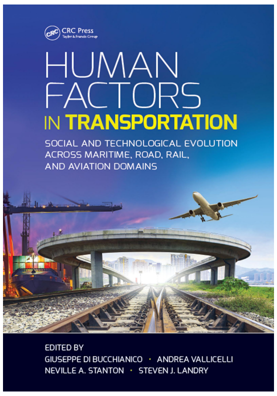

# Human Factors in Transportation
## Social and Technological Evolution Across Maritime, Road, Rail, and Aviation Domains

Giuseppe Di Bucchianico, Andrea Vallicelli, Neville A. Stanton, Steven J. Landry

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# 13

# *Drivers' Visual Scanning and Head Check Behavior on Approach to Urban Rail Level Crossings*

**Kristie L. Young, Michael G. Lenné, Vanessa Beanland,**
**Paul M. Salmon, and Neville A. Stanton**

**CONTENTS**

## 13.1 Introduction

Crashes at rail level crossings (RLCs) constitute a major safety concern, as they are often catastrophic, involving multiple fatalities and traumatic injuries. In 2011, 49 RLC (rail level crossing) collisions were recorded in Australia, leading to 33 fatalities (ATSB, 2012). The costs associated with RLC crashes in Australia have been estimated at approximately AUD $24 million per year. In the European Union (EU), RLC collisions and fatalities represent more than one-quarter of all railway crashes occurring on the EU railway system, with 604 fatal and serious injury casualties recorded during 2011 (European Railway Agency, 2013). Figures from the United States are similar, with 247 fatalities and 705 injuries at RLCs in 2009 (US Department of Transportation, 2014). Given the high levels of trauma and disruption to rail and road networks associated with RLC crashes, their prevention represents a key priority area for rail and road organizations around the world.

Factors contributing to RLC crashes are poorly understood; however, driver behavior is believed to play a key role (Davey et al., 2007; Lenné et al., 2011). Direct causal factors relating to driver behavior typically fall into two broad categories (Lenné et al., 2011). The first involves intentional noncompliance with crossing signals, whereby drivers detect the train and/or the activation of crossing warnings and fully understand the meaning of the warnings, but will nevertheless intentionally cross. A propensity to engage in risk taking or sensation seeking and a low perception of risk have both been found to contribute to intentional noncompliance at RLCs (Davey et al., 2008; Witte and Donohue, 2000). The second, particularly prevalent, category is unintentional noncompliance where drivers, for a range of reasons, fail to detect the crossing signals, fail to comprehend the signals' meaning, or fail to detect the train itself, and will enter the crossing as a train approaches. Indeed, it has been estimated that unintentional noncompliance accounts for almost half of all RLC crashes in Australia (ATSB, 2002). Diminished situation awareness, distraction, and inattention are likely to be key contributors to unintentional noncompliance at RLCs (Caird et al., 2002; Salmon et al., 2013); however, the reasons why situation awareness is degraded, or why inattention occurs, are less clear from previous research.

Studies examining driver behavior in the RLC context have been typically observational, employing on-site observers or video analysis (e.g., Meeker et al., 1997; Tenkink and Van der Horst, 1990; Tey et al., 2011). The primary measure derived from such observational studies is driver noncompliance with crossing signals, which has been estimated to be between 14% and 38% for active crossings with flashing lights and boom barriers (Meeker et al., 1997; Witte and Donohue, 2000). Observational studies do not, however, allow for an in-depth examination of driver behavior in terms of the factors underpinning compliance and noncompliance; particularly, situation awareness, workload, attention, and the system-wide factors underlying each of these. Developments in vehicle instrumentation now make it possible to examine driver behavior at RLCs in greater depth in on-road settings using a suite of onboard driver and vehicle monitoring equipment coupled with human factors methods.

This study focuses on RLCs in urban environments. In such areas, one factor that is likely to shape driver behavior on approach to RLCs and contribute to unintentional noncompliance is the location of crossings in high workload segments of the road network. Urban RLCs are often surrounded by busy shopping strips with high levels of pedestrian, vehicle, and cyclist traffic and a high level of visual clutter (objects unrelated to driving). Complex road environments that contain dense traffic and visual clutter have been shown to increase driver workload and the potential for distraction by removing drivers' eyes off the road or impairing their visual scanning patterns (Horberry, 1998; Jahn et al., 2005; Patten et al., 2006). Thus, the complex traffic environment in which many urban RLCs reside could induce high levels of driver workload and distraction, which in turn may lead to drivers paying less attention to the RLC due to their attention being diverted elsewhere. Pickett and Grayson (1996) identified three types of drivers who are likely to be involved in a crash at RLCs, one of which involved those drivers who are unaware of the signals due to inattention or distraction. Further, an analysis of Canadian RLC crashes over a 19-year period found that a number of crashes involved driver distraction as a factor contributing to drivers failing to see the signals/train at all, or in time to stop (Caird et al., 2002). Driver attention being diverted from the RLC can lead to a failure to safely negotiate the crossing. When the crossing is currently active and drivers fail to detect the signals in a timely manner, the results can be catastrophic. However, distraction and inattention may also affect crossing behavior when no train is immediately present, such as when drivers fail to detect traffic banking up on the far side of the crossing and are forced to queue on the crossing itself.

Little is known about where drivers direct their attention on approach to RLCs and the influence of a high workload environment on driver attention and behavior in relation to the crossing. This on-road study aimed to examine where drivers direct their visual attention on approach to urban RLCs situated in high workload areas—shopping strips. Drivers' eye glance data were examined for the 150 m approach to RLCs to identify what aspects of the road environment drivers focus their visual attention on and how much attention is focused on the crossing itself.

## 13.2 Method

### 13.2.1 Participants

Twenty drivers (11 males, 9 females) aged 18–53 years ($M = 26.8$, $SD = 9.2$) participated in the study. All participants held a current Victorian car driver's license, drove regularly in urban areas, and spoke English as their first language. Eight participants held a valid full car license while the remaining 12 held a valid P2 (second year provisional) license. Participants had held their car license for 8.5 years on average ($SD = 9.2$) and drove an average of 7.8 h ($SD = 5.5$) per week. Participants were recruited through a Monash University newsletter and were compensated for their time and travel expenses. Ethics approval was granted by the Monash University Human Research Ethics Committee.

### 13.2.2 On-Road Test Vehicle

The on-road test vehicle (ORTeV) is an instrumented vehicle equipped to collect vehicle and video data. Vehicle CAN-bus and video data were acquired using a Racelogic Video VBOX Pro system, which combines a GPS (global positioning system) logger, multiple cameras, and a 32-channel CAN (controller area network) interface. Vehicle data collected included: trip time and distance, GPS location, vehicle speed, brake pressure, and vehicle heading. Video data were derived from seven unobtrusive cameras which recorded forward and peripheral views spanning 90° each, respectively, as well as the driver, vehicle cockpit, and the rear of the vehicle. In the current study, the video data were used to manually code drivers' visual scanning behavior.

### 13.2.3 Driving Route

The driving route comprised an 11 km urban route in the southeastern suburbs of Melbourne. The route included arterial roads (80, 70, and 60 km/h) and shopping strips (40 and 50 km/h) and contained six RLCs, all with active controls (flashing lights with boom barriers and bells). The route took 20–25 min to complete. To ensure that participants would experience similar traffic conditions, all drives were completed on weekdays at 10 a.m. and 2 p.m. Direction instructions were provided prior to the drive and participants also carried a route map.

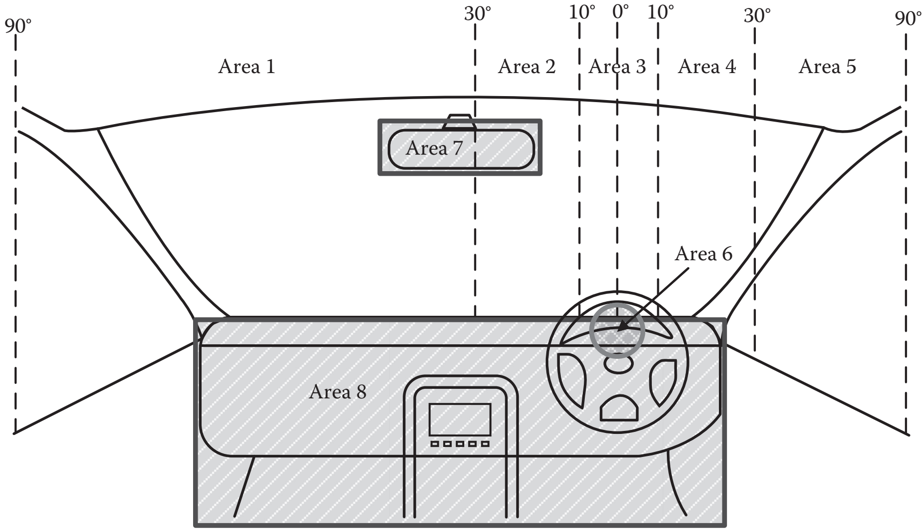
### 13.2.4 Procedure

Demographic details (age, gender, license type, driving history) were collected prior to the study. Participants were then seated in the ORTeV and the data collection systems were initiated. Participants completed the driving route while driving alone in the vehicle.

Two observers followed the participant at a distance in another vehicle to ensure they could redirect participants back on-course in the event that they took a wrong turn. Participants provided verbal protocols throughout the drive. After completion of the drive, drivers were taken back to the university where they completed an interview about their experiences during the drive.

### 13.2.5 Data Reduction

Five of the six RLCs encountered were examined in this study. One RLC was excluded from analysis as it was not located in a shopping strip area. Drivers' visual scanning behavior on the 150 m approach to each RLC (to the point where the vehicle cleared the train tracks) was manually coded using the onboard videos. The driver and forward-facing camera views were used to determine the location of each glance while the vehicle was moving. The locations of drivers' glances were coded across eight different areas including various segments of the forward and side roadway, mirrors, and inside the vehicle (Figure 13.1). The number and duration (ms) of glances to each of the eight areas, the mean distance from the RLC at which drivers glanced to off-road areas, and the percentage of time spent with eyes off the forward roadway was coded for the approach to each RLC. A glance was defined as an uninterrupted fixation to the area of interest. The video was recorded at 10 Hz, thus fixations were examined in 100 ms intervals by moving through the video frame by frame and recording in which area the driver's gaze was directed. Only glances where vehicle speed was above 0 km/h were coded.



*Area 1: 30–90° left
Area 2: 10–30° left
Area 3: road ahead (0° ± 10°)
Area 4: 10–30° right

*Area 5: 30–90° right
Area 6: speedometer
Area 7: rearview mirror
Area 8: other area in vehicle

**FIGURE 13.1**
Areas used for coding driver eye glances on approach to urban RLCs. *Only coded from start of approach to 30 m before RLC. Within 30 m, glances to these areas were assumed to be toward the RLC itself, rather than off-road.

Head checks directed toward the RLC were also examined. Drivers were coded as having executed a head check if, within 30 m prior to the crossing, their head direction and gaze fixation deviated in excess of ±30° horizontally (where 0° indicates straight ahead). Outside of the 30 m approach, glances in excess of ±30° were coded as being directed toward the footpath and shops.

Eye glance behavior was coded by a trained coder. A sample of approximately 10% of the RLC approach videos were independently coded by a second coder and inter-rater reliability was examined using Pearson's $r$. The reliability between the two raters was excellent for the number of glances made to each area ($r = 0.94$, $p < 0.001$) and the duration of glances ($r = 0.95$, $p < 0.001$).

## 13.3 Results

Eye glance data were not captured for two drivers due to video recording issues. As drivers' eye glance behavior is likely to be affected by the presence of a train or activated crossing signals, crossing events were coded as to whether the driver encountered a train or not and crossings where a train was present were directly compared with those where no train was present. Eye glance behavior was pooled across the five RLCs and examined across the eight glance areas when a train was present and not present in a series of generalized estimating equations (GEE). GEE is an extension of the generalized linear model and is useful for analyses such as these because it factors in correlations due to the repeated measurements. The models to examine the mean duration of glances and total percentage of time fixated on each area were specified with a normal error distribution, an identity link function, and the correlation matrix was specified as exchangeable due to convergence problems. The model to examine the mean distance from the crossing when off-road glances were made was specified with a normal error distribution, an identity link function, and the correlation matrix was specified as unstructured. Finally, the model to examine the frequency of glances to each area was specified with a Poisson error distribution and a log link function as it was count data and the correlation matrix was specified as exchangeable due to convergence issues.

### 13.3.1 Frequency and Duration of Glances

The mean number and duration of glances taken to each of the eight areas on the 150 m approach to urban RLCs is displayed in Table 13.1, separately for when a train was present and when no train was present. As shown, the on-road areas had the highest number of mean glances and glances to these areas were also of longer duration than glances to off-road areas. A GEE model was fitted to examine if the number of fixations made to each area differed across RLCs with a train present versus no train present. A significant train presence by glance area interaction was found ($p < 0.001$), whereby, when there was a train, drivers made a greater number of glances to all areas except the speedometer, which they glanced at more frequently when no train was present.

The GEE model for the mean duration of glances to each area revealed a similar pattern of results, with a significant train presence by glance area interaction ($p < 0.001$) indicating that, on approach the crossings, drivers glanced to all areas longer when a train was present, apart from the speedometer and rearview mirror, which they glanced at for longer

**TABLE 13.1**

Mean (*SD*) Frequency and Duration of Glances Made to Each Area on Approach to Urban RLCs as a Function of Train Status

| | Mean Frequency | | Mean Duration (s) | |
|---|---|---|---|---|
| **Area** | **Train** | **No Train** | **Train** | **No Train** |
| 1: 30–90° left (footpath and shops)[a] | 0.5 (0.8) | 0.2 (0.5) | 0.8 (0.2) | 0.6 (0.1) |
| 2: Roadside to 30° left | 2.2 (1.7) | 1.0 (0.8) | 0.7 (0.5) | 0.5 (0.2) |
| 3: Road ahead (0 ± 10°) | 9.3 (4.3) | 6.7 (2.9) | 2.7 (1.5) | 2.7 (1.8) |
| 4: Roadside to 30° right | 5.0 (2.6) | 3.8 (2.6) | 1.0 (0.5) | 0.8 (0.6) |
| 5: 30–90° right (footpath and shops)[a] | 0.9 (1.2) | 0.6 (0.9) | 1.1 (0.3) | 0.8 (0.2) |
| 6: Speedometer[a] | 0.5 (0.6) | 0.7 (0.9) | 0.2 (0.1) | 0.4 (0.3) |
| 7: Rearview mirror[a] | 0.6 (0.7) | 0.6 (0.8) | 0.4 (0.1) | 0.6 (0.2) |
| 8: Other area in vehicle[a] | 0.6 (0.6) | 0.5 (1.0) | 1.2 (0.4) | 0.9 (0.3) |

[a] Defined as off-road glances.

when no train was present. Taken together, these results reveal that drivers made longer and more frequent glances to the forward roadway on approach to urban level crossings when a train was present compared to when no train was present. However, the findings also reveal that drivers made longer, more frequent glances to a number of off-road areas when a train was present, including to footpaths and shops on either side and to other areas inside the vehicle.

### 13.3.2 Percentage of Time Fixated on Off-Road Areas

Given that the individual glance duration and frequency data are substantially affected by travel speed and the overall duration of the approach period, the percentage of time spent fixated on a particular area was also examined as it controls for the total time spent on approach. Table 13.2 displays the percentage of time spent fixated on each of the eight areas on approach to the urban RLCs. The data show that drivers spent just under 10% of time on approach to the urban crossings with their visual attention *off* the forward roadway (9.5% when train present and 8.3% when no train present). The GEE

**TABLE 13.2**

Percentage of Time Fixated on Each Area on Approach as a Function of Train Status

| | % of Time | |
|---|---|---|
| **Area** | **Train** | **No Train** |
| 1: 30–90° left (footpath and shops)[a] | 2.7 | 0.7 |
| 2: Roadside to 30° left | 4.6 | 2.5 |
| 3: Road ahead (0 ± 10°) | 69.2 | 73.1 |
| 4: Roadside to 30° right | 16.7 | 16.1 |
| 5: 30–90° right (footpath and shops)[a] | 3.2 | 2.4 |
| 6: Speedometer[a] | 0.5 | 1.5 |
| 7: Rearview mirror[a] | 0.8 | 1.5 |
| 8: Other area in vehicle[a] | 2.3 | 2.2 |

[a] Defined as off-road glances.

model for the percentage of time drivers spent looking at each area revealed a significant train presence by glance area interaction ($p = 0.044$). The majority of the time was spent glancing at the road ahead, regardless of whether a train was present or not, but when a train was present drivers spent slightly less time glancing at the road ahead and more time glancing at roadside areas, particularly to the right. In contrast, when no train was present drivers predominantly looked at the road ahead but spent a higher proportion of time glancing at the speedometer and rearview mirror. The proportion of time glancing at other in-vehicle areas did not vary between train present and no-train crossings.

### 13.3.3 Distance from the RLC When Off-Road Glances Made

Examining the distance drivers were from the crossing when they glanced to off-road areas can provide insights into drivers' visual scanning strategies and how they may regulate their off-road glances in relation to the crossing. Drivers were defined as reaching the crossing when the front of the vehicle was level with the first rail of the train tracks. Table 13.3 shows the mean distance (in meters) drivers were from the crossings when they glanced to each of the five off-road areas on approach to each RLC. As displayed, the drivers were quite far from the RLCs when they made their glances to the off-road areas, particularly to the off-road area that was unrelated to driving—"other area inside the vehicle," suggesting a fairly conservative off-road scanning strategy. Results of the GEE model revealed a significant train presence by glance area interaction ($p = 0.002$). Drivers glanced to all off-road areas a longer distance from the crossings when a train was present, compared to when no train was present, apart from the rearview mirror, which drivers were presumably using to monitor vehicles behind them as they came to a stop for the train.

### 13.3.4 Head Checks toward the RLCs

Driver head checks within the 30 m immediately prior to entering the crossing were examined. Table 13.4 details the mean number of head checks made and the distance from the crossing when the first and final head checks were made. Data are reported descriptively due to the limited number of head checks made by drivers (the median number of head checks made was 0, regardless of whether a train was present). Drivers made only a small number of head checks of the RLCs, with many drivers making no head checks. Drivers made slightly more head checks overall when a train was present, although head checks were typically performed earlier when no train was present at the crossing.

**TABLE 13.3**

Mean (*SD*) Distance (m) from RLCs When Glances Were Made to Each Off-Road Area as a Function of Train Status

| Area | Train | No Train |
|---|---|---|
| 1: 30–90° left (footpath and shops) | 91.7 (3.5) | 71.5 (24.6) |
| 5: 30–90° right (footpath and shops) | 97.5 (19.0) | 84.4 (25.7) |
| 6: Speedometer | 103.3 (34.8) | 80.6 (36.6) |
| 7: Rearview mirror | 53.9 (18.2) | 86.5 (39.3) |
| 8: Other area in vehicle | 92.9 (29.9) | 91.9 (37.8) |

**TABLE 13.4**

Mean (*SD*) Number of Head Checks and Distance (Meters) from RLC When First and Final Head Checks Made as a Function of Train Status

| | Train | No Train |
|---|---|---|
| *Mean Number of Head Checks* | | |
| Left | 0.14 (0.14) | 0.14 (0.14) |
| Right | 0.42 (0.37) | 0.23 (0.25) |
| *Mean Distance from Crossing: First Head Check* | | |
| Left | 6.9 (12.2) | 15.0 (11.2) |
| Right | 12.1 (8.0) | 15.4 (9.2) |
| *Mean Distance from Crossing: Final Head Check* | | |
| Left | –1.3 (11.6) | 6.4 (10.6) |
| Right | 8.9 (8.1) | 11.2 (8.1) |

## 13.4 Discussion

Eye glance and head check behavior were examined to determine to what areas, and for how long, drivers direct their visual attention when approaching RLCs situated in urban shopping strips. Results revealed that drivers spent the majority of their time on approach to urban crossings with their visual attention focused *on* the forward roadway (over 90%). However, the findings also show that drivers do direct their visual attention off the forward roadway to a range of areas inside and outside the vehicle when approaching urban RLCs. Within the 150 m approach, drivers spent around 10% of the time fixated on off-road areas.

The presence of a train at the urban RLCs did influence drivers' visual scanning behavior. Drivers took longer and more frequent glances to the forward roadway on approach to urban RLCs when a train was present compared to when no train was present. Drivers also glanced at the speedometer and rearview mirror for longer periods on approach when no train was present. However, results also revealed that drivers took longer and more frequent glances to a number of off-road areas when a train was present, including the footpaths and shops on either side and to other areas inside the vehicle. One explanation why drivers spent more time looking at these off-road areas when a train was present is that they were travelling slower in these situations due to the need to come to a stop at the crossing. That is, drivers may have felt more confident looking at areas unrelated to driving when travelling at the slower speeds associated with the presence of trains. Glances to these off-road areas were also typically short (<1.5 s) and were made when drivers were a fair distance from the crossings (>50 m), suggesting that drivers better regulated their off-road glances on immediate approach to the crossings. Further, due to the slower speeds drivers also spent more time on approach to the crossing, which explains the fact that overall glance durations and frequencies were greater when a train was present compared to when no train was present. When controlling for this time difference and instead comparing the percentage of time spent looking in each area, drivers still spent longer looking at off-road areas in the presence of a train, compared to when no train was present.

Driver head check behavior within the 30 m immediately prior to entering the crossing revealed that, on average, drivers made a very small number of head checks at the level crossings, with many drivers not making any head checks at all on approach. Drivers made a slightly higher number of head checks when a train was present, but these were performed later in the approach than when no train was present. These findings indicate that drivers rarely actively check for trains at urban crossings, particularly when the crossing signals are not activated on approach. In an earlier study of driver behavior at level crossings in rural areas, Lenné et al. (2013) found that drivers completed a higher number of head checks (5–6) at passive crossings (stop and give way) compared to actively controlled (boom barrier) crossings (1–2 checks). Taken together, the results of both studies suggest that, at urban RLCs located in high workload areas, drivers have become heavily reliant on the crossing signals to alert them to the presence of a train. It is also possible that drivers may be restricted in their ability to perform effective head checks in built-up urban environments, such as the ones examined in this study, as their sightlines are restricted by buildings and other infrastructure. Nevertheless, drivers failing to scan the crossing for trains, regardless of the reason, could be problematic in a number of instances; for example, if the RLCs warning infrastructure fails or when drivers' attention is diverted momentarily away from the crossing warnings immediately prior to activation.

This is the first study to examine drivers' visual scanning and head check behavior on approach to urban RLCs in an on-road context. Our findings extend previous observational studies (e.g., Meeker et al., 1997; Tenkink and Van der Horst, 1990; Tey et al., 2011) by moving beyond examining driver compliance at RLCs to exploring an aspect of driver behavior that may underlie why drivers fail to comply with crossing signals, namely where they focus their visual attention on approach and how this is shaped by the wider road environment. Overall, the visual scanning findings from the current study suggest that while drivers spend the majority of the time on approach to urban crossings with their eyes on the forward roadway, they do also look at various off-road areas, even when a train is approaching. Our findings therefore lend support to previous work by Caird et al. (2002) and Pickett and Grayson (1996) which suggest that driver distraction could play a role in drivers failing to detect the signals at RLCs. Further work should investigate the mechanisms underlying driver distraction at RLCs. Is the environment too visually demanding or attention grabbing leading drivers to pay less attention to RLCs? Are the RLCs not conspicuous enough in busy urban areas? Or do drivers simply not consider RLCs to be risky enough to warrant their undivided attention?

Visual scanning behavior provides important insights into driver behavior at high workload urban crossings; however, this is only part of the picture. As part of the wider rail program, the authors are interrogating drivers' verbal protocols and post-drive interview data to build a more comprehensive picture of driver behavior on approach to urban RLCs. These analyses will provide insight into where drivers direct their cognitive as well as their visual attention on approach to urban crossings, the information cues used to identify the presence of the crossing and make a crossing decision and if behavior in this context is influenced by driver experience.

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## References

ATSB. 2002. Level crossing accidents: Fatal crashes at level crossings. *Paper Presented at the 7th International Symposium on Railroad-Highway Grade Crossing Research and Safety*, Melbourne, Victoria, Australia.

ATSB. 2012. Australian rail safety occurrence data 1 July 2002 to 30 June 2012. Report number RR-2012-010. Australian Transport Safety Bureau, Canberra, ACT.

Caird, J.K., Creaser, J.I., Edwards, C.J., and Dewar, R.E. 2002. A human factors analysis of highway-railway grade crossing accidents in Canada. TP 13938E. Transport Canada, Ottawa, Canada.

Davey, J., Wallace, A., Stenson, N., and Freeman, J. 2008. Young drivers at railway crossings: An exploration of risk perception and target behaviours for intervention. *International Journal of Injury Control and Safety Promotion*, 15(2), 57–64.

Davey, J.D., Ibrahim, N.R., and Wallace, A.M. 2007. Human factors at railway level crossings: Key issues and target road user groups. In Anca, J.M. (Ed.), *Multimodal Safety Management and Human Factors: Crossing the Borders of Medical, Aviation, Road and Rail Industries*. Aldershot: Ashgate, pp. 199–210.

European Railway Agency. 2013. Intermediate report on the development of railway safety in the European Union. European Railway Agency Safety Unit, May 15, 2013.

Horberry, T. 1998. Bridge strike reduction: The design and evaluation of visual warnings. PhD thesis, University of Derby, UK.

Jahn, G., Oehme, A., Krems, J.F., and Gelau, C. 2005. Peripheral detection as a workload measure in driving: Effects of traffic complexity and route guidance system use in a driving study. *Transportation Research Part F: Traffic Psychology and Behaviour*, 8(3), 255–275.

Lenné, M.G., Beanland, V., Salmon, P.M., Filtness, A.J., and Stanton, N. 2013. Checking for trains: An on-road study of what drivers actually do at level crossings. In Dadashi, N., Scott, A., Wilson, J.R., and Mills, A. (Eds.), *Rail Human Factors: Supporting Reliability, Safety and Cost Reduction*. London, UK: Taylor & Francis, pp. 53–59.

Lenné, M.G., Rudin-Brown, M., Navarro, J., Edquist, J., Trotter, M.G., and Tomesevic, N. 2011. Driver behaviour at rail level crossings: Responses to flashing lights, traffic signals and stop signs in simulated driving. *Applied Ergonomics* 42(4), 548–554.

Meeker, F., Fox, D., and Weber, C. 1997. A comparison of driver behaviour at railroad grade crossings with two different protection systems. *Accident Analysis and Prevention*, 29(1), 11–16.

Patten, C.J., Kircher, A., Ostlund, J., Nilsson, L., and Svenson, O. 2006. Driver experience and cognitive workload in different traffic environments. *Accident Analysis and Prevention*, 38(5), 887–894.

Pickett, W. and Grayson, G.B. 1996. Vehicle driver behaviour at level crossings (No. 98). Transport Research Laboratory, Berkshire, United Kingdom.

Salmon, P.M., Lenné, M.G., Young, K.L., and Walker, G.H. 2013. An on-road network analysis-based approach to studying driver situation awareness at rail level crossings. *Accident Analysis and Prevention*, 53, 195–205.

Tenkink, E. and Van der Horst, R. 1990. Car driver behaviour at flashing light railroad grade crossings. *Accident Analysis and Prevention*, 22(3), 229–239.

Tey, L.S., Ferreira, L., and Wallace, A. 2011. Measuring driver responses at railway level crossings. *Accident Analysis and Prevention*, 43(6), 2134–2141.

US Department of Transportation. 2014. *Railway-Highway Grade Crossing Facts and Statistics.* Federal Highway Administration. Retrieved January 8, 2014, from: http://safety.fhwa.dot.gov/xings/xing_facts.cfm

Witte, K. and Donohue, W. 2000. Preventing vehicle crashes with trains at grade crossings: The risk seeker challenge. *Accident Analysis & Prevention*, 32, 127–139.