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Short Communication

An illusory size–speed bias and railway crossing collisions

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ABSTRACT

Collisions between motor vehicles and trains at railway level crossings have been a high-profile issue for many years in New Zealand and other countries. Errors made in judging a train's speed could possibly be attributed to motorists being unknowingly subjected to a size–speed illusion and this could put them at considerable risk. Leibowitz (1985) maintained that a large object seems to be moving slower than a small object travelling at the same speed. Support has been provided for Leibowitz's theory from studies using simple shapes on a screen. However, the reasons behind the size–speed illusion remain unknown and there is no experimental evidence that it applies to an approaching train situation. To investigate these issues, we tested observers' relative speed estimation performance for a train and a car approaching at a range of speeds and distances, in a simulated environment. The data show that participants significantly underestimated the speed of the train, compared to the car. A size–speed illusion seems to be operating in the case of the approaching train in our simulation and may therefore be a risk factor in some railway level crossing collisions.

1. Introduction

The prevalence of railway level crossing collisions has been an on-going and vexing problem for civilians and authorities worldwide. In 2008, there were 468 deaths attributed to vehicle collisions with trains at level crossings in Europe, including Great Britain (Rogers, 2010). In the same year, the United States recorded 220 deaths (excluding pedestrians and 'other'), with the total number of collisions reaching 2248 (excluding pedestrians/'other') (Federal Railroad Administration Office of Safety Analysis, 2008).

In New Zealand, it is generally acknowledged that railway level crossing collisions occur at an unacceptable frequency (Ministry of Transport, 2005c). For the last ten years, there was an average of 14 vehicle collisions at level crossings, which have involved either fatalities or injury, with an average of 19–20 fatalities/injuries annually (Ministry of Transport, 2004, 2005a, 2005b, 2006, 2007, 2008, 2009, 2010).

Rural areas in particular (roads with speed limits of over 70 km/h) have had a high incidence of level crossing collisions. This can occur despite a strong probability of a motorist encountering a level crossing that has either good visibility of the railway track over a respectable distance, and/or warning procedures in place – employing either active protection devices (alarm bells and/or barriers) or passive protection devices (warning signage only). Over 1700 rural level crossings in New Zealand use passive protection measures, mainly because of relatively low traffic volumes and no apparent visibility issues (Ministry of Transport, 2005c). Despite improvements in risk management procedures (e.g., upgrading warning protection devices in some areas), and recent efforts to educate drivers of the risk with a comprehensive advertising campaign, there has not been a significant decrease in the number of incidents per year.

Research into these types of collisions have addressed many aspects of driver behaviour, including driver expectations (Leibowitz, 1985; Witte and Donohue, 2000), the effect of good or restricted visibility of the track (Ward and Wilde, 1996), estimates of perceived risk (Ward and Wilde, 1996; Wilde, 1994) and deliberate risk taking behaviours (Witte and Donohue, 2000). Many of them point to motorists making decisions based on their own thought process of perceived risk first and foremost, even if such a decision is contrary to road law. But what underlying factors influence our judgement of perceived risk? The basis of this judgement seems to rely on external cues available to the motorist, and the most salient of these are visual. Therefore, it is reasonable to ascertain that visual information received and interpreted by the driver influence to a large degree the driver's decision whether or not to proceed through a level crossing.

A number of studies have inferred that it is the poor ability of observers to perceive the correct speed of an approaching train, particularly when the train is some distance away from the observer that leads to railway crossing collisions (Meeker et al, 1997; Mok and Savage, 2005; Savage, 2006). In particular, Leibowitz (1985) suggested that judging a train's speed and distance was subject to an illusory size–speed bias. He noted that a large object seems to be

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moving more slowly than a small object, even when the small object is moving at the same speed or, in some cases, even faster. Leibowitz formulated this speed illusion theory after making observations of moving aircraft. A large aircraft (such as a jumbo jet) appears to be moving much more slowly than a smaller aircraft, even though the reverse may actually being true. Leibowitz theorized that this misjudgement of a large object's perceived velocity arose from the way the human visual system processes and interprets optical information. When tracking moving objects, pursuit eye movements maintain the object in the foveal region of the eye. The speed of the pursuit movements, determined by the actual velocity of the object, in turn determines its perceived velocity (Leibowitz, 1985). However, a large object requires less of an effort to maintain its form in the foveal region because it covers a much greater area. Leibowitz argued that, because of the reduction of effort, there is less smooth pursuit eye movement, and this leads to the visual system underestimating the perceived velocity of the object. Therefore, according to Leibowitz, the greater the size of the object, the slower it appears to be moving.

Despite the fact that such an illusion may play a large part in railway crossing collisions, (and indeed with other large vehicles, such as heavy load trucks and buses at *t*-intersections), there has been very limited follow up research into Leibowitz's size–speed illusion. One study examining the size increase of a rectangular object (equivalent to the perceived approach speed) found that participants took longer to respond when the object in question was larger than when it was smaller, indicating that the larger object 'appeared' to be moving slower (Cohn and Nguyen, 2003). In addition, the time needed to make the necessary decisions increased as the starting size of the object increased (Cohn and Nguyen, 2003).

In another test of the Leibowitz hypothesis, Barton and Cohn (2007) used computer generated virtual approaching spheres. Results showed that participants were inclined to indicate that a smaller sphere was approaching faster than a larger sphere, even when the larger sphere was approaching up to 57% faster than the smaller sphere. Although they demonstrated the basic size–speed illusion, it was only tested with an object (a sphere) moving directly towards the observer. Leibowitz postulated his original size–speed theory in the context of approaching trains but his theory was never tested or verified using actual or computer generated trains. The lack of adequate simulation facilities at the time probably factored into this. Computer graphics systems have now advanced sufficiently to enable realistic simulations of moving objects (e.g., cars and trains) in a controlled laboratory setting. We have made use of this new technology and the purpose of the experiment reported here was to verify that Leibowitz's size–speed illusion applies in the case of approaching trains. Our aim was to test the hypothesis that a train appears to be moving slower than a smaller vehicle (a motor car) travelling at the same speed.

2. Method

2.1. Participants

10 Volunteers (5 females and 5 males) were recruited from the University of Waikato student and staff population, ranging from 20 to 50 years of age (M = 29.7 years; SD = 9.4). All participants had normal or corrected visual acuity (at least 20/20) and were reimbursed for their participation by way of a 10 dollar fuel voucher.

2.2. Experimental setup

All computer simulations were run on a Dell OptiPlex 760 Minitower PC with 3 GHz processing speed and displayed on a 21.5" LCD Dell flat screen computer monitor. The participant was seated directly facing the computer monitor screen. Their eyes were 56 cm away from the monitor such that the field of view of the display screen matched that of the virtual camera used to construct the scenes (see below). The participants used a chin rest in order to keep their head fixed for the duration of the trials and they viewed the display with both eyes. All stimuli were presented without audio. The experiment room was windowless and painted black to reduce glare. All lights (except for essential computer monitors) were switched off during the experiment except when short breaks were provided. The stimuli consisted of animated sequences (1680 × 1050 pixels resolution at 60 Hz) as described below (Fig. 1).

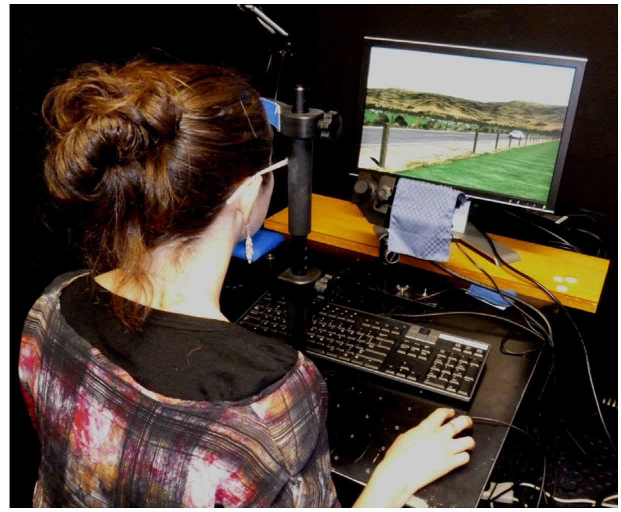

Fig. 1. Experimental apparatus set-up.

2.3. Stimuli

The monitor screen displayed a computer simulation of a vehicle approaching from the right, with background scenery typical of a New Zealand rural environment. The vehicle displayed was either a freight train complete with carriages or a motor car (see Fig. 2) with the vehicle type randomized across conditions. The vehicles consisted of a light grey sedan car and a freight train locomotive, with 16 shipping container carriages. The simulated dimensions of the train were 209 m (length), 2.20 m (width) and 3.15 m (height). For the car, the corresponding dimensions were 3.80 m, 1.80 m, and 1.45 m. In order to make the car distinguishable from the background at all three distances we found that it was necessary to make it a bit lighter than the (larger) train. The car's contrast was 28% relative to the background, and the train was 13%.

The rural environment scene (which served as the background) and the moving vehicles were created using 3DS Max 2010 32-bit (Autodesk, 2010). In order to create realistic stimuli, photos of real-life scenes and vehicles were rendered onto the 3D meshes underlying the background and the car and train. The field of view of the simulated camera creating the images was 39.6° × 30.2° (horizontal × vertical) and the line of sight of the camera was directed 80° from the straight ahead direction (20° relative to the track/road) in order to simulate looking down the track/road and to include the maximum length of the train at the start of the trials.

The observer location was 6 m from the centre of the vehicle's path. At a distance of 60 m along the track from the *t*-intersection (depicted in Fig. 2), the visual angle subtended at the eye of the participant by the front face of the train was 2.05° and 2.92° (horizontal × vertical). The total projected width of the length of the train was 8.30°. For the car, the comparable angles were 1.68°, 1.52° and 2.28°.