuing traffic)

CGI: Computer-generated imagery

FWI: Fatalities and Weighted Injuries

MCB: Manually controlled barrier crossings, with full barriers across the road and light signals

MCG: Manually controlled gated level crossing, with swing gates operated by railway staff, and usually no light signals

OC: Open crossings, with no light signals or barriers

Situation awareness: Understanding of what is happening and what might happen in the near future

SRM: Safety Risk Model

INTRODUCTION

Level crossings in Great Britain are very safe by international standards; nevertheless, while the number of fatalities in the rail and road systems in Great Britain have fallen over the last ten years, the incidence at level crossings has remained relatively constant; only in the last two years has there been some evidence of a possible reduction. Total risk at level crossings is calculated at 11.3 Fatalities and Weighted Injuries (FWI) per year, and this is approximately eight percent of the total risk on GB railways [1].

In 2011/12, there were more than 3,800 reported incidents of misuse by road users at level crossings, and RSSB states that these incidents are under-reported [1]. The need to tackle the issue of road user behaviour at level crossings is therefore very clear.

In 2009 RSSB commissioned a review of signs and signals at level crossings to determine, from first principles, what signs, signals and markings would be beneficial in reducing road user errors at level crossings. As part of this study, a laboratory experiment was conducted to assess road users' situation awareness. Endsley defines situation awareness as, 'knowing what is going on around you,' [2] and differentiates between three levels:

1. Perception, which involves taking in information through the senses
2. Comprehension, which is about assigning a meaning to the information, through processes such as combination, interpretation, storage and retrieval
3. Projection, the highest level of situation awareness, in which information about current events is used to forecast future events

Poor situation awareness has been identified as a primary factor in accidents involving human error [3], and could be associated with incidents at level crossings.

This paper focuses on road users' awareness of two key hazards at level crossings:

- *Blocking back*, which occurs when vehicle drivers enter the level crossing at a time when the crossing exit is blocked (eg by queuing traffic). According to Version 6 of the Safety Risk Model (SRMv6), this is the cause of approximately 7% of the risk associated with vehicles at level crossings.
- A*nother train coming* through the crossing, which causes about 10% of the risk associated with pedestrians at level crossings.

According to the Highway Code [4], drivers in Great Britain must, 'Never drive onto a crossing until the road is clear on the other side.' At automatic and open crossings, drivers are provided with the sign in Figure 1, which reminds them that this is the case.

Figure 1: Sign used to instruct drivers not to drive onto the crossing if the exit is blocked

The primary indications that more than one train will pass through the crossing during a single road closure are that any signals provided continue to flash red, and the barriers, if provided, stay down. Additional measures are, however, provided at level crossings where the road is not fully closed off by barriers. These measures include:

- The tone of the audible alarm changes after the first train passes through the crossing
- At automatic crossings with half barriers, the sign shown in Figure 2 is used
- At automatic crossings with no barriers, the signal shown in Figure 2 is used (it appears black when not activated, and the background flashes red when it is activated.

Figure 2: Sign (left) and light signal (right) advising road users that another train may pass through the crossing

A range of measures therefore exists to warn and inform road users not to block back on the crossing, and that more than one train may come through the crossing. This experiment sought to evaluate the effectiveness of these measures.

Road users are poor at recalling the presence of road signs in environments they have experienced. Johansson and Rumar [5] showed that a large proportion of drivers were unaware of the road signs that they passed. In their study, drivers were stopped after they had passed a road sign and only 47% were able to recall seeing it. They suggest that the road user may be predisposed to attending to items of visual information which have more of an impact on their actions and immediate wellbeing.

Nevertheless, other research has shown that road signs do have a priming effect on driver behaviour, resulting in drivers responding more quickly to the hazards which they represent [6]. This leads us to expect relatively poor recall of signs, but better awareness of any hazards or appropriate courses of action to take. In other words, one might expect level one and two situation awareness (recall of perceived information) to be low in relation to signs, and level three situation awareness (projection of information to forecast future events) to be high.

Also interesting is the potential for elements that aren't present being recalled; the psychological phenomenon of closure happens when, if sufficient information about an object or scene are present, the mind completes the picture and sees the full object or scene, even though key details are missing [7]. This could result in elements that are not present in the environment being recalled due to a strong association between the element and the level crossing environment.

Research questions

This research addressed the following questions:

- Does participants' awareness of the potential for more than one train to pass through the crossing vary by type of level crossing?
- Do current second train warning signs and sounds affect awareness of the potential for second trains?
- Are participants aware that they should not enter the level crossing before the crossing exit is clear?
- Is awareness of blocking back dependent on level crossing type if a lorry is parked at the level crossing exit?

METHOD

Participant road users watched a series of videos showing virtual reality (CGI) approaches to level crossings, and were asked a series of questions to probe their awareness of key aspects of the scenario which they had experienced.

Equipment

Videos of the virtual reality approaches to level crossings were recorded using TRL's car driving simulator (DigiCar) and SCANeR Studio software. The software allows the driver's point of view to be adjusted and a maximum speed to be set. This enabled, for example, horse riders to view the scenes from the left hand side of the road, and from a point higher than car drivers. Their videos also proceeded at a slower pace than videos for drivers of motorised vehicles. A laptop computer, and a Christie VividGreen projector were used to project the visual scenes onto a screen in a laboratory environment. The laboratory environment was set up to ensure that participants viewed the scenes from an appropriate distance for the size of the images presented. Care was taken to ensure that no distractions were present within the participants' field of view.. A joystick was used to allow participants to indicate their preferred speed choice.

Trial videos

There were two key factors to be considered during this analysis: type of level crossing (five types) and presence of second train warnings (two options). These variables were combined to give a total of six scenarios as shown in Table 1.

Table 1: Summary table of the combinations of type of level crossing and presence of second train warnings

Type of LC	Location	Road Speed	2nd train warnings
MCB	Town	30mph	No
MCG	Village	30mph	No
AOCL	Village	30mph	No
AHB	Inter-urban	50mph	No
AHB	Inter-urban	50mph	Yes
OC	Rural	60mph	No

Virtual reality approaches to each of these types of level crossing were constructed, and care was taken to ensure that all of the signs, signals and road markings, as well as the appearance of the crossing itself, were realistic and complied with regulations [8,9].

As the type of level crossing is highly dependent on factors such as road and rail traffic, they do tend to be installed in surroundings that are different to one another. Thus, the type of level crossing also dictated the type of surrounding and road speed.

Two AHB scenarios were constructed, one of which was located on a single track section and one on a double track section. In the latter scenario it would be possible for more than one train to pass through the crossing without the barriers being raised; thus, road users were given the prescribed warnings, comprising a traffic sign, and an audible warning which changed in tone after the first train passed.

Images of the level crossing environments used during the study are shown in Figure 3.

Figure 3: Images of the level crossing environments used (top left: OC, top right: AOCL, centre left: AHB, centre right: AHB Max, bottom left, MCB, bottom right: MCG)

In order to prevent participants from developing an expectation about the content of the videos, each participant was shown three level crossing scenarios, and six other scenarios which contained a selection of road scenes unrelated to the aims of this analysis. The order in which videos were presented was balanced.

Participants

Sixty participants were recruited at random from TRL's participant database of almost 2000 road users to take part in the trials. Participants were a mixture of male and female road users, with a split between four age groups (17-25, 26-40, 41-55 and 56+). Participants also represented different groups of road user; twenty-five were car drivers and the remainder were HGV or bus drivers (ten of each), motorcyclists, cyclists or pedestrians (five of each).

Trial protocol

After their arrival at TRL, participants were accompanied to the trial room. An eye tracker was fitted to collect data which has been analysed and reported separately [10]. The eye tracker used was lightweight and fitted to a headband worn by the participant. It did not interfere with their vision and is unlikely to have impacted on measures of situation awareness.

Participants were then given tasks to immerse them into the scenario. They were asked to watch each scenario and to indicate, using the joystick, whether they would normally prefer to travel faster, slower or at the same pace. They were also asked to indicate any hazards for which they thought they should stop by squeezing the trigger button on the joystick. This joystick task aimed to focus participants' attention on the videos and strengthen their immersion in the scenario. The data from this task were not recorded.

The experimenter stayed with the participant for the duration of the trial. After the participant viewed each level crossing approach they were asked a number of questions to gauge their situation awareness. This process was repeated for all of the videos (including those not relevant to the study aims).

Measures

Questions were generated to test three levels of situation awareness for *another train coming and blocking back* scenarios. Most of the questions on another train coming evaluated awareness and expectations about the barriers and traffic light signals. A direct question about the possibility of another train was only asked during the AHB Max scenario, in order to minimise the likelihood of participants being alerted to the possibility of another train, and responses being affected by the questions asked during other scenarios. In order to gauge awareness regarding blocking back, participants were asked questions covering their awareness of the presence of other road users, ability to identify those that may impede progress, and understanding of how this would affect one's own future actions.

RESULTS

The sample included 60 participants who each viewed three out of six level crossing scenarios and videos of other road scenes that aimed to distract them from the purpose of the study. Each level crossing approach was presented, on average, thirty times.

Another train coming

Measures taken to examine awareness of *another train coming* were:

- Recall of the 'Another train coming if lights continue to show' sign
- Recall of the presence (or absence), current status and likely future status of the barrier
- Recall of the presence (or absence), current status and likely future status of the light signals

As expected, participants' recall of the 'Another train coming if lights continue to show' sign was low. This sign was only presented in the AHB Max scenario, but only four out of thirty participants recalled its presence after the video was stopped. This sign was in full view during the final seconds of the video.

In contrast, most of the participants were correct in identifying whether they had seen a barrier. There were some exceptions; one of the participants who viewed the AHB Max scenario incorrectly stated that there was no barrier, and three who viewed the AOCL scenario incorrectly identified that there was a barrier. The difference between the AOCL and AHB Max scenarios in terms of the proportion of presentations in which an incorrect answer was given was approaching statistical significance ($z=1.52$, $p=.06$). This may potentially highlight the role that expectation plays when people approach level crossings.

Participants who said that they had seen a barrier at the level crossing were asked whether it was blocking the road or whether it was open. In all cases, participants who identified that there was a barrier in the scenario stated that the barrier was blocking the road (even if there was no barrier present in the scene).

Participants who identified that a barrier was present after watching the level crossing scenarios were also asked how they would expect the barrier position to change if the video were to continue from where it finished. There were a number of items in the AHB Max scenario to warn the participant that a second train was approaching, including the sign shown in Figure 2, and the pitch and frequency of the audible warning also changed after the first train passed in order to indicate the approach of another train. Table 2 shows the number of presentations in which participants assumed that the barrier would open after the first train had passed.

Table 2: Number of presentations in which participants assumed the barrier would rise after the first train

Scenario	N	Number who assumed barrier would rise
AHB	29	27
MCG	30	29
MCB	31	29
AHB Max	29	22

A series of proportion tests were carried out to determine if there was a significant effect of level crossing type on whether or not participants assumed the barriers would rise after the first train passed. As a number of proportion tests were conducted, a Bonferroni correction was applied. This showed that a significantly lower proportion of people stated that:

- The barrier would open after the first train had passed in the AHB Max scenario than in the AHB scenario, $z = 2.64$, $p < .01$.
- The barrier would open after the first train had passed in the AHB Max scenario than in the MCG scenario, $z = 3.44$, $p < .01$.

There were no significant differences between the proportion of participants who assumed the barriers would open after the first train passed at other level crossing types. The results suggest that participants did not consider that the barriers at the crossing may stay down for another train. Although there was a statistically significant increase in the proportion of participants who considered this possibility when a sign and audible warning were presented, the size of the increase was small.

The second approach taken to assess participants' awareness of another train coming was to evaluate their recollection, comprehension and projection of the aspect displayed by the light signals. Participants were asked if they saw any traffic light signals during the video. In most cases participants were aware of the signals where they were present; however, in the MCG scenario where there were no light signals, four out of thirty participants incorrectly stated that there were and a further two were unsure. The difference between this and the AHB Max scenario in terms of correct responses given was also statistically significant ($z=2.94$, $p<.01$).

Participants who said that they saw light signals were asked what aspect the signals were showing when the video ended, and most participants correctly identified that the signals had been displaying a flashing red aspect; however, there was one participant in each of the AHB Max, AOCL and MCB scenarios who gave an incorrect response when questioned. Interestingly, those who thought there was a light signal at MCGs (which there was not) gave a range of different answers when asked what state it was displaying.

Participants were asked whether they would expect the light signals to change after the first train had passed. Data for the AOCL scenario was not included in the analysis since the design of this scenario meant that more than one would not pass through the level crossing during a single closure. Table 3 shows that in all scenarios, and even those with 'another train coming' warnings, most participants assumed the light signals would change after the first train had passed.

Table 3: Number of presentations in which participants assumed that the signals would change

Scenario	N	Assumed signals would change
MCB	30	27
AHB Max	29	26
AHB	29	26

The proportion of participants who assumed that the light signals would change after the first train had passed did not differ by level crossing type ($z = 0.06$, $p > .05$). This was found despite the presence of a number of cues, including an 'another train coming if lights continue to show' sign and a change in the pitch and frequency of the audible warning, in the AHB Max scenario to warn the participant that a second train was approaching.

Finally, participants who experienced the AHB Max scenario were asked directly whether they would expect another train to pass through the crossing. The results of this question need to be interpreted with caution because the question itself would have prompted participants to consider the possibility of a second train passing through the crossing. Responses to this question are given in Table 4, and show that just under half of respondents did not think that another train could pass through the crossing or were unsure, even when prompted by the question, and having experienced a scenario with a sign that indicates that this is a possibility.

Table 4: Participants' expectations of another train coming through the crossing in the AHB Max scenario

Expectation	Number of participants
Yes, a further train could pass	17
No, a further train could not pass	2
Unsure	11

Blocking back

Four key measures were taken to evaluate awareness regarding blocking back. These were:

- Awareness of the 'Keep Crossing Clear' sign
- Awareness of other road users in the virtual reality environment
- Awareness that the lorry parked on the other side of the crossing would affect the participant's progress
- Awareness that they should not proceed onto the level crossing once train had passed and the lights and barriers (if present) indicated that the crossing was clear.

In each of the AHB, AHB Max and AOCL scenarios only one or two participants recalled the 'Keep Crossing Clear' sign, indicating that recall of this sign was low. In the OC scenario, however, almost a quarter of the participants recalled this sign, significantly more than in any of the others ($z=2.63$, $p<0.01$). It may be that more attention was given to signs in this scenario than any of the others because there are no active controls such as barriers or light signals. Most participants who took part in the experiment, however, did not recall this sign.

Only car drivers, bus drivers and HGV drivers were included in the remainder of the analysis, which focussed on the crossing exit being blocked by a stationary lorry. This is because these are the only road users whose progress would be affected by a lorry parked on the other side of the crossing.

Awareness of another road user was generally high, and lowest in the MCG scenario where other road users were still very clearly visible, albeit more obscured by the gates than in other scenarios. Only one participant in the AHB Max and MCB scenarios stated that there were no other road users present. However, on the approach to the MCG, only 15 out of 21 participants identified that there were other road users.

Table 5: Participants' responses to questions regarding blocking back

Scenario	N	Number who saw other road users	Number who saw the lorry	Number who would proceed
AHB	18	18	17	3
AHB Max	19	18	18	3
AOCL	18	18	17	3
MCB	22	21	21	3
MCG	21	15	10	11
OC	22	22	22	6

Overall, most participants identified that their progress would be most directly affected by the lorry on the other side of the level crossing, although some did not. Fewer than half of the participants viewing the MCG scenario identified the lorry as most directly affecting their progress. This result may have been found due to the fact that MCG gates are made of larger materials and cause more of an obscuration of the road ahead than other types of barrier.

Participants were finally asked whether they would expect to proceed over the level crossing once the train had passed and the level crossing was clear. In most of the scenarios, fewer than a fifth said that they would proceed, thus indicating that they were aware of factors other than trains, lights and barriers which should influence their decision to enter the crossing. However, approximately half of the drivers experiencing the MCG scenario said that they would proceed, and over a quarter said that they would proceed at the OC.A significantly higher proportion of people stated that they would proceed at the MCG than at other level crossing types, $z = 2.46$, $p < .01$. There were no statistically significant differences between the proportion of participants who expected to proceed after the train had passed and other level crossing types.

DISCUSSION

This study aimed to assess participants' situation awareness when approaching level crossings, using computer simulation methods.

Participants' recall of signs was low. Very few recalled the 'another train coming' sign or the 'Keep crossing clear' sign. One factor contributing to this might be that there are many signs on the approach to level crossings, and this may put a strain on short-term memory, ultimately reducing the ability to recall individual items. Nevertheless, other studies have also found that recall of traffic signs can be low. The notably different scenario was the Open Crossing scenario in which almost a quarter of participants recalled the 'Keep Crossing Clear' sign. One reason for this might be that people are relatively unlikely to come across crossings without any active controls, and therefore participants may have been searching for information and taking in the information on signs in order to interpret their environment. In addition, the sign is salient to immediate task demands, and this may have further increased recall of the sign. This explanation would fit with previous research which has found that people are likely to search for information that is directly relevant to them.

Indeed, participants' recall of active controls such as traffic light signals and barriers was significantly higher than recall of signs. Almost all of the participants who were presented with a scenario with light signals or barriers correctly recalled their presence. There were, however, two interesting cases where some of the participants incorrectly stated that one of these elements was present when it was not. For example, the MCG that was presented to participants had gates but no light signals, yet a small but significant percentage of participants said that they recalled seeing light signals. Conversely, the AOCL scenario had light signals but no barriers, and again a small but significant percentage of participants recalled seeing barriers which were not present. Both of these types of level crossing are relatively unusual in Great Britain; there are many more level crossings, especially on frequently used roads, that have both barriers and light signals. This finding highlights that expectation may play an important role in recollection of the details of a scene.

The difference between level crossing types in terms of awareness of potential for more than one train to pass through was small. On the whole participants assumed that the barrier would rise and the light signals would change immediately after the first train passed. In the AHB Max scenario slightly more participants thought that the barrier might not rise after the first train. This difference of one in ten participants was statistically significant but small in size when considering that specific measures are in place to target this issue. This does suggest that there is room for improvement with current measures.

When asked directly whether another train might pass through this crossing, just over half of participants said that they would expect this to happen; however, most of these participants had also said that they expected the barrier to rise after the first train. It is important to consider that the question itself may have prompted participants to consider the possibility of a second train. Thus, these results need to be interpreted with caution.

In most scenarios, very few participants recalled seeing the 'Keep Crossing Clear' sign, although in the Open Crossing scenario almost a quarter of participants recalled the sign. This is a similar result to the recall of the 'Another Train Coming' sign, and could be explained by road users searching for information in their environment in order to understand how to use the crossing.

In most scenarios almost all of the participants identified that a stationary lorry on the other side of the crossing would affect their progress, and again most participants said that they would not proceed over the crossing when the lights changed from flashing red, barriers or gates opened or trains passed. However, the MCG scenario yielded strikingly different results. Fewer than half of the participants identified the lorry as affecting their progress, and again fewer than half said that they would not proceed even if the gates were opened. Thus, it seems that participants who experienced this approach were not as aware of the blocking back scenario that would occur if they were to proceed onto the crossing. MCGs have bulky gates rather than the thinner type of barrier seen at some other types of level crossing. These gates cause more of a visual obstruction of what is on the other side of the crossing than barriers, so this may have had an influence on participants' awareness of the stationary lorry at the crossing exit.

Nevertheless approximately one in four participants who took part in this experiment were prepared to enter the crossing even though the exit appeared blocked. It may be that some participants would only check whether or not the exit is impeded after the train has passed, the barrier has been lifted, or the lights stop flashing, but on the whole, the results do suggest that there is room to improve road users' awareness regarding blocking back.

CONCLUSIONS

This experiment with 60 participants has evaluated road users' awareness of the possibility that another train might arrive at the crossing after the first train has passed, and also their awareness that they should not block back over the crossing.

Awareness of the 'Another Train Coming' sign was low, and in general participants' expectations regarding the active crossing controls (where present) were that they would change to allow road users through immediately after the passing of the first train. Although where signs and audible warnings (changing in tone) were present in the scenario the level of awareness increased, the size of this increase was small.

Awareness of the ‘Keep Crossing Clear’ signs was also low. Although awareness of road users that it would impede their progress was generally high, almost a quarter of participants said that they would enter the crossing despite the exit being blocked. This suggests that current measures aimed at preventing blocking back are not as effective as they could be.

Alternative methods of raising awareness of another train coming scenarios or blocking back should be designed and tested with participants, and measures that are shown to be beneficial should be considered for implementation.

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APPENDIX 1:

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