RESEARCH REPORT

Testing the limitation of Sighting Distances in the AS1742 Part 7 Standard

Revision 1.2 (20/08/2015)

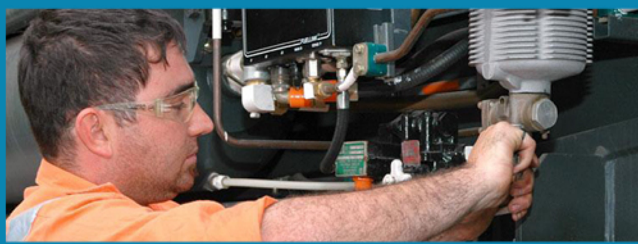

Table of Contents

1 Document Control Sheet

111 Alinga Street, Canberra City, ACT 2601 PO Box 238, Civic Square, ACT 2608, Australia Phone: 02 6274 7405 www.acri.net.au	**Document Title:**	Research Proposal – Review of S3 (Stop Sign) Level Crossing Sighting Distance
	Document No.:	Final report 1.4
	Project Number:	LC/2
	Project Name:	Review of S3 (Stop Sign) Level Crossing Sighting Distance
	Proposed Project Participants:	• CARRS-Q, Queensland University of Technology • School - Optometry and Vision Science, Queensland University of Technology • Appleton Institute for Behavioural Sciences, CQUniversity Australia

Amendment Record

Version	**Change Record**	**Section(s)**	**Author(s)**	**Date**
1.0	Initial version	ALL	Gregoire Larue, Ashleigh Filtness	30/06/2015
1.1	Revision including ACRI's comments	ALL	Gregoire Larue	03/07/2015
1.2	Revision including ARTC's comments	ALL	Gregoire Larue	15/07/2015
1.3	Revision including ACRI and PTV's comments	3; 5; 8	Gregoire Larue	06/08/2015
1.4	Revision including ACRI's comments	ALL	Gregoire Larue	19/08/2015

2 Definitions

ACRI	Australasian Centre for Rail Innovation
CARRS-Q	Centre of Accident Research and Road Safety – Queensland
CQU	Central Queensland University (CQUniversity)
QUT	Queensland University of Technology
SD	Standard Deviation
SEM	Standard Error of the Mean

3 Executive Summary

Australian Standard AS1742 Manual of Uniform Traffic Control Devices Part 7 (AS1742 Part 7) provides a method of calculating the sighting distance required to safely proceed at passive level crossings based on the physics of moving vehicles. The required distance becomes greater with higher line speeds and slower, heavier vehicles so it may return quite a large sighting distance.

The formula, within AS1742 part 7, relating to vehicles at stop signs has been demonstrated to be unreliable at high train speeds for heavy vehicles.

At the upper end of the sighting distances proposed (notionally greater than 750 metres), industry has raised concern around whether or not a driver would be able to reliably identify a train and assess its rate of approach (i.e. speed) in order to take an informed decision regarding whether or not it would be safe to proceed across the level crossing.

In order to determine if a driver is able to make a reliable judgement to proceed in these circumstances, the project proposed an approach to collect and analyse data that would assess both the sighting distance at which a train becomes identifiable, and an estimation of the rate of approach of that train at distances greater than 750 metres (and up to 1500 metres).

To assess this there were two questions that needed to be answered:

1. At what distance is a train clearly visible and identifiable as an approaching train?
2. At what speed does it become difficult to accurately judge train speed for the purpose of deciding to cross a level crossing?

Once these factors are known:

3. As speed is a factor in the AS1742 Part 7 calculation, can the answers to 1 and 2 be resolved into a single limit beyond which the formula cannot be relied upon to return a safe sighting distance where an accurate judgement can be made?

Where the formula calculates to a distance greater than this limit, local assessment of the level crossing would need to be made in order to provide the required sighting distance.

From the data, it was also considered if it might be possible to identify at what distance it becomes more difficult to accurately judge train speeds for the purpose of deciding to traverse the level crossing.

A site was selected in Victoria at a location on the V/Line Werribee line that carried high speed train traffic, and 36 participants with good visual acuity observed 4 trains in the 100-140 km/h range. The distances where they first saw the train and where they first identified its movement were recorded. Speed estimates were also collected as soon as participants reported that they first saw the train moving, as well as at three locations of interest: 1,100 metres, 750 metres and 350 metres. Participants self-reported the confidence that they had in their identification of the detection of the train movement, as well as their confidence in their speed estimates.

While most participants saw the train from a very long distance, as can be inferred from the average distance where the train was first seen (2,149 metres, S.D.=306), large variability was observed between participants, with 4 participants consistently detecting trains later than other participants. No obvious factor was found to explain such performance. Eighty-five percent of participants identified the train further than 1,450 metres, while the worst participant first recognised the train at a distance of 779 metres.

Participants were able to identify the train as moving on average at a distance of 1,298 metres (S.D.=485).

Eighty-five percent of participants reported the train as moving at distances further away than 750 metres. At distances further than 580 metres from the vehicle, the trains were clearly identified as approaching by all participants.

Participants' detection of the presence of the train tended to improve with experience, but a similar trend was not observed for detection of the movement of the train.

Participants' estimates of train speeds were very poor (at least 30% under the actual train speed) and they underestimated the speed of the oncoming trains at all distances recorded during the study: 350 metres, 750 metres and 1,100 metres, and at the distance that they first recognised that the train was approaching. Data showed a significant trend for less accurate speed judgements for longer distances and for faster trains (130km/h versus 110 km/h). The difficulty in estimating train speeds is further supported by the lack of improvement with practice (results are similar for the 4 trains observed); the high level of confidence reported by participants in their speed estimates, despite great inaccuracy; and their self-reported improvement with practice, which was not observed in the objective data.

In addition, the data analysis was unable to identify a distance beyond which participants' estimation of train speed deteriorates, as those tested were unable to judge train speeds accurately at all distances. Participants' estimates were least inaccurate at distances of 350 metres or less.

In summary, participants were not able to accurately judge the approach speed of trains at any distances, with large underestimations at all distance. , It is therefore not possible to determine a single limit beyond which the formula cannot be relied upon to make reliable judgements based on train presence and speed. If the sighting distance was 580 metres, all of the participants would have perceived that the train was moving as soon as it became visible for each of their trials. If the sighting distance was 750 metres, 85% of participants would have perceived the train as moving as soon as it became visible for each of their trials. If the sighting distance was 780 metres, all of participants would have detected the train as soon as it became visible for each of their trials. If the sighting distance was 1,450 metres, 85% of participants would have detected the train as soon as it became visible for each of their trials.

Risk assessment, taking into account this sighting information and other relevant factors described in the standard's appendices, is required to evaluate whether the required sighting distance provided by the formula in the standard can be relied upon or whether alternative arrangements for heavy vehicles should be provided.

4 Introduction

This project undertook a work program to review human limitations regarding effective sighting distances at passive Stop Sign (S3) controlled level crossings.

4.1 Background

Australian Standard AS1742 Manual of Uniform Traffic Control Devices Part 7 (AS1742 Part 7) provides a method for calculating the sighting distance required to safely proceed at passive level crossings based on the physics of moving vehicles (Standards Australia, 2007). The required distance becomes greater with higher line speeds and slower, heavier vehicles so it may return quite a large sighting distance.

The standard is based upon the requirement that a road user stopped at the crossing must have enough time to traverse the crossing before an approaching train arrives at the crossing from the point where the road user can first see the train (Kallberg, 2011).

The formula within the standard is included at Figure 1 below.

D3 CROSSINGS PROTECTED BY STOP SIGNS - CROSSING VISIBILITY

A road vehicle driver approaching a crossing protected by stop signs, when stopped at the stop line needs to be able to see far enough along the railway to be able to start off, cross and clear the crossing safely before the arrival of any previously unseen train. The required sight triangles to achieve this are shown in Figure D2.

Distance S_3 is the minimum distance at which an approaching train must be seen in order for the design vehicle to start off and clear the crossing by the safety margin shown in Figure D2. Distance S_3 is given by the following:

$$S_3 = \frac{V_T}{3.6}\left(J + G_s\left(2\,\frac{\frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L}{a}\right)^{1/2}\right) \qquad (3)$$

for a train approaching from either direction.

Notation in Equation (3) is given in Figure D2 and as follows:

J = sum of the perception time and time to depress clutch (general case assumption 2.0 s).

L = length of design vehicle, see Table D1.

a = average acceleration of the design vehicle in starting gear, see Table D1.

G_s = grade correction factor, see Table D2.

TABLE D1 DESIGN VEHICLE STOPPING, START-UP AND CLEARANCE PARAMETERS

Vehicle type	B_T(s)	J(s)	L (m)	a (m.s^{-2})
Semi-trailer	1.0	2.0	19.0	0.36
B-double	1.0	2.0	25.0	0.36
Road train-double	1.5	2.5	36.5	0.29
Road train-triple	2.0	2.5	53.5	0.29

Figure 1: Extract from AS1742 part 7, Appendix D describing sighting distance requirements for heavy vehicles at stop signs.

This formula has been demonstrated to be inaccurate at high train speeds for heavy vehicles and a margin of "more than 15 seconds extra could be required to safely clear the crossing than what may have been allowed for in the road design" (Trevorrow & Clark, 2009). It has to be noted that longer four trailer road trains ('quads') are operating in Australian regions such as the Pilbara (Schlenk, 2014), and these would require even longer sighting distances due to their heavier load and lower acceleration capabilities. Higher mass road vehicles are of particular concern for the safety of level crossings, due to the longer time they need to traverse the crossing, as well as the higher effects such vehicles can have in case of a collision with a train (Matters, 2010).

These findings have prompted a review of the AS1742 Part 7 Standard.

At the upper end of the sighting distances proposed (750 to 1,500 metres), industry has raised concern around whether a driver would be able to reliably identify a train and assess its rate of approach in order to make an informed decision regarding whether it would be safe to proceed across the level crossing.

Research has shown that the road users significantly underestimate speeds of large objects as compared to smaller objects in the distance (Barton & Cohn, 2007; Cohn & Nguyen, 2003); that road users do not adapt their safety gaps to the train speed (Cooper & Ragland, 2008), using similar safety gaps independently of the speed of the approaching train (Clark, 2010); and the visual field [part of the peripheral visual field around the fixation point inside which sources of information can be processed at a single glance (Ball, Beard, Roenker, Miller, & Griggs, 1988)] deteriorates as a function of vehicle's speed and driver's age (Rogé & Pébayle, 2009). Further, changes in speed can also have an effect on the perceived duration of the approach of an object (Matters, 2010). However, there is little evidence that mild impaired visual acuity increases the likelihood of being involved in a road crash, suggesting that reduced visual acuity in older drivers should have a limited effect on the chances of collisions (Buchner, Koepsell, McCloskey, & Wolf, 1994). Factors such as early visual attention and mental status are factors that better explain the crash frequency for older drivers (Owsley, Ball, Sloane, Roenker, & Bruni, 1991).

4.2 Project Objectives

The key objectives of the project are as follows:

In order to determine if a driver is able to make a reliable judgement to proceed in these circumstances, the project proposes an approach to collect and analyse data that would assess both the sighting distance at which a train is first identifiable as a train, and an estimation of the rate of approach of that train, at distances greater than 750 metres (and up to 1500 metres).

To assess this there are two questions that need to be answered:

1. At what distance is a train clearly visible and identifiable as an approaching train?
2. At what speed (V_T) does it become difficult to accurately judge train speed for the purpose of deciding to cross a level crossing?

Once these factors are known:

3. As speed is a factor in the AS1742 Part 7 calculation, can the answers to 1 and 2 be resolved into a single limit beyond which the formula cannot be relied upon to return a safe sighting distance where an accurate judgement can be made?

Where the formula calculates to a distance greater than this limit, local assessment would need to be made.

From the data it was also considered if it might be possible to identify at what distance it becomes more difficult to accurately judge train speeds for the purpose of deciding to traverse the level crossing.

Sighting distance and approach speed (V_T) have been selected as the principle research questions as these are the main variables that a driver would consider (potentially subconsciously) when deciding if it would be safe to cross (distance at which the train is identified, and the speed at which of the train is approaching).

Vehicle acceleration and other variables are not considered in these research questions as the standard already includes provision for vehicle acceleration in the table included at D1 within Figure 1 above.

Driver judgement itself is not included in these research questions as it also depends on variables that are untestable such as driver experience and familiarity with the vehicle (Beanland, Lenne, Salmon, & Stanton, 2013). Instead, by seeking to measure the limitations of the ability of drivers to identify a train and assess its approach speed, the project seeks to identify the point at which the information required to make a judgement is unreliable.

4.3 Project Scope

4.3.1 In Scope

The proposed project involved a series of experimental field tests, which answered key questions regarding human limitations in the capacity to firstly identify a train and then judge the approach speed of that on-coming train. The tests were conducted in conditions simulating a stationary heavy vehicle at a Stop Sign controlled level crossing during clear visibility (daytime).

The key aspects considered were:

(1) the distance when a driver first identified a train;

(2) the distance when the driver first identified the train to be moving; and

(3) the ability of the driver to perceive the rate of approach (speed) of that train.

The evaluation comprised two stages:

- Prospective empirical field test data collection, which answered the above questions for a representative sample of participants.
- A qualitative component requiring participants to reflect on their experience during the field test, in particular probing further their confidence and factors influencing their judgement of distance and the speed of trains.

4.3.2 Out of scope

Excluded from the project scope is specific exploration of the following factors:

- assessment of when participants judge it is safe to cross. This is dependent on additional variables than cannot be reliably explored within the scope of this project;
- variations in visual acuity due to age or ocular disease;
- visibility changes due to adverse weather;
- visibility changes under darkness (night time);
- participant sleepiness or fatigue;
- differences due to type of driving licence e.g. open vs provisional or passenger vehicle vs heavy vehicle;
- differences between demographic groups e.g. gender or age difference;
- influence of train travel speeds outside the range of usual operations at the selected site;
- failure in human conscious attention e.g. loss of situation awareness and look-but-fail-to-see; and
- the vehicle metrics taken into consideration within AS1742 Part 7.

5 Method

The research questions addressed by the study were as follows:

1. Is there a maximum sighting distance beyond which a train cannot be reliably
    a. recognised/detected; and
    b. detected as moving?
2. Is there a maximum train speed beyond which a driver's judgement cannot be relied upon to provide an approximate assessment of the rate of approach of the train?
3. Based on the answers to 1 and 2 above, is it possible to derive a single limit beyond which the AS1742 Part 7 formula cannot be relied upon to provide a safe sighting distance where an accurate judgement can be made?

From the data it was also considered if it might be possible to identify at what distance it becomes difficult to accurately judge train speeds for the purpose of deciding to traverse the level crossing. The study aims to determine the limitations of human visual capacity in accurately detecting both the movement of trains approaching level crossings with stop signs, and the rate of approach of those trains. A mixed methods approach including both quantitative and qualitative analysis was undertaken. The novel nature of this real-world field project required detailed piloting work, which resulted in the design presented in the following sections.

Data collection was undertaken using two approaches:

(1) empirical field tests under daylight conditions; and

(2) retrospective survey.

Data obtained were considered collectively. The field testing used a repeated measures design with 36 participants. Qualitative investigation always followed completion of the field testing. The following sections provide an overview of the trial site, experimental design, recruitment of participants, procedure, materials, data analysis and pilot testing.

5.1 Trial Site

It was not possible to use a passive level crossing for data collection due to the low rail traffic volume at such sites, as well as the difficulty in providing a safe environment for participants (that is it was not possible to safely park a vehicle at a level crossing without obstructing the road). Further, such an approach would have also limited the number of participants that could be tested simultaneously.

The site used for data collection is located in Victoria, on the Werribee line between the Lara and Corio stations. The research team was located on a maintenance track off Rennie St, Corio. This section of the rail track provided a long straight track with good visibility, relatively high train frequency during peak hours (3 tracks), and speeds over 100km/h. The site was located between two active level crossings, however the level crossings were further than 2km away and their active equipment could not be seen or heard by participants.

The visibility at the site was adequate for the study only on one side, as the visibility on the other side was blocked by a series of three bridges. Only traffic from Melbourne (i.e. west bound) could be used. The layout of the rail tracks allowed for trains travelling in that direction to always be visible, as these trains were running on the track closest to the location where the vehicles were parked.

The research team and the research participants were located further down the maintenance track off Rennie St, in order to ensure that the participants were not distracted by the nearby road traffic. Care was taken to ensure that the observer position reflected that of a typical truck driver stopped at a passive crossing (e.g. height of a truck cabin, as the vehicles were parked 1.5 metres above the rail track, approximately 7 metres from the rail line at a 90 degree angle).

Figure 2: Trial site. Trains were approaching on the right track.

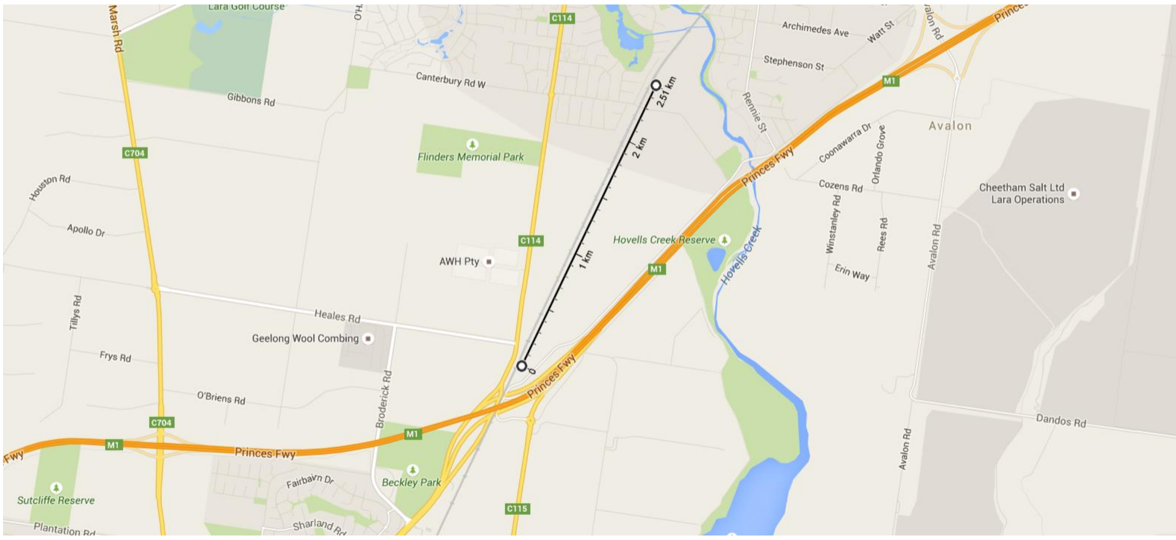

Figure 3: GoogleMaps top view of the trial site. The part of the track that could be seen by participants is highlighted, as well as its length.

The timetable for this location is provided in Figure 4. Six trains were observed by participants between 13:45 and 16:40. The first two trains were used to practice (referred to as Practice trains 1 and 2), while the last four trains were used as test trains (used for data analysis and referred to as Trains 1 to 4). Trains 1, 2 and 4 were faster trains (see Figure 5 on the right), while Train 3 was a slower train (see Figure 5 on the left).

Melbourne – Geelong

	MONDAY – FRIDAY															
Service	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN	TRAIN
Service Info.			★ ☕ LD						★ ☕ LD							
Southern Cross Stn dep	05:42	06:47	07:22	07:37	09:00	10:00	11:00	12:00	13:00	13:20	14:00	14:40	15:20	15:59	16:19	16:37
Footscray	05:51u	06:56u	07:31u	07:46u	09:08u	10:07u	11:07u	12:07u	13:07u	13:28u	14:07u	14:47u	15:27u	16:08u	16:27u	16:44u
Newport	05:58u	07:01u	–	–	09:13u	10:14u	–	12:14u	–	–	14:14u	–	15:33u	16:13u	16:32u	–
Werribee	06:14u	07:23u	–	08:10u	09:26u	10:27u	11:27u	12:27u	13:28u	13:47u	14:27u	–	15:47u	–	16:47u	–
Little River	06:23	07:33	–	08:19	09:35	10:36	11:36	12:36	–	13:56	14:36	–	15:58	–	16:58	–
Lara	06:29	07:40	–	08:25	09:41	10:42	11:42	12:42	–	14:02	14:42	15:17	16:06	16:38	17:06	⊢
Corio	06:33	07:45	–	08:29	09:45	10:46	11:46	12:46	–	14:06	14:46	–	16:11	–	17:11	–
North Shore	06:35	07:48	–	08:31	09:47	10:48	11:48	12:48	–	14:08	14:48	15:23	16:14	–	17:15	–
North Geelong	06:39	07:51	–	08:35	09:51	10:52	11:52	12:52	–	14:12	14:52	15:27	16:18	16:47	17:19	17:24
Geelong arr	06:45	07:55	08:22	08:39	09:54	10:55	11:55	12:55	13:52	14:15	14:55	15:30	16:22	16:50	17:26	17:29
Geelong dep	06:51	07:57	08:27	08:41	09:56	10:57	11:57	12:57	13:57	14:17	14:57	15:33	16:24	16:52	–	17:31
South Geelong	06:56	08:01	–	08:44	09:59	11:00	12:00	13:00	14:01	14:20	15:00	15:36	16:28	16:55	–	17:34
Marshall arr	–	–	08:35	–	10:04	11:05	12:05	13:05	14:06	14:27	15:05	15:41	16:37	17:00	–	17:42
Waurn Ponds	–	08:20	08:40	08:58	10:11	11:12	12:12	13:12	14:11	–	15:12	15:47	–	17:08	–	–
			W						W							

Figure 4: Train timetable for the site. The adjacent station is Lara station; trains arrived around 5 minutes after departing the Lara station. Trains highlighted in blue are practice trains; trains highlighted in red are test trains.

Figure 5: Observed trains. Left: slower train (110km/h); Right: faster train (130km/h).

5.2 Experimental design

A repeated measure design was used with train speed as a within-subject factor. All participants completed one testing session. The testing session comprised a visual acuity test to ensure that drivers were fit to hold an Australian driving licence. Eye contrast sensitivity tests were also conducted. These tests were conducted in a controlled environment with adequate lighting (in an established Optometry practice) and can be found in Appendix A.

The first two trains that participants saw were used as practice trials, and data were not analysed. The following four trains were used for data analysis. The participants were instructed to look for approaching trains from the East direction five minutes before a train was due. The equipment was started at that time: the smartphone apps - developed and used to record participants’ responses - were started, the laser range finder was in position to measure trains at a predetermined position, located around 1.6 kilometres away from the participants. RTmaps, the software used to synchronise the data from all the devices used in this study, was also started. As the train approached the predetermined location, measurements from the laser range finder were triggered and occurred every second (when measurements were successful). The head of the tripod was turned when required to follow the approaching train movement.

Participants said the word ‘Train’ when they first saw the train. At that time, the research assistant next to the participant pressed the corresponding button on the smartphone. As the participant could see the train moving, they gave a speed estimate (rounded to the nearest 10 km/h). At that time, the research assistant pressed the corresponding button on the smartphone, and then recorded the value on the recorder sheet (see Appendix B). In parallel, and usually after, the phone provided alarms at the additional pre-determined distances, at which point the participant also provided a speed estimate rounded to the nearest 10km/h. This value was recorded by the research assistant on the recorder sheet. After the train had passed, the participant provided an assessment of their confidence in their detection of the movement of the train and their speed estimates in a 7-points Likert scale. Lighting conditions were also measured after the train passed using a calibrated lux meter.

A retrospective questionnaire aligned to the research questions was undertaken with study participants after they had completed their field study (see Appendix C).

5.3 Participants

Participants were healthy adults who were regular licensed drivers. They were recruited from the general public in the Geelong area (closest city to the trial location). Recruitment was stratified so as to obtain a participant population with equal gender split and a variety of ages and driving experience. However, due to the small sample size no direct comparisons were made between demographic groups. All participants were required to have adequate vision (or corrected vision) to legally hold a private driving licence. Participants were excluded when their vision did not follow the minimum requirements to hold a driving licence. Ethical clearance was obtained from the QUT Ethics Committee (clearance number 1500000219).

5.4 Procedure

The rail sighting study was conducted between the 25th May and the 4th June 2015 with one session undertaken each week day. Each session tested four participants simultaneously. The study sessions commenced at 12.30 at the Robinson Family Optometry practice, 165 High St Belmont, Geelong where after signing the consent form, each participant had their eyesight acuity and contrast sensitivity tested binocularly (with both eyes open) using standardised chart-based tests when wearing their habitual refractive correction for driving. This ensured that they were within the vision parameters for holding an Australian driver’s licence. Participants were then individually instructed about the activities and procedure required during their engagement in the study. Following this instruction, participants were transported by car to the study site located south of the Lara train station. Concurrently, at the observation site, the equipment required for the study was set up ready for the arrival of the participants and commencement of the study.

On arrival at the study location, the participants and the research team received correct personal protective equipment to wear and were briefed by a fully qualified protection officer (level 3) on rail safety procedures, including appropriate behaviour when in the rail corridor. The four similar cars used for the study were strategically positioned side by side 80cm apart and staggered to provide a similar view from each driver’s seat of approaching trains along the rail corridor (see Figure 6). Markers were located on the ground to ensure that the cars were parked in the same position for all the sessions. For the study each participant was assigned a driver’s seat and was accompanied by a research officer who was seated in the passenger seat to record the participant’s responses.

Participants were asked to imagine they were out driving and stopped at a rail level crossing with a stop sign. The study procedure required each participant to tell the research officer when they first saw the train in the distance using the word “train”, secondly to identify when they saw that the train was moving by saying “moving” and at this point give an estimate of the approaching trains speed to the nearest 10 km/h (see Appendix D for the instructions provided to participants). As the train approached at 1100 meters, 750 metres and 350 metres (each distance signalled by a ring of the smart phone application), the participant was asked to provide an estimate of the trains speed to the nearest 10km/h. The timing of each response made by the participant was recorded using a smart phone application with estimated train speeds recorded by the research officer. After each train had passed, the research officer recorded how confident the participant felt with their rail sighting observations regarding seeing the train moving and their train speed estimates, on a scale of 7 from extremely confident to extremely unconfident.

Participants observed a total of six trains during the course of the afternoon study session; the first arrived at approximately 13.38 and the second at 14.02. These first two trains were used as a practice for participants to become familiar with the procedure, with the observations made by the participants recorded by the research officer. A further four trains passed at 14.42, 15.17, 16.06 and 16.38 with the results from each participant recorded by the research officer. The results from the observations of these four trains are presented in this report. During the 50 minutes period between Trains 2 and 3, participants were invited to take a short break at Lara if they wished and participants were transported there and back in time to observe Train 3.

In addition to the observational study, each participant completed a questionnaire. The first section of the questionnaire was completed between Trains 2 and 3 and recorded the participant’s background and demographic information. The second section of the questionnaire was completed after the final train and consisted of retrospective questions about the participant’s experience in estimating train speeds during the study and any history of incidents involving trains. Following the last train, while participants completed the survey, the equipment was packed up and participants were paid their incentive. At the conclusion of the session participants were transported back to the original meeting place or an alternative destination in Geelong if requested.

Figure 6: Positioning of the vehicles and the measuring equipment at the site.

5.5 Materials

5.5.1 Laser range finder

A laser range finder was used to measure train distances and speed. The Newcon LRB 4000 CI laser range finder was used (see Figure 7) and set to record both distances and speed of objects. The measuring range of this equipment is 20 metres to 4,000 metres, with an accuracy of +/- 1 meter. Speed measurements operate in the 5-400km/h range, with an accuracy of +/- 2km/h. Each of the measurements takes up to 0.3 seconds. Measurements can also be taken in an automatic way every second. The output data can be collected on a computer connected to the device via a RS232 port. The computer can also be used to trigger measurements without touching the device. The laser range finder was mounted on a Manfrotto 475B digital pro tripod, associated with a Manfrotto 128LP head. The tripod was a heavy tripod in order to ensure that the device was in a stable position during data collection even under the windy conditions at the trial site. The head had to be modified in order to connect the equipment both to the tripod and to the computer.

Figure 7: Train distance and speed measuring equipment

5.5.2 Smartphones

Four Samsung S4 smartphones were used to record the moments when the participants first saw the train and first identified that the train was moving. An app was developed (see its graphical interface in Figure 8) where the research assistant pressed appropriate buttons as participants said that they saw the train (saying 'Train') or saw it moving (saying a number representing the speed estimate). Further, the phone was set to ring at the three positions of interest to this research in order to obtain train speed estimates by participants: when the train was 1,100 metres away, 750 metres away and 350 metres away.

A fifth Samsung S4 smartphone was used to create a portable Wi-Fi hotspot, which created a network between the four other smartphones and the computer linked to the laser range finder.

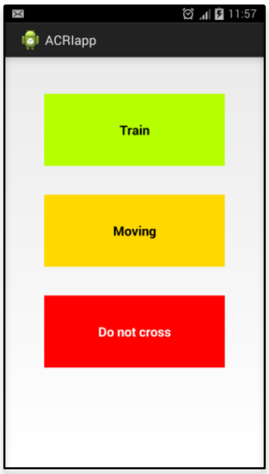

Figure 8: Graphical interface of the app developed to record participants responses

5.5.3 Synchronisation interface

The software RTmaps version 3.4.10 was installed on the computer linked to the laser range finder. This software was used to ensure a unique recording time for the different devices. Raw socket server components were used to communicate with the four smartphones, while a serial port component was used to communicate with the laser range finder. Components were created to listen to and record the laser range finder outputs, as well as trigger repetitive laser range finder measurements from the computer's keyboard. A component was also created to record the buttons that were pressed on the smartphones, as well as the ID of the smartphone and the delays in the communication. The smartphone app also contained heart beats, which were used by RTmaps to ensure that the communications between the computer and the smartphones was not lost, or could be restored after detection and reporting of the communication failure in the console window of the RTmaps software. Measurements of train speed and distances were used to trigger the alarm sounds played by the smartphones at the three locations of interest. The time when the alarm sound was provided was obtained as follows:

$$t_i = \frac{d - d_i}{v}$$

Where:

- t_i is the time to wait before the train is in position *i* (in seconds);
- d is the last train position measured (in metres);
- d_i is the position of interest *i* (in metres); and
- v is the last train speed measured (in metres per second).

These values were also stored in the smartphones, to overcome any communication failures that could occur as the train was approaching, and increasing the chance to provide the alarm sound at the appropriate time.

The architecture of this synchronisation interface is presented in Figure 9.

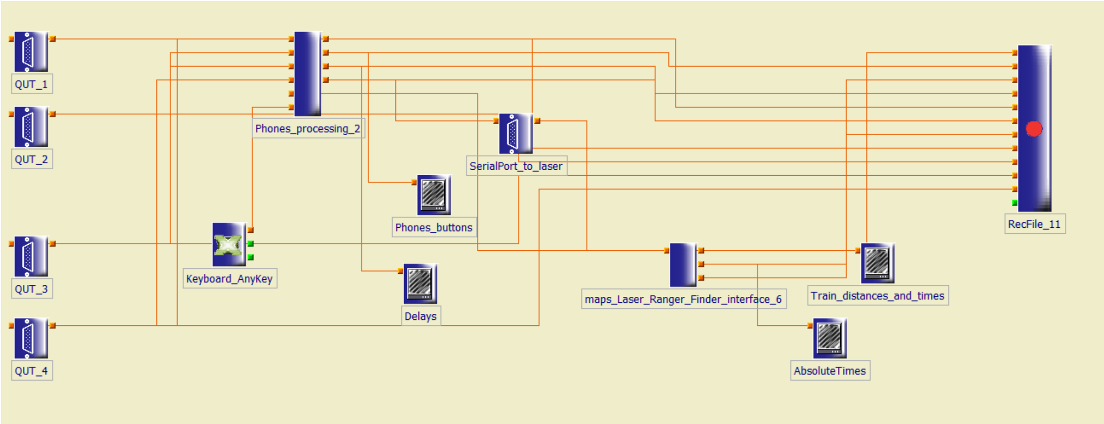

Figure 9: Architecture of the synchronisation framework.

The laser range finder was continuously scanning for data (speed and distance) when the train reached a predetermined location. Each data point (time, distance, speed) was recorded by RTmaps in a text file.

At the three locations of interest 1,100 metres; 750 metres and 300 metres), RTmaps:

- sent a signal to the smartphones;
- recorded the time at which the signal was sent; and
- the smartphones played a sound to tell participants to provide a speed estimate.

When the 'Train visible' or 'Train moving' button were pressed, the smartphone sent a message to RTmaps so that a timestamp was recorded, as well as the ID of the smartphone and the button pressed. Similarly, when the participant could see the train is moving, they pushed the 'Train moving' button. When any button was pressed, a tactile feedback was provided, as well as a change in the button's colour for a couple of seconds.

5.6 Data analysis

5.6.1 Dependent variables

The following train measurements were recorded:

- approach speed (km/h);
- approach distance in relation to participant measures (m).

Participant measurements were as follows:

- distance at which the approaching train becomes recognisable (m);
- distance at which the approaching train becomes identifiable as moving (m);
- speed estimates at locations provided by the research team (km/h);
- perceived reliability of the speed estimate provided by the participant (very high, high,… to very low).

Environment measurements were also recorded:

- ambient illumination (lux).

5.6.2 Statistical analyses

Multivariate analysis of variance (MANOVA) and Generalised Linear Mixed Models were used to analyse the data of this repeated measures design. MANOVA were run on SPSS version 21, while Generalised Linear Mixed Models were run on R version 3.1.1. These analyses were used to evaluate the effect of train speeds and location of the train on the dependent variables.

5.7 Pilot testing

Using a field test methodology provides much needed validity to the results, which would not be possible from simulator-based testing. However, it introduces a number of potential confounding factors that need to be controlled as much as possible and considered in the analysis. In order to establish the desired control, in-depth pilot testing was critical.

Pilot testing was conducted in Queensland, in the Brisbane areas. It was conducted from the platform of three different stations, with trains running in the 50-80km/h range. Pilot testing allowed for the confirmation of the reliability of the equipment (and resulted in the further development of alternative ways to trigger and record data in order to reduce the likelihood of losing data due to technical issues). It also allowed the development of the design, including the way participants provide speed estimates so that the process did not overload the participant and impact their ability to provide estimates in a timely manner.

Site visits were also required to ensure that:

- the selected site allowed appropriate sighting distance for participants;
- the number of participants that could be run at the same time was sufficient;
- the travel time required to reach the site could be accommodated; and
- the session timing was adequate for train traffic and ensured clear visibility.

6 Results

6.1 Participant demographics

Thirty five participants completed the study protocol. Demographics are presented in Table 1 and visual acuity in Table 2.

Recruitment of participants for the study was carried out through approach emails to a number of volunteer organisations in Geelong and on the Deakin University student job board. To be included in the study, participants were required to hold an Australian driver licence, regularly drive and live in the Geelong area. Over half of the participants held an open licence with the remaining participants holding a P1 or P2 licence. The gender distribution of participants was almost even, with 19 (54.3%) males and 16 (45.7%) females completing the study. The age of participants ranged between 18 and 63 years of age, with a mean age of 30.4 years. All participants had completed high school with approximately half having completed an undergraduate degree. The number of kilometres driven in a month recorded by participants varied substantially and ranged between 40 and 4500 kilometres, the mean distance for kilometres driven per month was 1162. Almost all (85.7%) participants crossed an active rail level crossing with a frequency of once a month or more and two thirds of participants crossed a passive railway crossing once a month or more. A near miss or incident with a train had been experienced by two of the study participants. Over half of the participants said they used train travel once a month or more with approximately one quarter using rail travel once a week or more. Almost half (45.7%) of participants recorded said they had received a speeding ticket or had been involved in a crash.

Table 1: Participants' demographics and familiarity with railway level crossings

	Frequency	Proportion
Gender		
Male	19	54.3
Female	16	45.7
Licence type		
P1	2	5.7
P2	11	31.4
Open	21	60.0
Prob	1	2.9
Highest education		
High school	12	34.3
TAFE	3	8.6
Undergraduate	19	54.3
Post graduate	1	2.9
Other		
Passive level crossing frequency		
Rarely	11	32.4
Once a month or more	10	28.6
Once a week or more	9	25.7
Once a day or more	5	14.3
Active level crossing frequency		
Rarely	5	14.3
Once a month or more	7	20.0
Once a week or more	16	45.7
Once a day or more	7	20.0

Near miss/incident with train		
No	**33**	**94.3**
Yes	**2**	**5.7**
Have a speeding ticket or crash		
Yes	16	45.7
No	19	54.3
Train travel		
Rarely	13	37.1
Once a month or more	14	40.0
Once a week or more	8	22.9
Once a day or more	0	

Individual eye tests were conducted using standard charts to assess that each participant had the minimum visual acuity standard or better required to hold an Australian driver licence. Participants who usually wore corrective lenses or spectacles were asked to wear them for the test and during the study. The mean score for participants in the study was Right eye habitual -0.159, Left eye habitual -0.162, Binocular habitual -0.182 and Binocular 1.957. All participants had visual acuity required to hold an Australian driver licence.

Table 2: Participants' visual acuity

	Mean	Standard deviation	Range
Age	30.4	14.2	18 - 63
KM driven per month	1162	981	40 - 4500
Number of trains seen per week	2.2	2.2	1 - 10
Eye tests			
Right Habitual	-0.159	.0560	-0.26 - -0.06
Left Habitual	-0.162	.0508	-0.22 - -0.06
Binocular Habitual	-0.182	.0371	-0.20 - -0.08
Contrast sensitivity	1.957	.0779	1.90 - 2.05

6.2 In situ measures

6.2.1 Distance where trains become visible

Trains were identified as a train by participants at a distance of 2,149 metres (SD=306) on average (see Figure 10). Statistical analysis conducted with Generalised Linear Mixed Models - with log link to take into account the lack of normality of the sample data collected - showed that while distances for train 1 and 2 are similar, the third and fourth trains were detected at further distances. The first two trains were identified at an average distance of 2,089 metres, while train 3 was identified 169 metres further (t=2.463, DF= 95, p=.016), and train 4 was identified 137 metres further (t=2.155, DF= 95, p=.034). It has to be noted that the difference for Train 3 could be due to the fact that the locomotive was different to the other trains. However, these results suggest - even when discarding data from Train 3 - that participants were able to improve their detection ability with practice. This suggests that participants learnt where the trains can be expected to appear on the horizon, as well as their particular features (such as the headlight).

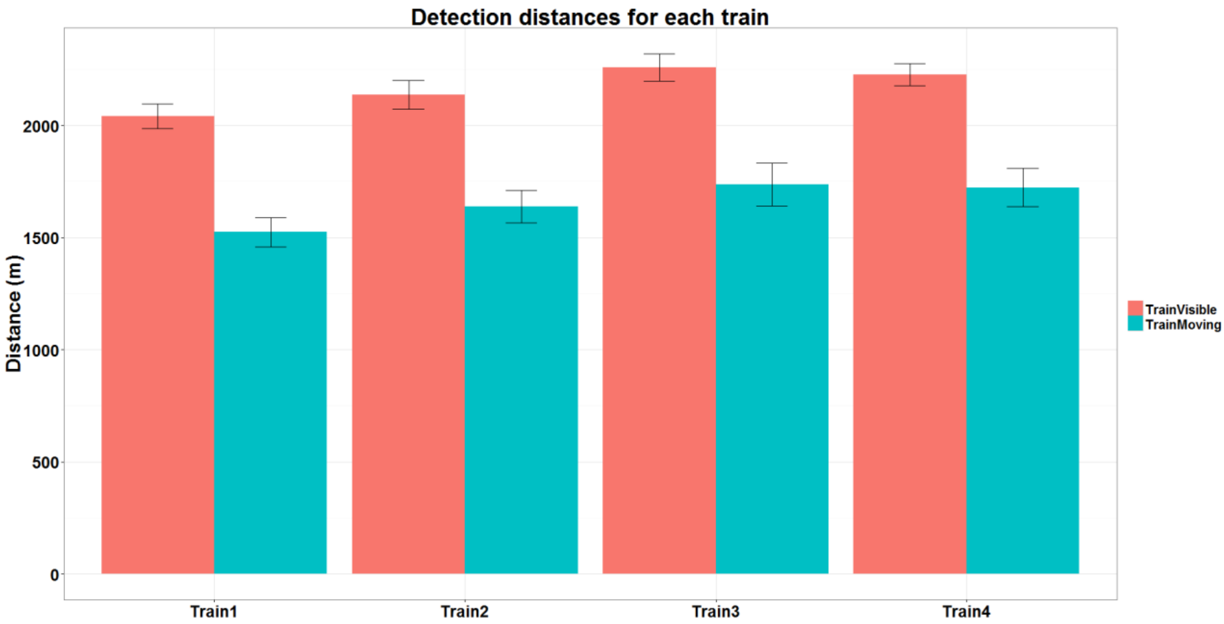

Figure 10: Distances where train is identified and detected as moving. Error bars represent SEM.

These averages are masking large differences between participants. The differences can be seen in Figure 11 and in Figure 12. The limited number of participants does not allow the distribution to have converged to a normal distribution (Figure 12). Four participants could be considered as outliers with very low values compared to the other participants. These participants were consistently found to provide values lower than other participants for every train. This reduced performance cannot be attributed to their visual acuity, which was highly above the minimum requirements for holding a driving licence, lack of attention (participants were instructed to look for trains 5 minutes before the train arrived) or delays due to the equipment communications. Therefore, it is not possible to exclude such values.

Overall, all participants were able to detect the train at each of their trials at distances greater than 780 meters. Fifteen percent of participants were able to detect the train for every trial at distances greater than 1,450 metres. Half of the participants were able to detect the train at each of their trials at distances greater than 2,180 metres.

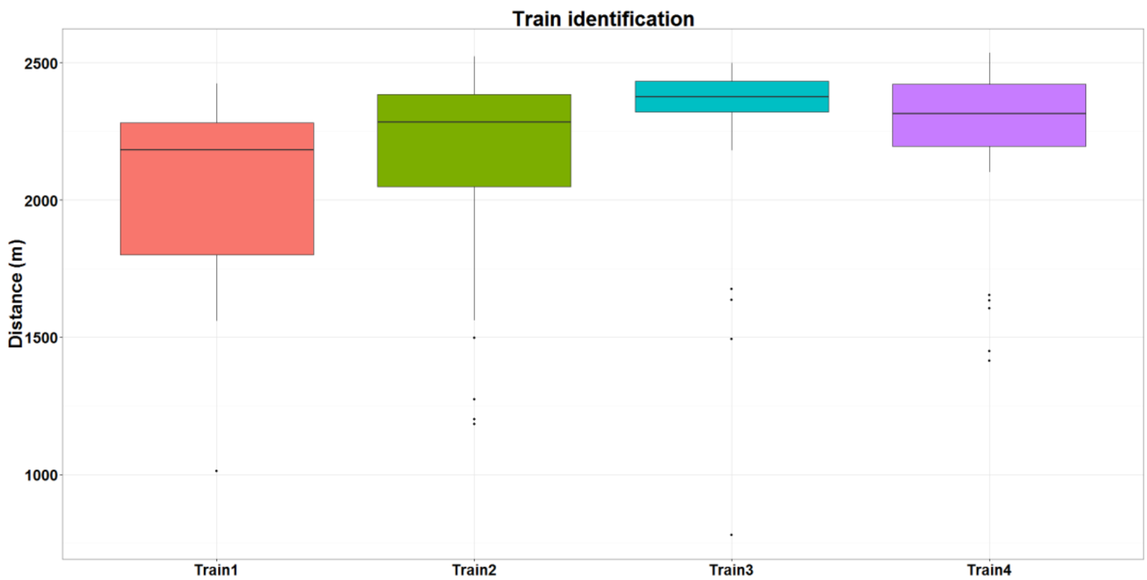

Figure 11: Boxplot of the distances where the train was first identified.

Figure 12: Distribution of the distances where the train was first identified.

6.2.2 Distance where train movement is perceived

Train movement was identified by participants at an average distance of 1,298 metres (SD=485), as shown in Figure 10 for each train. Statistical analyses conducted with Generalised Linear Mixed Models showed that the train had no effect on the distance at which it was identified as moving (i.e. approaching). While participants were able to improve the detection of the train with practice, a similar effect was not observed for the detection of the movement of the train.

Data was collected with four participants at the same time. The positioning of vehicles is slightly different, and the participant seated in the vehicle furthest from the track had a better chance of detecting the train movement. However, this advantage is small: the furthest vehicle is 1.5 metres further than the closest vehicle, which is a small difference compared to the distances of interest in this research (over 700 metres). Statistical analyses confirm this, as no difference was found due to the position of the vehicle.

Large variability between participants was also observed for this variable, as can be seen in Figure 13 and Figure 14.

Overall, all participants were able to detect the train movement at each of their trials at distances greater than 580 metres. Fifteen percent of participants were able to detect the train for every trial at distances greater than 750 metres. Half of the participants were able to detect the train at each of their trials at distances greater than 1,440 metres.

The cumulative distribution for both the train detection and the train movement detection are presented in Figure 15. This figure also presents the speed underestimation at the different distances investigated in this study (for details, see section 6.2.4 page 25).

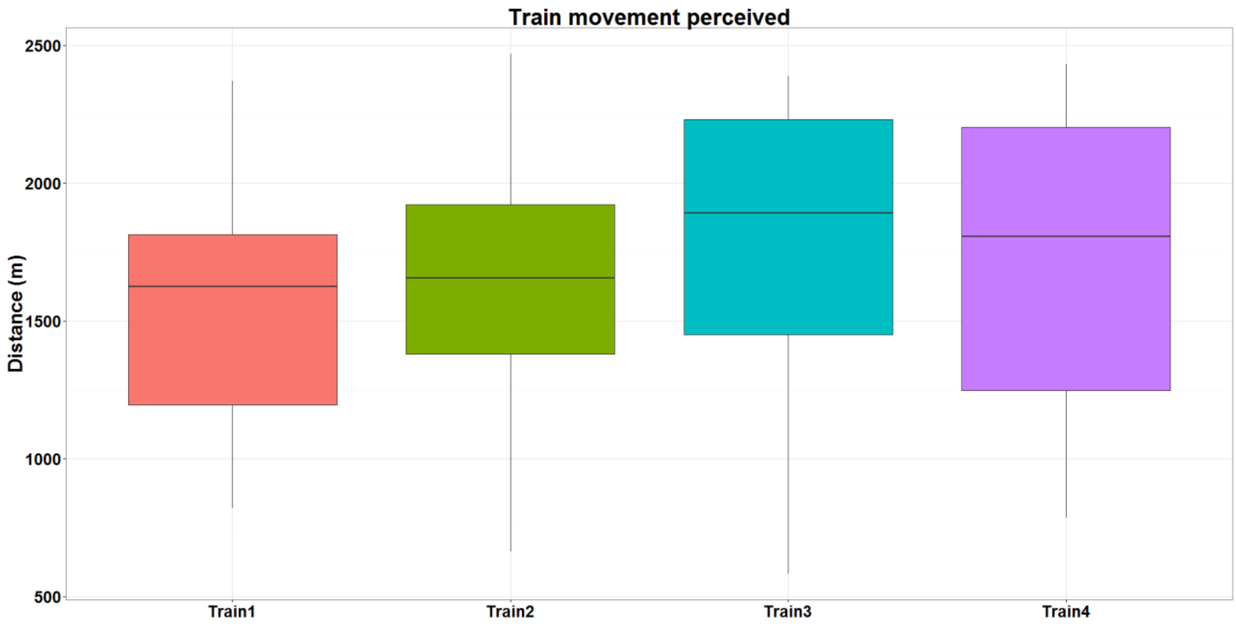

Figure 13: Boxplot of the distances where the train movement was first detected.

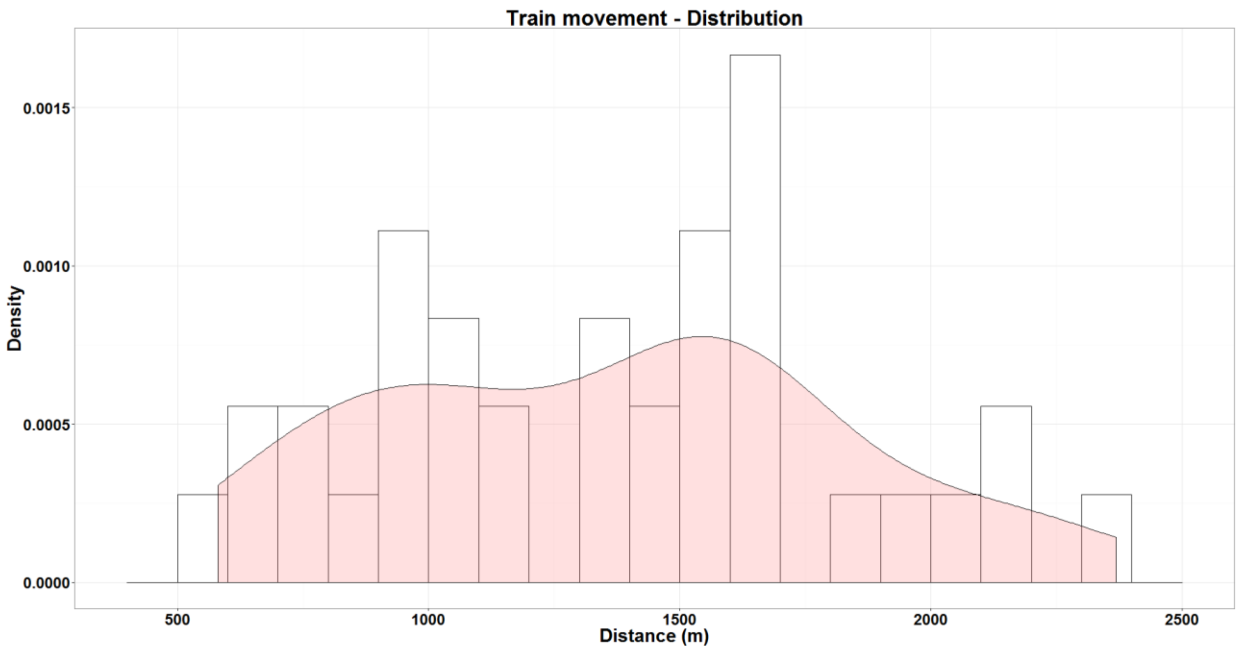

Figure 14: Distribution of the distance where the train movement was first detected.

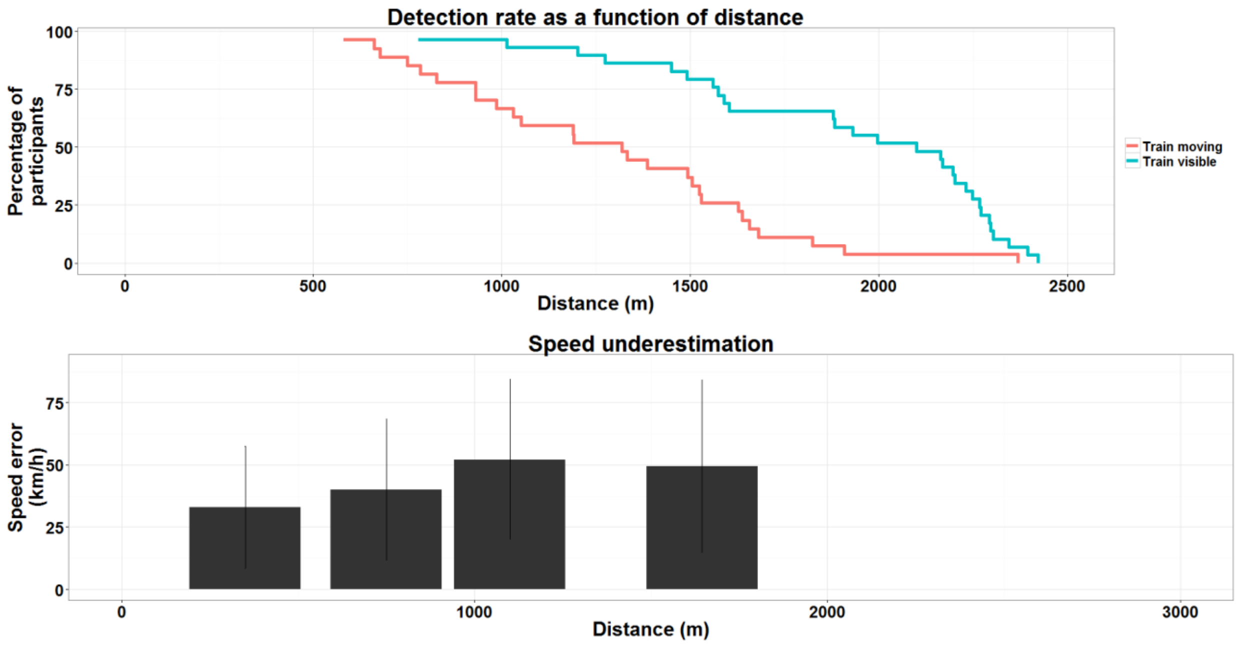

Figure 15: Top: Cumulative distribution for train and train movement detections; Bottom: Speed underestimation at the corresponding distance (Note that the underestimation at 1.6km is for the location where the train is first seen as moving). Error bars are standard deviations.

6.2.3 Actual train speeds

The four observed trains represented two train speeds. Train 1, Train 2 and Train 4 were traveling at approximately 130km/h, Train 3 travelled at 100km/h. As the actual train speeds were very similar data and were not normally distributed, non-parametric analysis was used to compare train speeds. Only the train speeds at the three set locations (1100 metres, 750 metres and 350 metres) were considered as these were fixed for all participants. Nine different testing sessions were completed, as 4 participants observed each train. Therefore, the analysis is based on nine measurements for each location for each train. Overall train speeds are presented in Figure 16.

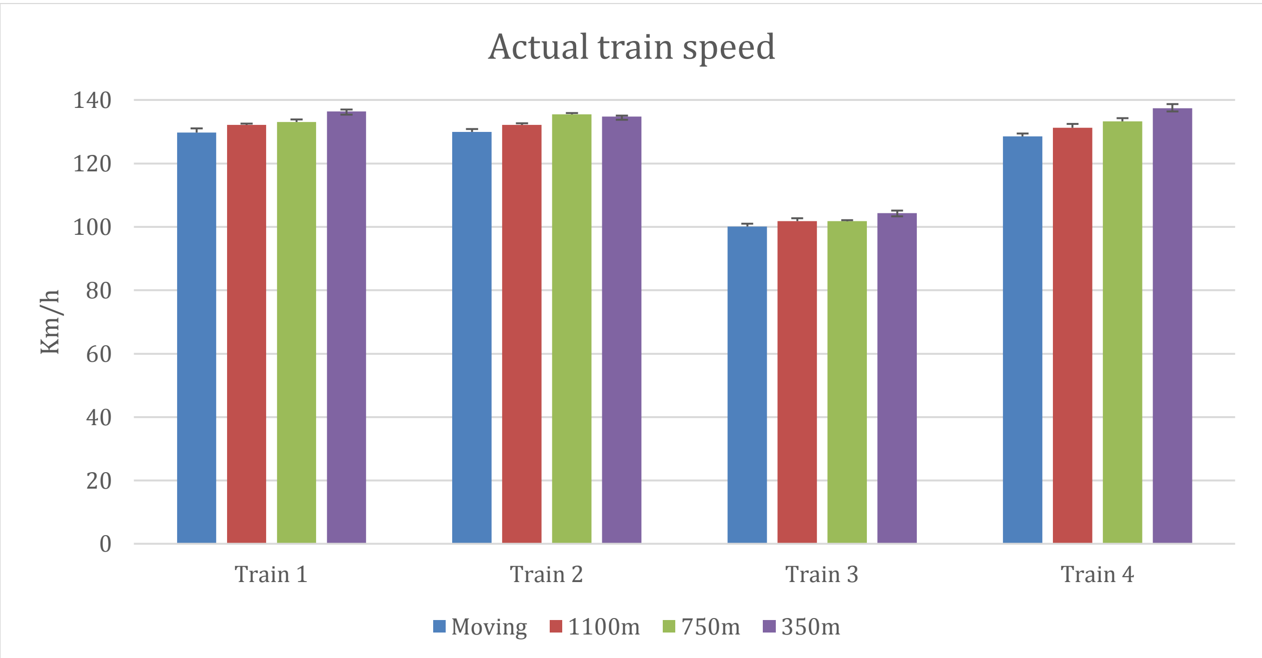

Figure 16: Actual train speed of each train. Error bars represent SEM.

Change in train speed on approach

A Friedman's ANOVA compared the speed at location 1 (1100 metres), location 2 (750 metres) and location 3 (350 metres) for each train separately. There was no significant difference in the speed of Train 2 [χ^2 (2) = 4.71, p = .095] and Train 3 [χ^2 (2) = 3.600, p = .165]. However, Train 1 [χ^2 (2) = 10.211, p = .006] and Train 4 [χ^2 (2) = 8.375, p = .015] travelled significantly faster as they approached the participant. In practice, Train 1 was travelling on average 4.22km/h faster at 350 metres than 1100 metres, and Train 4 was travelling on average 6.22km/h faster at 350 metres than 1100 metres. These small differences are much less than the inaccuracy of participants speed estimates, therefore it is unlikely to have affected the results.

Difference between train speeds

A Kruskal-Wallis test for independent measures demonstrated a significant difference in speed between the trains for each location: Location 1 [χ^2 (3) = 21.679, p <.001], Location 2 [χ^2 (3) = 21.765, p <.001] and Location 3, [χ^2 (3) = 20.413, p <.001]. Post hoc analysis was undertaken using a series of Mann-Whitney tests with an adjusted p value of (.05/7) .007. Post hoc analysis revealed Train 3 to be going significantly slower that Train 1, 2 and 4 (p < .001). There were no significant differences between the speeds of any other train. These results are consistent with the type of trains approaching: all trains were VLocity trains – the newest addition to V/Line's fleet, which can operate at speeds up to 160 km/h – except for train 3, which was using a N-class locomotive with a top speed of 115 km/h.

6.2.4 Participants' estimates of train speed

Participants consistently underestimated the speed of trains, with the exception of one participant who consistently overestimated train speed by a large amount. This participant is considered an outlier and has been removed from the inaccuracy in train speed estimation analysis. Figure 17 demonstrates the mean km/h by which participants underestimated the train speed at each location. Overall, there was a significant main effect of Train [F (2.36,47.09) = 59.546, p <.001, Partial Eta2 = .749, ε = .785], post hoc analysis demonstrating that estimations were more accurate for the slower moving Train 3 than Train 1, 2 and 4 (p<.001). There was no difference in the accuracy of train speed to any of the other trains.

There was also a significant main effect of location [F (1.528,30.57) = 19.167, p <.001, Partial Eta2 = .489, ε = .509]. Post hoc analysis demonstrated that there was no significant difference between speed estimate when the train was first seen to be moving and at 1100m away (p = .118). At these locations, errors of 47% and 41% were observed (averaging to 44%, as no statistical difference was observed). Participants then became more accurate with their speed estimate as the train became closer. At 750 metres estimates were significantly more accurate than when the train was first seen to be moving (p = .003) or at 1100m (p <.001), with error rates decreasing to 36%. At 350 metres mean speed estimate was significantly more accurate than at 750 metres (p=.015), 1100m (p =.001) and when the train was first seen to be moving (p=.001), with error rates decreasing to 29%.

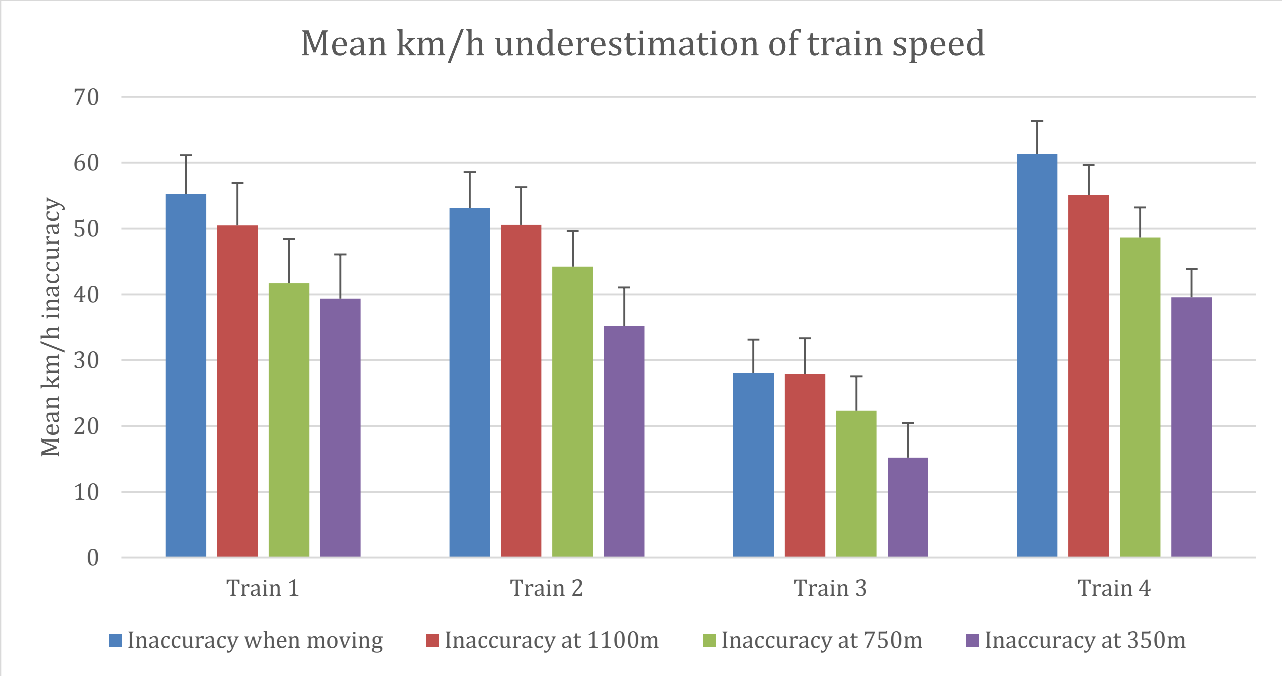

Figure 17: Mean km/h underestimation of train speed

6.2.5 Participants' confidence in their estimates of train speed

After each train, participants were asked how confident they were that the train was moving and how confident they were on their speed estimates. All participants are included in analysis as there were no evident outliers for this measure. Non-parametric Friedman ANOVA was used because of categorical data.

There was no significant difference of the confidence of the moving decision [χ^2 (3) =3.138, p =371] and confidence of the speed decision [χ^2 (3) =6.167, p =104] between trains. This is despite the slower speed of Train 3. Consistently speed confidence was rated as less confident than for the train moving.

7	Extremely confident
6	Moderately confident
5	Slightly confident
4	Neither
3	Slightly unconfident
2	Moderately unconfident
1	Extremely unconfident

Figure 18: Mean confidence of train moving and train speed estimates for each train. Error bars represent stand error of the mean

To investigate if accuracy improved when confidence was higher, the mean speed underestimation at 350 metres for fast trains (Train1, 2 and 4) for each confidence level is presented in Table 3. The mean speed underestimation for each confidence level of Train 3 is presented in Table 4. Results are for 36 participants; however, there are some cases of missing data. These tables show that participants' confidence in their speed estimates were not related to their actual performance in estimating speed.

Table 3: Mean speed underestimation at 350m per confidence rating for fast trains (Train 1, 2 and 4)

Confidence level	N	Mean underestimation (km/h)	Standard deviation
1 extremely unconfident	3	55.7	2.3
2 moderately unconfident	5	43.6	16.6
3 Slightly unconfident	9	38.9	16.0
4 neither	8	35.0	20.2
5 Slightly confident	28	37.1	23.6
6 Moderately confident	36	43.1	19.6
7 Extremely confident	8	46.4	7.7

Table 4: Mean speed underestimation at 350m per confidence rating for fast trains (Train 3)

Confidence level	N	Mean underestimation (km/h)	Standard deviation
1 extremely unconfident	1	21	NA
2 moderately unconfident	4	-0.5	17.79
3 Slightly unconfident	7	19.57	27.01
4 neither	3	12.33	22.28
5 Slightly confident	7	21.43	25.66
6 Moderately confident	12	20.33	20.49
7 Extremely confident	1	38	NA

6.2.6 Retrospective questionnaire

Participants completed a post study questionnaire once all trains had been observed. Confidence measures were taken using a 7 point scale. Non-parametric tests have been used for analysis.

Participants felt significantly more confident about the speed estimate of the last compared with the first train [χ^2 (1) =18.241, p <.001], as can be seen in Figure 19.

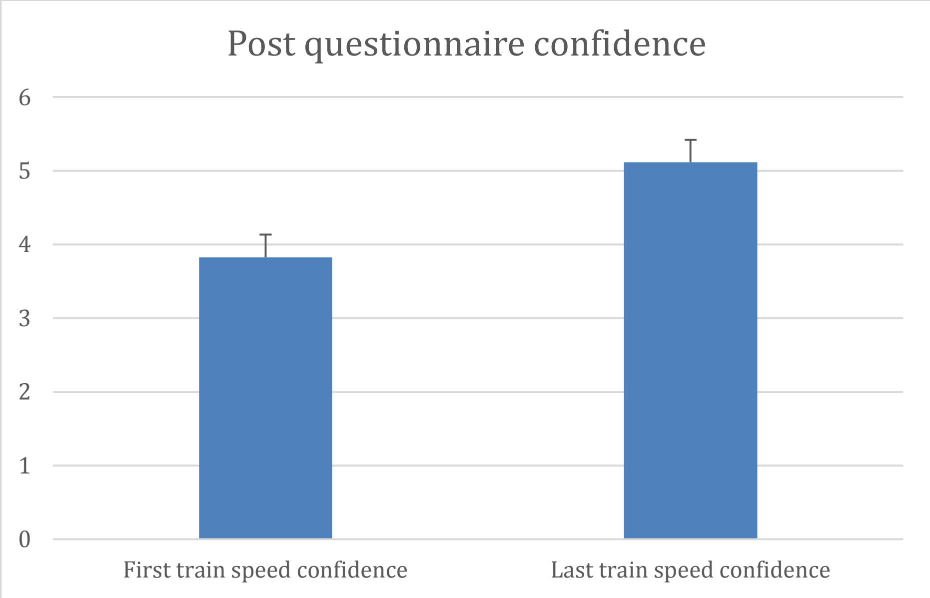

Figure 19: Mean confidence of train moving and train speed estimates for each train. Error bars represent stand error of the mean

In general, participants were slightly more confident about their response that the train was moving after all train observations than at the time of each observation (from 5.3 to 6.0), as shown in Figure 20.

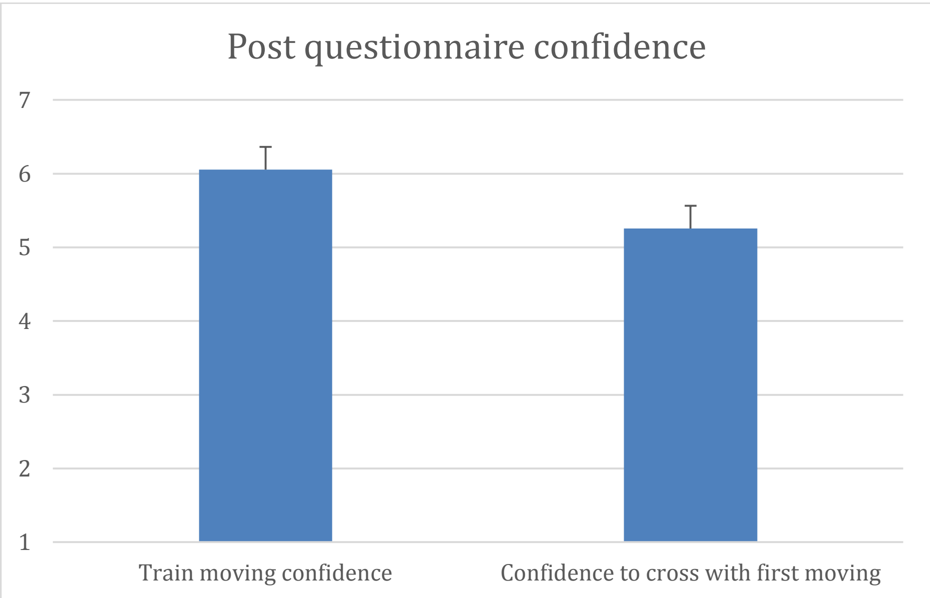

Figure 20: Mean confidence of train moving and train speed estimates for each train. Error bars represent stand error of the mean

Generally, participants reported that they had no difficulty sighting trains (see Table 5), with 4 participants reporting difficulty and 1 participant who did not answer the survey question. Two thirds of participants reported it was harder to estimate slow trains, three participants found it harder to estimate fast trains and nine found the estimation of speed to be the same for both fast and slow trains. This illustrates how participants were not able to estimate train speeds. The tests showed that they were actually better at estimating speeds for slower trains.

In general, all participants reported that estimating speed was easiest when the distance of the train was closer (350 metres) and three quarters of participants found that speed estimation became easier as the study progressed. This, however, was not confirmed by the analysis of the speed estimates they provided, as no improvement was observed throughout the experiment. An equal number of participants thought it would be easier to see a train in darkness than in light.

Table 5: Retrospective questionnaire

	Frequency	Proportion
Trains observed		
Four	4	11.4
Six	31	88.6
Difficulty sighting trains		
No	30	85.7
Yes	4	11.4
N/A	1	2.9
Hardest to estimate speed		
Slow	23	65.7
Fast	3	8.6
Same	9	25.7
Easiest speed location		
When moving	1	2.9
1100m	0	0
350m	34	97.1
Did speed estimation get easier		
Easier	26	74.3
Harder	1	2.9
Same	8	22.9
Would it be easier in:		
darkness	17	48.6
light	17	48.6
N/A	1	2.9
Train frequency expectation		
As expected	29	82.9
Less than expected	4	11.4
More than expected	2	5.7
Fastest train speed expectation		
Slower	6	17.1
Faster	5	14.3
Same	24	68.6
Slowest train speed expectation		
Slower	9	25.7
Faster	3	8.6
Same	23	65.7

7 Limitations

This study used a real-world field study design, which is appropriate to address the research questions and overcomes many of the limitations that are faced by similar studies that have been conducted in simulators, which while being practically easier to conduct, have severe and potentially fatal limitations in terms of validity. This is particularly important given the fact that this data will be used to inform standards. There are however, some limitations of the study design because of the field-based approach that need to be considered:

- In order for the study to minimize the number of variables, the same participants were used to consider repeated measures such as different train speeds and characteristics. It is assumed that the multiple times that participants were required to make sighting distance and train speed judgements would not be influenced by learning effects, given the extensive practice session undertaken prior to data collection.
- For practical reasons, the field study was conducted using existing V/line train traffic at the selected site. Therefore, the exact speed of the trains could not be controlled. Consequently, different participants may experience slightly different train speeds but those that are typical of everyday train traffic. No speeds atypical of that of V/line regional trains could be investigated for practical reasons.
- In order to achieve adequate sighting distance, train speeds and train traffic, it was not possible to conduct the study at a passive level crossing without collecting data for an extensive period of time. The data collection was hence conducted on the side of a rail track in the proximity of an active crossing (2km away).
- Participants were looking for trains over a longer period of time than is typical under normal driving conditions and were primed for the approaching trains – therefore the data represents that of an alerted driver.
- The number of participants was limited, and factors explaining the performance of outliers could not be ascertained. Only participants' visual acuity, appropriate sighting in the vehicle, sustained attention to the task and technical delays were factors that were controlled during the trial.
- Effects measured in this study were limited to two types of trains travelling in the 100-140km/h range due to the limited rail traffic available at the site.

8 Conclusion

At what distance is a train clearly identifiable as an approaching train?

The trains were first identified as a train 2,149 metres away on average (S.D.=306) by the participants seated in the vehicle. Eighty-five percent of participants identified the train further than 1,450 metres away, while the worst participant first recognised the train at a distance of 779 metres.

Participants were able to identify the train as moving on average at a distance of 1,298 metres (S.D.=485). Eighty-five percent of participants reported the train as moving at distances further away than 750 metres, while the worst participant judged that the train was moving 581 metres away from the vehicle in which they were seated.

At distances further than 580 metres from the vehicle, the trains were clearly identified as approaching by all participants.

Participants tended to improve at detecting the train presence with experience, but a similar trend was not observed for detection of the movement of the train.

At what speed and distance does it become difficult to accurately judge train speed for trains travelling in the 100-140km/h range?

Participants' estimates of train speeds were very poor and they underestimated the speed of the oncoming trains at all distances recorded during the study: 350 metres, 750 metres and 1,100 metres and at the distance that they first recognised that the train was approaching:

- When they first judged that the train was moving, their speed estimate was on average 47% lower than the actual train speed (70 km/h instead of 130 km/h)
- When the train was 1.1km away, their speed estimate was on average 41% lower than the actual train speed (80 km/h instead of 130 km/h), although no statistically significant difference was found between this location and the first speed estimate provided by participants.
- When the train was 750 metres away, their speed estimates were 36% lower than the actual train speed (85 km/h instead of 130 km/h)
- When the train was 350 metres away, their speed estimates were 29% lower than the actual train speed (90 km/h instead of 130 km/h)

Data showed a significant trend for less accurate speed judgements for longer distances and for faster trains (130km/h versus 110 km/h). The accuracy of speed estimates deteriorated as the distance increased from the nearest point of measurement (350 metres), that is, the point where their estimations were the least inaccurate. However, participants were unable to accurately assess fast train speeds at all distances. This is further supported by the lack of improvement with practice (results are similar for the 4 trains observed); the high level of confidence reported by the participants in their speed estimates, despite great inaccuracy; and their self-reported improvement with practice that was not observed in the objective data.

Can the answers to 1 and 2 be resolved into a single limit less than 1.5km beyond which the formula cannot be relied upon to return a safe sighting distance where an accurate judgement can be made for trains running in the 100-140km/h range?

If the sighting distance was 580 metres, 100% of participants would have perceived that the train was moving as soon as it became visible for each of their trials.

If the sighting distance was 750 metres, 85% of people would have perceived the train as moving as soon as it became visible for each of their trials.

If the sighting distance was 780 metres, 100% of participants would have detected the train as soon as it became visible for each of their trials.

If the sighting distance was 1,450 metres, 85% of participants would have detected the train as soon as it became visible for each of their trials.

The data analysis was unable to identify a distance beyond which people's estimation of train speed deteriorates, as those tested were unable to judge train speeds accurately at all distances. However, participants' estimates were least inaccurate at distances of 350 metres or less.

In summary, participants were not able to accurately judge the approach speed of trains at any distances, with large underestimations at all distances. Therefore, it is not possible to determine a single limit beyond which the formula cannot be depended upon to make reliable judgements based on train presence and speed. However, accurate speed assessment might not be a relevant factor for a risk assessment. Assessing the available gap might be a more important factor, in combination with the ability to detect the train and identify that the train is moving.

Risk assessment taking into account this sighting information, and other relevant factors described in the standard's appendices, is required to evaluate whether the required sighting distance provided by the formula in the standard can be relied upon, or whether alternative arrangements for heavy vehicles should be provided.

9 References

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Appendix A – Visual acuity tests

Visual acuity – EDTRS charts @ 3m working distance

Instructions: Participant to wear their usual driving glasses (if worn), seated at 3 metres from the letter chart. Use the eye patch or ruler to cover the non-tested eye.
Tick correct letters, cross out incorrect letters (circle if the participants changes an incorrect response to a correct one).
Start at the 6/12 line (marked with the red dot on the chart, this corresponds to the 0.3 line in the recording charts below), and ask participants to read all letters along that line. Move to lower lines.
Encourage participants to have a guess if they begin to hesitate.
Termination rule (ie. when to stop testing): when get 3 or more letters incorrect on a single line.
Test the R eye, L eye and then both eyes (binocular) together.

R Habitual

						@3M
	C	O	H	Z	V	1.1
	S	Z	N	D	C	1.0
	V	K	C	N	R	0.9
	K	C	R	H	N	0.8
	Z	K	D	V	C	0.7
	H	V	O	R	K	0.6
	R	H	S	O	N	0.5
	K	S	V	R	H	0.4
------	H	N	K	C	D	0.3
	N	D	V	K	O	0.2
	D	H	O	S	Z	0.1
------	V	R	N	D	O	0.0
	C	Z	H	K	S	-0.1
	O	R	Z	S	K	-0.2

L Habitual

						@3M
	Z	R	K	D	C	1.1
	D	N	C	H	V	1.0
	C	D	H	N	R	0.9
	R	V	Z	O	S	0.8
	O	S	D	V	Z	0.7
	N	O	Z	C	D	0.6
	R	D	N	S	K	0.5
	O	K	S	V	Z	0.4
------	K	S	N	H	O	0.3
	H	O	V	S	N	0.2
	V	C	S	Z	H	0.1
------	C	Z	D	R	V	0.0
	S	H	R	Z	C	-0.1
	D	N	O	K	R	-0.2

Binocular Habitual	
@3M R N O V S 1.1 Z C R D H 1.0 N V S O K 0.9 D R Z K O 0.8 S N H C V 0.7 C R V S Z 0.6 V K C N H 0.5 S V K D N 0.4 ------ K D H Z C 0.3 H Z C O R 0.2 O K D H N 0.1 ------ Z O N K C 0.0 R H S V D -0.1 D S O R Z -0.2	

Contrast sensitivity (with habitual Rx) – Pelli-Robson at 1m working distance

NOTES: Use +1.00DS correction, "O" for "C" and vice versa accepted as correct response

Instructions: Participant to wear their usual driving glasses WITH +1.00 flipper glasses over the top if aged 40 years or older, seated 1 metre from chart. Use the eye patch or ruler to cover non-testing eye.

Tick correct letters, cross-out incorrect letters (circle if changes response to correct letter). Encourage participants to have a guess if they begin to hesitate.

"O" for "C" and vice versa accepted as correct response.

Binocular

0.00	H	S	Z	D	S	N	0.15
0.30	C	K	R	Z	V	R	0.45
0.60	N	D	C	O	S	K	0.75
0.90	O	Z	K	V	H	Z	1.05
1.20	N	H	O	N	R	D	1.35
1.50	V	R	C	O	V	H	1.65
1.80	C	D	S	N	D	C	1.95
2.10	K	V	Z	O	H	R	2.25

____

Participant Questionnaire:

Do you wear any **<u>glasses or contact lenses when driving</u>**: ○ No ○ Yes

If yes, what **<u>type of glasses</u>** do you currently wear when driving (select the type most often worn if you have more than one set of driving glasses)?

○ Single focus
○ Bifocals or Trifocals
○ Multifocal or Progressive
○ Contact Lenses
○ Other (specify): ____________

How long has it been since you have had the lenses in your driving glasses changed? _____months OR _____years

Do you have or had any **eye conditions, injuries or surgeries** in the past? ○ No ○ Yes

If yes, please specify:

____

____

____

Appendix B – In-situ recorder sheet

Participant ID: ________________________________ Session ID: ________________________________

Speed estimates (Research assistant to complete)

	When train is moving	1,100 meters (1st beep)	750 meters (2nd beep)	350 meters (3rd beep)
Speed (kph)				

How confident were you at identifying that the trains were moving? Please tick one

Extremely confident	Moderately confident	Slightly confident	Neither confident nor unconfident	Slightly unconfident	Moderately unconfident	Extremely unconfident

How confident were you with your speed estimate? Please tick one

Extremely confident	Moderately confident	Slightly confident	Neither confident nor unconfident	Slightly unconfident	Moderately unconfident	Extremely unconfident

Lighting measurement (Research assistant to complete)

	In-vehicle	Outside vehicle
Lighting (lux)		

Appendix C – Questionnaires

DEMOGRAPHICS	
Date of Birth	
Gender	☐Male ☐Female
Current drivers licence type	☐Provisional 1 ☐ Provisional 2 ☐ Open
What type of license do you have in addition to a car license (e.g. motorbike, truck)?	☐None ☐Motorbike ☐Heavy Vehicle ☐Boat
On Average, how many kilometres do you drive a month?	____________ KILOMETRES
How frequently do you drive after dark?	☐Once a day or more ☐Once a week or more ☐Once a month or more ☐Rarely
Are you a shift worker?	☐No ☐Yes
What is your highest level of education?	☐High school ☐TAFE ☐Undergraduate degree ☐Postgraduate degree ☐Other
How often do you drive over a passive level crossing (with STOP or give way sign)?	☐Once a day or more ☐Once a week or more ☐Once a month or more ☐Rarely
How often do you drive over an active level crossing (with flashing lights)?	☐Once a day or more ☐Once a week or more ☐Once a month or more ☐Rarely
How many trains would you say that you encounter per week on average?	____________ TRAINS
Have you had a speeding ticket or a crash in the last three years?	☐Yes ☐No
Have you been involved in a crash in the last 3 years?	Yes □ No □ If yes, were you at fault? Yes □ No □

How frequently do you travel on trains?	☐Once a day or more ☐Once a week or more ☐Once a month or more ☐Rarely
What are your hobbies?	

RETROSPECTIVE QUESTIONS	
Did you have any difficulties sighting trains?	☐No ☐Yes – Please describe below
How confident did you feel with your first train speed estimation of the session?	☐Extremely confident ☐Moderately confident ☐Slightly confident ☐Neither confident nor unconfident ☐Slightly unconfident ☐Moderately unconfident ☐Extremely unconfident
How confident did you feel after your last train speed estimation?	☐Extremely confident ☐Moderately confident ☐Slightly confident ☐Neither confident nor unconfident ☐Slightly unconfident ☐Moderately unconfident ☐Extremely unconfident
How confident were you at identifying that the trains were moving?	☐Extremely confident ☐Moderately confident ☐Slightly confident ☐Neither confident nor unconfident ☐Slightly unconfident ☐Moderately unconfident ☐Extremely unconfident
Was it harder to estimate speeds of trains that you categorised in the slow range or of trains that you categorised in the fast range?	☐Slow range ☐Fast range ☐About the same
Which of these points was it easier to estimate speed for?	☐When you started seeing the train moving ☐The first time the phone beeped ☐ The last time the phone beeped
Did the task become easier or harder over the course of the study?	☐Easier ☐Harder ☐About the same
Was the number of trains that you saw on this line:	☐Lower than expected ☐Same as expected ☐Higher than expected
Was the fastest train that you saw today, faster than you would expect on this line?	☐Yes, it was faster than expected ☐No, it was slower than expected ☐No, it was the same as expected

Was the slowest train that you saw today, slower than you would expect on this line?	☐Yes, it was slower than expected ☐No, it was faster than expected ☐No, it was the same as expected
Do you think it is easier to see the trains in the:	☐Darkness ☐Daylight
When you can first tell the train is moving, how happy would you be to drive across the level crossing?	☐Extremely happy ☐Moderately happy ☐Slightly happy ☐Neither happy nor unhappy ☐Slightly unhappy ☐Moderately unhappy ☐Extremely unhappy
Have you ever had a near miss or an incident with a train	☐No ☐Yes – Please describe

Are you aware of anybody else that has had an incident with a train? If so, describe

____
____
____
____

What factors do you think influenced your estimations of speed?

____
____
____
____

Do you do anything (e.g. a hobby, work) that you think makes you good at estimating the speed of moving objects? Please detail

____
____
____
____
____

If you could describe level crossings in 10 words or less, what would they be?

____
____
____
____

Appendix D – Instructions provided to participants before a train arrives

Imagine you have stopped your vehicle (passenger car) at a level crossing with a STOP sign. You have to look for trains and decide whether it is safe for you to proceed through the crossing or not.

A train is approaching and should be visible within the next 10 minutes from the right side. When you see a train, say 'Train'. When you can tell that it is moving please tell me an estimate of its speed to the nearest 10 kilometre per hour (e.g: 10, 20, 30 etc.) You should only say the number not kilometres per hour. Please give the estimate as quickly as possible.

When you think that it is no longer safe to cross in your car anymore, say 'Unsafe'.

Additionally, the phone I am holding will ring three times as the train is approaching. When the phone rings, please tell me an estimate of the train speed to the nearest 10 kilometre per hour (e.g: 10, 20, 30 etc.). You should only say the number not kilometres per hour. Please give the estimate as quickly as possible.

If the phone rings before you have seen the train or that the train is moving it is not necessary to give a speed estimate in response to that particular ring. Please remember to say the word 'Unsafe' when it is no longer safe to drive across.

Remember:

- **Train**
- **Speed (number to the nearest 10)**
- **Unsafe**

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