An Evaluation of Retro-Reflective Screens to Aid Conspicuity of Freight Trains at Passive-Control Level Crossings

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This peer-reviewed paper was first submitted as an Extended Abstract and an Oral Presentation was recommended by two reviewers at the 2021 Australasian Road Safety Conference (ARSC2021) to be held in Melbourne, Australia in September. The two Reviewers also recommended that the Extended Abstract be expanded into a 'Full Paper' and undergo further peer-review as a journal submission by three independent experts in the field. The Extended Abstract will be published in the ARSC2019 Proceedings with a link guiding readers to this 'Full Paper' version which is being reproduced here with the kind permission of the authors and will only be available in this edition of the JRS.

Key Findings

- Freight trains are difficult to see at level crossings in rural areas at night;
- Retro-reflective screens that reflect vehicle headlights could improve visibility;
- Effectiveness of a prototype screen was evaluated using a reaction time experiment;
- Screen led to shorter reactions (increased visibility) with high beam headlights;
- But longer reactions (reduced visibility or maybe confused drivers) with low beam.

Abstract

Freight trains already passing through level crossings in rural areas at night can be difficult for approaching motorists to see. Crashes can occur if the crossing has 'passive' controls (Give way/Stop signs) and motorists fail to stop. Retro-reflective screens on the far side of the crossing to motorists that reflect headlights and produce a 'strobing' effect between carriages could increase train conspicuity. A prototype screen was applied to a crossing in South Australia. Four videos of freight trains at night from the perspective of an approaching vehicle (conditions: high versus low beam headlights, screen versus no screen) were recorded and used in a reaction time experiment with N=29 drivers. Mean reaction times to the four videos were examined using multivariate analysis of variance. Results were mixed. With high beam headlights, the screen led to shorter reaction times, which suggests it increased train visibility. With low beam headlights, it led to longer reaction times, which suggests it reduced train visibility or that it confused drivers. The detrimental effect of the screen with low beam headlights could be, at least partly, due to methodological limitations relating to differences between trains in the videos, the instructions given to participants, and the degree to which the experiment replicated real-world driver behaviour. However, the screen may genuinely have confused or distracted participants and may do so in real-world conditions. Further experimental testing would be required to determine whether the results in low beam conditions persist when potential methodological limitations are addressed.

Keywords

Trains, Passive-control level crossings, Rail safety, Reaction time experiment, Retro-reflective treatment

Introduction

In urban areas of Australia level crossings between railways and roads have 'active' controls (flashing lights, warning sounds and boom barriers) that are activated by track circuitry in response to an approaching train. However, many level crossings in rural areas have 'passive' controls (Give way or Stop signs), which require road users to look for trains and decide whether they are safe to cross the rail corridor.

The issue with passive crossings is the potential for human error. If a motorist fails to stop and check for trains a crash may occur. Trains (specifically freight trains) can be difficult to see at night in rural areas as there may not be any artificial lighting at the crossings and trains often have no lights or retro-reflective material on their sides, making it difficult to see a train already passing through the crossing when a vehicle approaches. Trains are also relatively infrequent in rural areas and drivers may become accustomed to not seeing one, assume the crossing is clear and drive straight through. These factors increase the risk of a collision. Research in Australia by Tey, Ferreira and Wallace (2011), which examined driver behaviour in video recordings at level crossings and in a driving simulator, showed that driver responses to passive crossings are poor compared to active crossings in terms of stopping compliance, approaching speeds and final braking position. Similarly, simulator research in Australia by Rudin-Brown, Lenné, Edquist and Navarro (2012) showed that crossing violations were less likely at active crossings than passive crossings. There are approximately 6,000 passive level crossings in Australia (Australian Transport Safety Bureau, 2008). It would be a long and expensive process to upgrade all passive crossings in Australia to active crossings or grade separated junctions (under/over passes).

A report from the Australasian Centre for Rail Innovation (ACRI) by White, Baldock, Woolley, Stokes, Royals and Sommariva (2015b) discussed less expensive, ‘passive’ solutions to improve train conspicuity at level crossings at night. One solution was the use of retro-reflective screens on the far side of the crossing to approaching drivers that reflect vehicle headlights. A passing train would intermittently obscure the retro-reflective surface, thereby alerting the driver to its presence through a strobing effect with the reflected headlights visible between carriages. This countermeasure may improve safety at level crossings at night and would not require an additional electricity supply or impede the function of trains or the existing infrastructure.

The present study evaluated the effectiveness of a prototype retro-reflective screen for improving the detection by motorists of freight trains at unsignalised level crossings at night. High quality videos of trains passing through a level crossing from the perspective of a vehicle on the approaching road were created. Day and night videos were created, with the night videos featuring both high and low beam vehicle headlights, and both the screen in place and absent. These videos were used in a reaction time experiment with a sample of drivers. The aim was to determine whether drivers react to trains at night faster when the screen is in place compared to when it is absent, thus demonstrating that it increases train visibility.

Methods

Participants

Participants were a convenience sample recruited through flyers posted around the University of Adelaide, as well as an email sent to undergraduate engineering students. They were required to have a full Australian (or equivalent international) driver licence in order to possess a basic level of driving experience and competency. They also had to be over 18 years of age and speak fluent English.

The sample consisted of 29 participants, with 12 (41.4%) males and 17 (58.6%) females. They ranged in age from 21 to 68 (mean=34.9 years, *SD*=15.2). Fourteen (48.3%) were full-time students, eighteen (62.1%) were working (12 full-time, five part-time, one casual) and two (6.9%) were retired. The highest education levels they had completed were: some high school = two (6.9%) participants, year 12 = twelve (41.4%), technical certificate = one (3.4%), diploma = two (6.9%), bachelor degree = four (13.8%), post graduate diploma = one (3.4%), post graduate degree = one (3.4%), four (13.8%) honours degree = four (13.8%), and master’s degree = one (3.4%) (highest education not recorded for one participant). Thirteen (44.8%) were not born in Australian (three from China, two from India, two from England, and one each from South Africa, Germany, Iran, Hong Kong, Vietnam and Scotland), with their mean years in Australia being 15.3 (*SD*=12.0).

Materials

The retro-reflective screen

The prototype (1,230mm high by 200mm wide) was made of diamond-grade material (to maximise illumination by headlights). It was attached to the back of a Stop/Give way sign on the opposite side of the railway line from where it would be viewed (see Figure 1). It was attached for the experiment using cable ties and gaffer tape, ensuing it could be removed easily once the collection of video footage had been completed.

The screen was applied to a railway site at Mile End, South Australia and pilot-tested at night-time. The following were assessed:

- whether the screen suitably reflected headlights,
- distances at which it could be seen with headlights,
- whether the size of the screen was suitable,
- optimal height for it to be attached,
- whether the temporary methods to secure it were suitable, and
- whether it provided the ‘strobing’ effect between the carriages of a passing train.

Production of videos

Following pilot-testing, a suitable location for recording video footage of freight trains passing through a level crossing with the screen was identified at Callington, South Australia with the assistance of the Australian Rail Track Corporation (ARTC). Importantly, this crossing was unsignalised, had a straight approaching unsealed road, had nothing obscuring the crossing from the perspective of an approaching motorist, and had no artificial lighting.

Researchers attended the site during the day and secured the screen to the back of a Stop Sign. Train schedules were provided by the ARTC in order to anticipate freight trains

Figure 1. Retro-reflective screen applied to the back of a stop sign

passing through the crossing. A car was parked 200 metres from the crossing on the approaching road in a lateral position consistent with the travel path of a car driving on the road. A high definition (4K) video camera (Sony HXR-NX80) was set up in front of the car (perspective of the driver) with the zoom set at 40%, which was subjectively determined to be consistent with a person's primary field of vision. Video footage of a passing train was recorded for the day condition. Next, footage of a passing train was recorded at night with the screen in place and the high beam headlights of the parked vehicle on and then the low beams on. After the train had passed, the screen was removed. The researchers waited for another train and again recorded footage with both high and then low beams. Removing the screen between trains meant that the train in the night videos with the screen was different from the train in the night videos without the screen.

Later viewing of the night footage with low beams and the screen in place revealed that it was inadequate for the experiment. The researchers therefore had to return to the site some weeks later to re-film this footage with a different train. The exact same procedure was used, except only footage at night with low beams and the screen was recorded.

Reaction time experimental materials

A computer program was developed to present train videos to participants for the reaction time experiment. Each video commenced with footage of the crossing with no train present. Participants were expected to react when the train passing through the crossing appeared. The lead-in time prior to the appearance of the train varied between 6, 12 and 18 seconds. This meant that the time passing before the appearance of the train in each video was unpredictable. The lead-in time for the day video was always 12 seconds. Footage of the train passing through the crossing lasted for 20 seconds.

The five individual videos in the program were:

- DDD: day, measured baseline reaction time with optimal light.
- NHU: night, high beams, untreated (no screen).
- NHT: night, high beams, treated (screen) – still from video provided in Figure 2.
- NLU: night, low beams, untreated.
- NLT: night, low beams, treated.

Figure 2. Still from NHT video showing a train passing through the crossing (note the retro-reflective screen on right side of road, which strobed between carriages)

Five rounds of the five videos were presented to each participant. The DDD video was shown first in each of the five rounds. The order of the night videos was varied between participants and between rounds. This was done to control for order effects and the five-round design allowed for practice effects to be examined. The participant was required to react when the train appeared by pressing any key on a keyboard, and then pressing a key again to move onto the next video (or the end screen if it was the final video). Reaction times to each video were recorded by the program. It should be noted that the DDD video showed the front of the train passing through the intersection. However, the night videos did not show the front of the train, as this would have had obvious lights on it. Instead, the lead-in time with no train would end and it would cut straight to the carriages already passing through the crossing. This replicated the situation in which a vehicle would approach the crossing when the front of the train had already passed but the carriages were still passing through.

Participants could incorrectly react to a video in two ways. Firstly, they might press a button before the train had appeared (i.e., during lead-in time), either accidentally or because they incorrectly thought they had seen a train. In such cases, the program would make a loud 'beep' sound, the video would continue (allowing them to correctly react when the train did appear), and an 'error' was recorded in a separate field in the data. Secondly, the 20 seconds in which the train was shown passing at the end of a video might conclude without the participant pressing a key. In such cases, the video would freeze (demonstrating its conclusion), the researcher would press a key on the laptop to skip to the next video (or the end screen), and a reaction time of 20 seconds was recorded. These 20 second reaction times were later identified as 'misses'.

To present the videos, a laptop computer was attached to a 65-inch high-definition Liquid Crystal Display (LCD) television via a High-definition Multimedia Interface (HDMI) cable. Participants sat one and a half metres from the screen and used a keyboard to respond. The experiment was conducted in a dark room to simulate night conditions.

Procedure

Participants attended a single session at the University of Adelaide. They were encouraged to bring any corrective eyewear that they require for normal driving. Upon arrival, an information sheet and a consent form were provided to them. They read both forms and signed the consent form. The information sheet informed them that they could withdraw from the study at any stage (until publication of the results) and that their data would remain confidential. It took approximately ten minutes for a participant to view and react to all videos. Participants were not informed about the retro-reflective treatment prior to taking part in the study but it was discussed with them following completion.

The following instructions were given before participants started the experiment:

"You are going to see a number of videos of a crossing between a railway line and a road. There will be both daytime and night-time videos. At first there will be no train in the crossing, but at some stage during the videos a train will suddenly be passing through. As soon as you see a train you need to press any key on the keyboard. It's a reaction time test, so you need to press the button as fast as you can when you see the train. If you press a button accidentally or you think you see a train and press a button, but the train has not appeared yet, the program will beep. That's okay, just keep going until you do see a train".

The study was conducted according to the National Health and Medical Research Council (NHMRC) National Statement on Ethical Conduct in Human Research 2007 (updated 2018) and was approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2018-037). Following completion of the experiment, participants and their data were only identified using an assigned chronological number. In gratitude for their time, participants were entered into a draw for an iPad.

Multivariate Analysis of Variance (ANOVA), with post-hoc pairwise comparisons, was used to examine reaction times to the night videos (NHU, NHT, NLU, NLT) and determine whether the reaction times were affected by the treatment, and whether this was affected by the headlight setting on the vehicle. For all analyses, an alpha level of 0.05 was used to determine statistical significance.

Results

The extent of 'errors' (participant reacted before train was present) and 'misses' (participant did not react to train) were examined. The number of errors was small, with 31 across all participants, videos and rounds (out of 725 total videos shown). The 31 errors were made by 17 different participants. Sixteen participants made between one and three errors, but one participant made six. Only three errors were made in day videos, with 28 in night videos. This was likely due to trains being more difficult to see in night videos. There was no pattern in the experimental round in which they occurred (4 in Round 1, 11 in Round 2, 7 in Round 3, 5 in Round 4 and 5 in Round 5).

The number of 'misses' was also small, with 13 across 725 total videos. However, all 13 were made in NLT videos. They were made by seven different participants. Five participants only made one miss, and all of these were in the first round. However, one participant made misses in rounds 1, 2 and 5 and another made a miss in every round. The tendency to make fewer misses in later rounds was likely due to practice effects, with participants becoming accustomed to the retro-reflective screen and understanding that the strobing effect meant a train was present. 'Misses' were recorded in the data as a reaction time of 20 seconds. This meant that, although few in number, they could increase the mean reaction time in NLT videos. Consequently, misses were removed from the data and not included in any analyses.

Mean reaction times to the day video across five rounds and to all night videos across five rounds were calculated for each participant. The mean day reaction time for all participants of 0.516 seconds ($SD=0.086$) was significantly faster than the mean night reaction time of 1.011 seconds ($SD=0.305$), according to a paired-samples t-test ($t(28)=9.7$, $p<.001$). This indicates that, not surprisingly, drivers react to trains faster in daylight compared to night-time conditions.

Mean reaction times to the night videos separately across five rounds were: NHU=0.923 seconds ($SD=0.175$), NHT=0.692 seconds ($SD=0.080$), NLU=0.675 seconds ($SD=0.150$), and NLT=1.760 seconds ($SD=1.135$). Figure 3 presents means and 95% confidence intervals. Means for NHT and NLU were similar and had overlapping confidence intervals. While the mean for NHU was higher (longer reaction time) than both NHT and NLU, the mean for NLT was much higher than all other means (confidence intervals for NHU and NLT did not overlap with any others). Mean reaction times were analysed using a repeated-measures ANOVA with two within-participants factors of vehicle headlight (high vs low beam) and presence of the retro-reflective screen (untreated vs treated). Main effects due to headlight ($F(1,27)=14.29$, $p=0.001$, $\eta^2=0.346$) and the screen ($F(1,27)=16.28$, $p<0.001$, $\eta^2=0.376$) and the interaction between these ($F(1,27)=38.80$, $p<0.001$, $\eta^2=0.590$) were statistically significant.

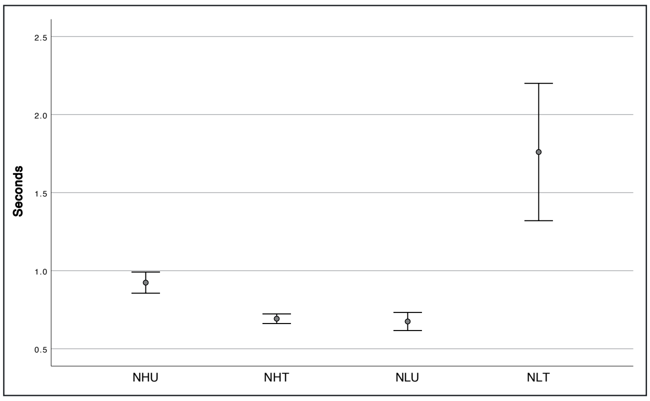

Figure 3. Mean reaction times and 95% confidence intervals across five experimental rounds

This suggests that each variable had a main effect on variance in reaction times (accounting for 35% and 38% of variance respectively), but by examining Figure 3 it is clear that the interaction effects (59% of variance) of the two variables mediate the direction (either shorter or longer reaction time) of each main effect. Consistent with expectations, the screen improved reaction times when high beam headlights were used (NHU vs NHT), but, contrary to expectations, led to a large increase in reaction times (slower reactions) when low beams were used (NLT vs NLU). Another unexpected result was that the NHT video, expected to be the easiest video in which to detect the train, did not differ from the NLU video, expected to be the most difficult video in which to detect the train. Pairwise comparisons showed that all means significantly differed from each other at $p<0.008$ (adjusted to a more conservative alpha level to account for multiple comparisons), except for NHT and NLU.

To examine the degree of practice effects in the experiment, repeated-measures ANOVA tests were used to determine whether the mean reaction times differed between experimental rounds for each video type separately (see Table 1). ANOVA models for NHU and NLT were statically significant. Pairwise comparisons showed that, for both NHU and NLT, Round 1 significantly differed from all other rounds at $p<0.05$. There were no significant differences between any of the later rounds. This indicates that participants improved from Round 1 to consistent reaction times in Rounds 2, 3, 4 and 5 and, therefore, that there were practice effects between Rounds 1 and 2.

Consequently, the final analysis examined mean reaction times to the night videos separately across the later four rounds (Round 1 excluded). The purpose was to examine reaction time results after participants had practised the four videos and their reactions had become consistent. Mean reaction times across Rounds 2, 3, 4 and 5 were: NHU=0.855 seconds ($SD=0.156$), NHT=0.684 seconds ($SD=0.088$), NLU=0.673 seconds ($SD=0.177$), and NLT=1.148 seconds ($SD=0.608$). Figure 4 presents means and 95%CIs. While the mean reaction times for NHU and

Table 1. Mean reaction times (in seconds) by experimental round and video type

Video	Round 1	Round 2	Round 3	Round 4	Round 5	Repeated-measures ANOVA
NHU	1.203	0.873	0.889	0.813	0.871	*$F(4,114)=9.95$, $p<0.001$, partial $\eta^2=0.262$
NHT	0.739	0.694	0.701	0.677	0.686	$F(4,114)=1.66$, $p=0.186$, partial $\eta^2=0.056$
NLU	0.771	0.669	0.761	0.633	0.647	$F(4,108)=1.43$, $p=0.248$, partial $\eta^2=0.050$
NLT	4.938	1.409	1.136	1.038	1.040	*$F(4,84)=10.10$, $p=0.004$, partial $\eta^2=0.325$

*Repeated-measures ANOVA model statistically significant at $p < 0.05$

NLT were slightly shorter (faster reactions) than when all five rounds were included, the same pattern of results was evident (NHT and NLU with similar means, NHU slightly slower, and NLT considerably slower). There was, however, a small overlap this time between the confidence intervals for NHU and NLT.

Mean reaction times were again analysed using a repeated-measures ANOVA with two within-participants factors of vehicle headlight and presence of the screen. Main effects due to headlight ($F(1,27)=4.75$, $p=0.038$, $\eta^2=0.150$) and the screen ($F(1,27)=9.24$, $p=0.005$, $\eta^2=0.255$) and the interaction between these ($F(1,27)=44.03$, $p<0.001$, $\eta^2=0.620$) were statistically significant. Pairwise comparisons showed that all means significantly differed from each other, except for NHT and NLU and NHU and NLT, at $p<0.008$ (more conservative alpha level for multiple comparisons). These results substantiate the earlier results in which all five rounds were included. It should be acknowledged that, while results excluding practice were interesting, they would not reflect real-world conditions, in which, if a screen was applied to an intersection, many drivers would travel through it for the first time and would not have prior understanding of its purpose.

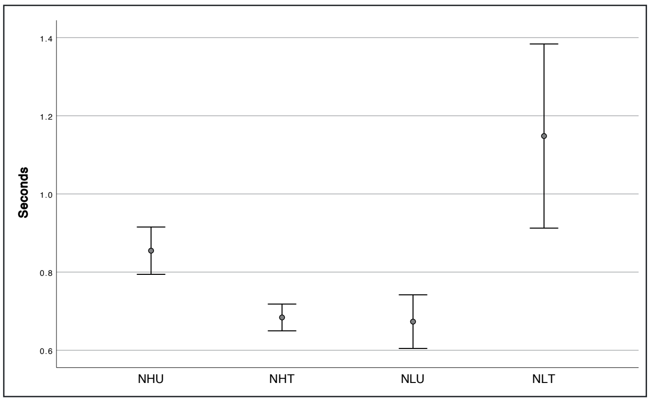

Figure 4. Mean reaction times and 95%CIs across Rounds 2, 3, 4 and 5

Discussion

The intention of this project was to evaluate the effectiveness of a prototype retro-reflective screen for improving the detection by motorists of freight trains travelling through unsignalised level crossings at night. A screen was pilot-tested, with the desired retro-reflective lighting effects achieved. It was then applied to a level crossing in the manner in which it would be used in real-world applications. Videos of passing freight trains from the perspective of an approaching vehicle were recorded and used in a reaction time experiment. The aim was to determine whether drivers react to trains at night faster when the screen is in place compared to when it is absent, thus demonstrating that it increases train visibility and potentially improves safety. Overall, the results were mixed in relation to the effectiveness of the screen. When the approaching vehicle was using high beam headlights, the screen led to shorter reaction times, which suggests it improved visibility of the train. The opposite was found for low beams. The screen led to longer reaction times, which suggests it reduced visibility of the train or possibly confused drivers. Furthermore, all occasions in which the participant failed to detect the train occurred when low beams were used, and the screen was present.

The effectiveness of the screen with high beams is a positive finding. The strobing effect appeared to provide a highly visible, dynamic cue for drivers to react to and it reduced the time for drivers to process the presence of a train. In a real-world situation, this improvement in reaction time (difference of 0.231 of a second between means for NHU and NHT) equates to a reduced stopping distance of 6.4 metres for a light vehicle travelling at 100 km/h on an unsealed road. This improvement is small but positive (note, however, that a vehicle should not be travelling through the crossing at 100 km/h, unless they have deliberately disobeyed the Give Way or Stop sign or failed to see it).

Train carriages, although dark, were visible in both night videos with high beams, which suggests that using high beams is the safest way to approach unsignalised level crossings in rural areas. It is common for drivers to use high beams in rural Australian areas at night. However, it cannot be expected that all drivers will use high beams when approaching a rural level crossing. This leads to the second result, which does not simply suggest that the screen is ineffective with low beams but that it can have a detrimental effect. It is unclear exactly why this result occurred, although there are several likely explanations. It is potentially due, at least in part, to methodological limitations. As mentioned in the methods section, there were different trains in the two low beam videos. The main noticeable difference was that, while the carriages were not visible in either, as it is very dark, there is a small light on the side of the train in the video without the screen (NLU). This light shows almost exactly as the train appears following the lead-in time and moves horizontally with the train. It is possible that the participants reacted to this cue. In comparison, the train in the video with the screen (NLT) has no such lights and participants only have the dully strobing screen (as it is very dark compared to the high beam videos) to react to.

Participants reacted to the low beam, untreated video (NLU) as quickly (see Figure 3 means) as the high beam, treatment video (NHT – in which the screen strobed brightly, and carriages were visible). This suggests that the lateral movement of the small light was clearly identifiable as train movement. In comparison, the strobing screen in the NLT video did not possess lateral movement. Ideally, future research would ensure that trains in all videos were equivalent in terms of lights and retro-reflective material on the sides of carriages. This may in practice prove difficult with videos of real trains (i.e., getting several trains that look the same could be problematic, especially given the large variation in the carriages they pull and the infrequency of trains in rural areas).

The large variance in reaction times for the NLT video (see Figure 3 confidence intervals) is consistent with confusion by the participants about whether they should react to the strobing screen. Also, there were not many 'misses' (participant did not react at all to train) during the experiment, but *all* were in the NLT video. These were removed from the analyses and so would not have affected the results. However, the misses in that condition (NLT) do suggest that participants were confused about whether the screen indicated a train. There were practice effects for this video (participants improved from Round 1 to 2 and most misses occurred in Round 1). However, even when Round 1 data were removed from analyses, reaction times to this video were still significantly longer than the other videos.

Confusion about whether the screen indicated a train could also have been due to the instructions given by the researcher. Participants were instructed to press a button as fast as they could when they saw a train. Therefore, they were looking for trains, not a strobing light. They may have noticed the strobing screen but decided not to let that distract them from spotting the train. Consideration had been given to different instructions. One option was "press the button when you see something you should brake for". However, the crossing featured a Stop Sign and so participants could have pressed the button immediately in response to that. Even if this issue could be addressed, participants may not have identified the strobing light as something requiring a braking response. Indeed, they may have falsely imagined it to be a distracting visual feature built into the experimental design.

The detrimental effect of the screen in low beam conditions is also likely to be accounted for by the operative lighting distance of low beam headlights (typically 40-50 metres). The distance of 200 metres between car and crossing in this experiment was likely too far for the retro-reflectiveness of the screen to be fully effective.

Despite the methodological limitations, it might truly be the case that the screen confuses or distracts the driver, and this may occur in real-world conditions. The longer reaction time (a difference of 1.085 seconds between means for NLU and NLT) equates to an increased stopping distance of 30.1 metres for a light vehicle traveling at 100 km/h on an unsealed road. This could compromise safety (again, however, a vehicle should not be travelling through the crossing at 100 km/h, unless they have deliberately disobeyed the Give Way or Stop sign or failed to see it). Further experimental testing of the screen would be required, ideally with all present methodological limitations addressed, to determine whether the results in low beam conditions persist. If this continues to be the case, efforts to improve conspicuity and safety at passive level crossings at night should be directed towards other viable countermeasures, if it is not possible to upgrade them to active crossings or grade separated junctions.

Other Potential Countermeasures

As mentioned earlier, it is possible that the lateral movement of lights on the side of the train in the NLU video worked as an effective train indicator. It seemed less confusing than the retro-reflective screen, which was strobing but stationary. This suggests that the best countermeasure to increase the conspicuity of freight trains already passing through an intersection at night when a vehicle approaches would be to have lights and/or retro-reflective material applied to freight trains. To achieve optimal safety results, this countermeasure would require that lights and/or retro-reflective material would be applied uniformly across the entirety of the sides of individual trains and uniformly across all trains in the industry. However, if the improved reaction times in the NLU condition in this study occurred because of a single small light, it is possible that even sub-optimal application of retro-reflective material to trains would be beneficial.

Rail Industry Safety and Standards Board (RISSB) Rolling Stock Standard AS7531:2015 Section 11 provides recommendations for the installation of retro-reflective strips to the sides of trains. The recommendations relate to mounting of the strips, spacing, materials, dimensions, and colour. Five of these are recommended and five are mandatory. The application of 'reflective delineators' according to this standard would be expected to markedly improve train conspicuity at night for approaching motorists. It should be noted that this would be most beneficial for freight trains. Applying reflective material to passenger trains may prove useful as an additional safety measure but would likely not be as beneficial because passenger train carriages have illuminated windows that provide lateral light movement.

The reduction of speed limits on approaches to level crossings is widely recognised as an important safety measure (White, Baldock, Woolley, Stokes, Royals and Sommariva, 2015a; Edquist, Stephan, Wigglesworth and Lenne, 2009), as hazard detection capacity declines at higher travelling speeds. In particular, speed limits at approaches in rural areas could be dropped from open 110 km/h and 100 km/h limits to 80 km/h. This would be relatively inexpensive to implement. Where level crossings are controlled by Stop signs, speed limits could be sequentially reduced down to a very low speed in the immediate vicinity (White et al., 2015b).

As well as the retro-reflective screen evaluated in the present report, the ACRI report by White et al. (2015b) also mentioned the following countermeasures:

- Local area traffic management interventions (horizontal/vertical deflections) force vehicles to reduce speed but may not be easily implemented on unsealed roads.
- Elimination of Give Way signs in favour of Stop signs, as they indicate that the driver needs to stop rather than continue through the crossing if a train is not detected.
- Illumination of the crossing, although this could be cost prohibitive to implement at a large number of level crossings.

Limitations

This study had several limitations. Firstly, the design meant that the experiment was measuring whether participants were able to perceive the train in conditions in which they were *actively looking for one*, but was not necessarily generalisable to all circumstances, including less attentive motorists in real-world situations. Secondly, the footage was replicating the point of view of a stationary observer 200m from the crossing. In reality, the observer would have been in a moving vehicle. An alternative approach would have involved footage from a vehicle travelling toward the train, and assessment of the distance from the crossing at which the train was detected. This, however, would have been difficult to organise, requiring exact timing of the arrival of the train, and taken much longer to collect footage, as a larger number of trains would have been required. Finally, the study could not demonstrate the durability of the prototype and, therefore, its ability to retain long-term retro-reflective effectiveness. That would require further testing in a separate field trial.

Conclusions

Given the detrimental effect of the screen on reaction times and detection rates in low beam conditions, the overall conclusion is that further experimental testing would be required to demonstrate the conclusive feasibility of retro-reflective treatment of level crossings. Future research should seek to address the current methodological limitations. It would not currently be prudent to recommend a larger field trial of the screen, particularly in real-world conditions with actual vehicles and drivers.

Acknowledgements

The authors would like to thank staff at the South Australian office of Australian Rail Track Corporation (Gary Templeton, Phillip Campbell, and Kleo Ioannidis) for their assistance with training, with the provision of train schedules, and with facilitating safe access to level crossings for collection of the footage used in this experiment. The authors would also like to thank Craig Kloeden, for developing the reaction time experimental program, and Martin Elsegood for helping to record video footage of trains passing through the level crossing at Callington, both from the Centre for Automotive Safety Research.

Funding

This work was funded by the Australasian Centre for Rail Innovation. Representatives of the funding organisation were involved in the study design and the decision to submit the paper for publication. They were not involved in the design, production or pilot-testing of the retro-reflective screen, the collection of data, the manuscript preparation, or the analysis and interpretation of the data. The Centre for Automotive Safety Research at the University of Adelaide is supported by the South Australian Department of Planning, Transport and Infrastructure.

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