Accident Analysis and Prevention 99 (2017) 110–113

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Fixating on the size-speed illusion of approaching railway trains: What we can learn from our eye movements

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ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form 30 October 2016
Accepted 14 November 2016

Keywords:
Level crossing collisions
Size-speed illusion
Eye movements
Eye fixations
Speed perception
Railway

ABSTRACT

Railway level crossing collisions have recently been linked to a size-speed illusion where larger objects such as trains appear to move slower than smaller objects such as cars. An explanation for this illusion has centred on observer eye movements – particularly in relation to the larger, longer train. A previous study (Clark et al., 2016) found participants tend to make initial fixations to locations around the visual centroid of a moving vehicle; however individual eye movement patterns tended to be either fixation-saccade-fixation type, or smooth pursuit. It is therefore unknown as to which type of eye movement contributes to the size-speed illusion. This study isolated fixation eye movements by requiring participants to view computer animated sequences in a laboratory setting, where a static fixation square was placed in the foreground at one of two locations on a train (front and centroid). Results showed that even with the square placed around the front location of a vehicle, participants still underestimated the speed of the train relative to the car and underestimation was greater when the square was placed around the visual centroid of the train. Our results verify that manipulation of eye movement behaviour can be effective in reducing the magnitude of the size-speed illusion and propose that interventions based on this manipulation should be designed and tested for effectiveness.

1. Introduction

The rate of collisions between vehicles and railway trains at level crossing intersections is a worldwide issue that has necessitated thorough investigation over the last ten years or so. Recent research (Clark et al., 2013) indicates that a factor that may account for these types of incidents occurring is an illusory bias known as the size-speed illusion. The size-speed illusion was a theory proposed by Leibowitz (1985), and referred to the concept that larger moving objects appear to move slower relative to smaller objects travelling at the same velocity or in some instances even faster. In the case of level crossing collisions the observer may perceive the larger, longer train to be moving slower, as opposed to a more familiar, smaller vehicle such as a car. This theory was tested and confirmed by Clark et al. (2013) by using computer generated movie clips of moving vehicles (trains and cars).

More recently, Clark et al. (2016) proposed that eye movement behaviour could be a reason for this illusion. They tested the eye movements of observers in a laboratory-based setting with simulated moving trains and cars, set in a rural environment background. They found that participants tended to look further away from the front of a train, as opposed to a car, in a region termed the 'visual centroid' – defined as the weighted vector average of the velocity of the front and the rear of the moving vehicle (Clark et al., 2016). For long objects approaching observers in depth, fixating on the visual centroid region results in a slower optical speed on the retina, and therefore eye velocity is slower.

Underestimation of the train's speed, relative to the car was widespread across their participants; however individual observers demonstrated different types of eye movement patterns. Many observers utilised a fixation-saccade-fixation type strategy, where an observer would make an initial fixation to the visual centroid region of the vehicle, and then make catch up saccades and fixations as the vehicle moved along its trajectory. Other participants employed a different type of eye movement – smooth pursuit, where after the initial fixation; they steadily tracked the vehicle's motion throughout the trial.

After this initial finding, the same study isolated and manipulated smooth pursuit eye movements by placing a dot at different regions of train shapes and car shapes. When participants were required to pursue a dot placed at the front of the train shape, the size-speed illusion was eliminated. Pursuing a dot on the visual

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http://dx.doi.org/10.1016/j.aap.2016.11.013

centroid of the train shape resulted in underestimations of its velocity, consistent with the underestimations of the train in the virtual world setting.

Forcing observers to use smooth pursuit eye movements confirmed the robustness of the size-speed illusion, and also offers one option to reduce the effect of the illusion. We wanted to see if the size of the illusion could also be manipulated by forcing observers to make the saccade-fixation type of eye movement demonstrated by many of our observers.

When fixations occur, the moving vehicle moves past the point of gaze and its speed can be estimated from the image motion near to where one is looking. For the pursuit case, the vehicle image remains relatively stationary on the eye and the speed estimate must be derived from the eye muscle signals ('extra-retinal signals') as well as the motion of the background (Wurtz, 2008). It is not known which of these two cases is more conducive for causing the size-speed illusion. Knowing this would help determine the optimum intervention strategy for eliminating entirely, or reducing the size-speed illusion and, by implication, railway crossing collisions that may have occurred as a result of this illusion. Therefore, this experiment was designed to isolate participant fixations to a single region on the screen, which corresponds to an initial fixation made to the front of a vehicle (car or train), or to the visual centroid (train only). Participants' estimates of the vehicle's speed were recorded and analysed as in previous studies (Clark et al., 2016).

2. Method

2.1. Participants

Sixteen participants (6 male and 10 female) were recruited from the student population at the University of Waikato, ranging in age from 20 to 40 years of age ($M = 27.5$, $SD = 2.25$). All participants had normal or corrected visual acuity (at least 20/20), held a full driver's license, and were reimbursed for their voluntary participation by either receiving a 1% course credit for their respective course (psychology students only), or a $10 petrol voucher. All recruitment and test protocols were subjected to, and received ethical approval by the University of Waikato's School of Psychology Human Research and Ethics committee.

2.2. Apparatus

All stimuli were presented using a Dell OptiPlex 760 Minitower PC, and displayed on a VIEWPixx display (VPixx Technologies) with a 1920 × 1200 pixel resolution (screen size 48.5 cm × 30.3 cm) and a refresh rate set at 60 Hz. Eye movement data were recorded using an EyeLink 1000 Desktop System (Eyelink 1000, SR Research, Ltd., Ontario, Canada), averaging 0.25°–0.5° accuracy. A chinrest was used to ensure that each participant's head remained fixed for the duration of the trials and this was located 57 cm away from the monitor screen, producing a field of view (FOV) of 40° × 30° (horizontal x vertical).

2.3. Stimuli

The simulated vehicles for the experiment consisted of a light blue sedan car, and a freight train with 16 container carriages. The background setting was typical of a New Zealand rural environment, consisting of either a stretch of road or a railway track, running across farmland and placed perpendicular to the observer's line of sight. The virtual dimensions of the train were 186 m (length), 2.23 m (width) and 3.25 m (height). For the car, the corresponding dimensions were 3.81 m, 1.65 m, and 0.95 m respectively. The light blue colour scheme was selected for the car based on photometer readings from previous studies (Clark et al., 2016) which matched the average luminance of the car image to the overall average luminance of the train image.

The background rural environment scene and the moving vehicles were created using 3DS Max 2010 32-bit (Autodesk, 2010). Stimuli were created by rendering photos of real-life scenes and vehicles onto the 3D meshes underlying the background and the car and train. The virtual FOV was set to match the screen FOV above, and the line of sight (from the observers point of view) 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.

A bright pink fixation 'square' was added to the movie sequence. This square was a stationary object in the virtual world and therefore did not move with the vehicles. The square was placed in the world at the position corresponding to one of two locations for the train – a 'front' region and a 'centroid' region. For the car, the square was placed at the same position coordinates used for the front region of the train (Fig. 1).

2.4. Design

Three test blocks of 42 trials (total 126 trials) were presented, each with a short break (5 min) between each test block. During each test block the participants viewed an approaching car; paired with an approaching train, with the fixation square placed at either of the locations described above (the order in which vehicle appeared first was randomised by the computer programme). Each stimulus presentation was 400 milliseconds (m s) in length. During a trial the speed of the car (standard stimulus) always approached at 80 km/h, whereas the train (comparison stimulus) was set to one of seven speeds in km/h (60, 70, 80, 90, 100, 110 or 120) during their 400 m s presentation. Stimulus presentation time (400 m s) was shorter for this experiment than in previous studies (where presentation times were set at 1000 m s and 3000 m s respectively; Clark et al., 2013, 2016), however this was deemed necessary to match the average time taken to initially make a saccade and then fixate on a specific point in a dynamic scene, before the scene changes.

A within-subjects, repeated measures design was used, with all the participants viewing the same simulations (two fixation square location conditions × seven approach speed conditions), with the presentation of trial pairs counterbalanced to eliminate order effects.

The distance between the participant and the level crossing entry point/intersection junction was set at 18m, done in order to match the 18 m condition used in Clark et al.s' (2016) smooth pursuit experiment as closely as possible.

2.5. Procedure

The trial commenced with a blank (uniform grey) display screen. Next, the screen showed the background rural setting with the viewpoint orientated in the direction of the road or railway track, and off to the right hand side. On each trial, an animated sequence of an approaching vehicle (standard car or comparison train) was presented followed (1000 m s later) by a sequence showing the other vehicle type. A response screen was then displayed, containing the question "Which vehicle was faster?" (standard vs. comparison vehicle, two-alternative forced choice (2AFC) procedure). Participants were required to respond by either pressing the right mouse button (if they thought the first vehicle was faster) or the left mouse button (if they thought the second vehicle was faster). Participants were also instructed to fixate on the square throughout the duration of the trial. The eye tracker was implemented for the purpose of verifying that participants were indeed looking at the square for the duration of the trial.