The assessment of hazard awareness skills among light rail drivers

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ABSTRACT

Light rail (LR) is a popular means of public transportation worldwide, in use in more than 380 cities worldwide. Light Rail Drivers (LRDs) must have good hazard awareness: the ability to understand the complexity of the traffic environment and anticipate road events. Yet, no study has examined LRDs ability to anticipate hazards, and this is the purpose of this study. The experimental group included 28 certified LRDs from the LR in Jerusalem. The control group included 26 students from BGU, with no experience with LR driving. Participants observed 18 short video clips of the driver's field of view and had to press a response button each time they identified a hazard. Participants' eye movements and button presses were recorded throughout the experiment. In general, LRDs were better at identifying hazards compared to the control group. Novice LRDs with less than 1 year of LR driving experience were more likely to respond to hidden hazards. The implications are discussed.

Keywords: Light rail drivers, hazard awareness, eye movements, Light rail driving experience.

1 INTRODUCTION

Light rail (LR) is one of the most popular means of public transportation worldwide, currently operated in more than 380 cities all around the world, transferring approximately 13.6 billion passengers daily (Dauby, 2015). LR driving is a complex task that needs to be performed in a dynamic and complex environment of urban traffic, often under high levels of mental workload. According to Naweed and Rose (2015) the most risky areas with high potential for a crash include intersections that are used by all road users or areas where the track runs along the road without any segregation, where the potential for conflicts with other road users is highest and often unpredictable. While the LRD needs to safely navigate through this complex traffic environment and anticipate road hazards there are additional challenges imposed on the driver, he also has to maintain a high level of customer service by following a strict time schedule and provide a pleasant trip to the passengers (Naweed and Rose, 2015; Nazning, Currie and Logan, 2017).

According to Naweed et al. 2017, good LR driving not only requires the awareness of the various elements in the environment but also the ability to understand the environment's complexity and be prepared for unexpected events. This ability of anticipating hazardous events, known as hazard perception (HP), has been studied widely in the domain of automobile driving (e.g., Chapman and Underwood, 1998; Horswill and McKenna, 2004; Sagberg and Bjørnskau, 2006; Borowsky, Shinar, and Oron-Gilad, 2010). HP can be defined as drivers' ability to "read" the road and anticipate hazardous situation (Horswill and McKenna, 2004). It is argued that of the many driving skills that a driver possesses only HP has been found to correlate with traffic crashes (Horswill and McKenna, 2004). For example, Horswill et al. (2015) found that drivers who failed in the Queensland's official hazard perception test (HPT) were 25% more likely to be involved in a crash in the preceding year as well as in the year following the test compared to drivers who passed the test successfully.

Such findings, among others, promoted HPT to be an integral part of the official licensing procedure in the UK among others since 2002 (Crundall, 2016). While HPTs have been widely studied with respect to car drivers, there seems to be no indication for using this kind of measure to evaluate LRD driving performance.

One of the most consistent findings with respect to HP is that experienced drivers possess better HP skills compared to young-novice drivers (e.g., Sagberg and Bjørnskau, 2006; Borowsky, Shinar, and Oron-Gilad, 2010). This superiority is typically reflected by faster response times to hazards (Horswill and McKenna, 2004; although see Borowsky and Oron-Gilad (2013) for further discussion on this measure), and more effective road scanning patterns (Chapman and Underwood, 1998). In addition, experienced drivers are better than young-novice drivers at anticipating hidden hazards (Borowsky et al., 2010; Vlakveld et al., 2011), situations where the hazard instigator is obscured behind an object or another road user (e.g., a pedestrian is obscured behind a parked truck and might burst into the road).

2 OBJECTIVES

The aim of this study was to generate a valid HPT for LRDs in order to evaluate their HP performance and to define a gold standard for adequate performance that can later be used by LRD trainers and other stakeholders.

3 METHOD

3.1 Participants

Fifty-four participants took part in this study. The experimental group consisted of 28 participants (one female) who were learners or novice drivers (3) or qualified LR drivers (24) of the Jerusalem LR Transport (JLRT), ranging in age from 26 to 62. The control group included 26 students ranging in age from 25 to 28. This group had no prior knowledge or experience in LR driving. All participants had at least 5 years of driving experience, uncorrected Snellen visual acuity of 6⁄9 (20⁄30) or better, and normal contrast sensitivity. All had 5+ years of driving experience. All participants filled a demographic questionnaire before the experiment began.

3.2 Materials and Apparatus

3.2.1 Eye tracking laboratory

The experiment was conducted in the eye tracking laboratory at BGU. A 20” LCD wide screen with 1360* 768 pixels, connected to a Pentium 4 PC, was used to display the movies. Participants sat 65 cm from the LCD, which provided them with a visual field of 22 degrees vertically, and 35 degrees horizontally. Another PC was used to operate the eye tracking software interface and to control the participant’s computer. Eye movements were recorded with an Eye Tracking System (ETS; Applied System Laboratories, Model D6), sampling the visual gaze at 60 Hz, with a nominal accuracy of 0.5 degrees of visual angle. The D6 facial recognition algorithm allows head free eye tracking without putting any equipment on the participant.

3.2.2 Hazard perception movies and software.

A Panasonic Lumix G DMC-G7 camera with an Olympus 7-14 mm wide lens mounted in the middle of the internal side of the driver's cabin's windshield directed toward the rails was used to record the video footage.

Recordings of the drive from both directions of the route were made on different days and hours with different drivers. Each recoding lasted about 50 minutes and covered the whole 13.8 km route along one travel direction. The movies were edited into dozens of short segments (24-42 seconds). A representative sample of these segments were presented to a group of experts (LR drivers qualified trainers) at the JLRT in order to get a grasp of the typical hazardous situations that LR drivers might experience when driving along the route at different days and hours. Based on their comments, 18 short driving movies were selected for the experiment. Of these 18 movies, 2 were used for practice purposes only. Of the remaining 16, 13 were day-time and 3 were night time drives. Each movie contained a different number of hazardous events, totalling 50.

Movies were displayed randomly to the participant on a 20" LCD and he or she was asked to press a designated response button whenever they identified a hazardous situation. The participant's response had no effect on the movie and it continued playing to its end. At the end of each movie the participant indicated the reason for each response and typed it into a designated text-box on the screen. A fixation screen (a grey screen with a small black circle in the middle) was presented for 500msec before the beginning of the next movie. An in-house software was used to present the movies and to record all button presses and the associated reasons as well as eye movements' data.

3.2.3 LR road hazards classification

Typical hazards that appeared in the movies included situations such as pedestrians walking in parallel and near the tracks, pedestrians and bicycles who were crossing the tracks, a passing train in the opposite tracks, other vehicles crossing at crossroads, etc. Figure 1 contains examples for typical hazards.

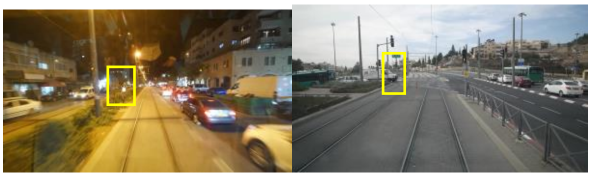

Figure 1 - Two examples of typical hazards in night-time (left) and daytime (right)

Aiding the experts' comments, all hazards were predefined by the research group and in case of disagreements they were settled through discussion. The durations of the hazardous situations varied from 24 to 42 seconds. They were classified according to a taxonomy proposed by Borowsky and Oron-Gilad (2013) as belonging to one of three types: (1) *Visible-Potential (VP)* hazard. This type of hazard includes situations where the hazard instigator is visible, but the hazard instigator had not entered the driver's path. This type of hazard requires the driver to monitor the hazard, but it does not require any evasive action. A potential hazard can materialize at any given moment. For example, a pedestrian walking parallel to the tracks. (2) *Hidden-Potential (HP)*. This type of hazard includes situations where the hazard instigator is hidden behind other road users or behind some objects and therefore it cannot be seen by the LR driver. In this type of hazard, the hazard instigator does not enter the driver's path and the driver should monitor the area from where a hazard instigator might appear. For example, a passing train in the counter-tracks that can obscure potential pedestrians behind it. (3) *Visible-Materialized (VM)* hazard. This type of hazard is similar to visible potential hazards, but in this case it actually materializes. For instance, a pedestrian that darts into the tracks very close to the front of the train.

3.3 Procedure

The participant arrived to the lab, signed a consent form and went through a visual acuity test and a contrast sensitivity test. The participant was then asked to seat in front of the display and to fill a demographics questionnaire. Once finished, (s)he went through a short eye calibration process and a detailed instructions page was presented on the screen explaining the participant that (s)he is about to observe a sequence of LR driving movies that were taken from a LRD's perspective and that their task is to press a response button whenever they identifies a hazard. Next, two movies were presented as practice to allow the participant to get familiarized with the experimental task. Then, the participant was asked to start the HPT. As described above, in this phase 16 driving scene movies were displayed to the participant and he was asked to press a response button whenever he identified a hazard. At the end of each movie the participant indicated the reasons for each button press. The experiment ended at the end of this phase.

4 RESULTS

The data collected on each participant includes two types of information: (1) behavioural response, and (2) eye movements. For the purpose of this paper, we will focus on the button press analyses.

3.4 Hazard detection (probability to identify a hazard)

This measurement describes the probability of a participant to respond to a certain hazard. The dependent variable is binary distributed indicating whether a participant identified the hazard ("1") or not ("0") within the allotted time. For this analysis two independent variables were included in the model: Group (control, novice LR drivers, experienced LR drivers), and Hazard Type (materialized, potential-visible, potential-hidden). A binary logistic regression model was utilized within the framework of General Linear Mixed Models (GLMM), with a logit link function. The independent variables and their interaction were included as fixed effects and participants were included as a random effect. Applying a backwards elimination procedure, the final model's results are summarized in Table 1. Post hoc pairwise comparisons was done using the Bonferroni correction.

Table 1 - A summary of the final hazard detection model's fixed effects

Source	F	DF1	DF2	Sig	Estimated Means (SE)
Group	12.20	2	2691	<0.01	C=0.3 (0.03), NLR= 0.72 (0.07), ELR=0.44 (0.04) NLR >ELR >C (P_{adj}=0.01; P_{adj}=0.03 respectively)
Hazard Type	52.01	2	2691	<0.01	VP=0.47 (0.03), HP=0.26 (0.04), VM=0.74 (0.04) MV>VP>HP (P_{adj}<0.01; P_{adj}<0.01 respectively)
Group*HazardType	14.58	4	2691	<0.01	See Figure 2 left panel

Note for Tables 1 and 2. C, LRN and LRE stands for Control, Novice LR drivers, and Experienced LR drivers. VP, HP and VM stands for Visual-Potential, Hidden-Potential and Visual-Materialized hazards respectively.

Figure 2 left panel describes the interaction between group and hazard type. Post hoc pairwise comparisons analysis revealed several patterns. First, novice LR drivers and experienced LR drivers were significantly more likely to respond to visible-potential hazards than the control group (NLR: $P_{adj}<0.01$, ELR: $P_{adj}<0.01$). Novice LR drivers were significantly more likely to respond to hidden-potential hazards than experienced LR drivers. ($P_{adj}<0.01$) and the control group ($P_{adj}<0.01$). In addition, experienced LR drivers were more likely than the Control to respond to these type of hazards ($P_{adj}=0.01$). Second, while Novice LR drivers had a similar response probability for all types of hazards, both the control group and Experienced LR drivers were more likely to respond to visible-materialized hazards, followed by visible potential hazards followed by hidden potential hazards (ELR: VM> VP; $P_{adj}<0.01$, VP>HP; $P_{adj}<0.01$; Control: VM> VP; $P_{adj}<0.01$, VP>HP; $P_{adj}<0.01$).

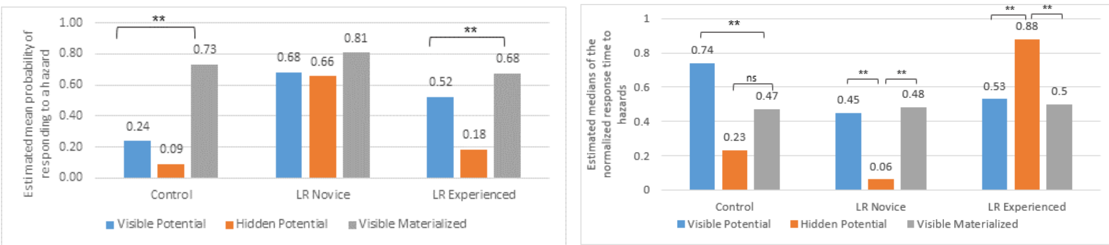

Figure 2 - Interaction between Group and Hazard type.

The left panel refers to the estimated probability to identify a hazard and the right panel to the estimated medians of the normalized RT. Note. '*' indicates P<0.05, '**' indicates P<0.01, ns means not significant.

3.5 Normalized response time

This variable measures the time interval between the beginning of the hazardous situation and the time when the button press was initiated *divided by the duration of the time window of that hazard*. Since the dependent variable is bounded (between 0 and 1), it is not normally distributed. Thus, we applied a natural logarithm (LN) transformation on it. We then utilized a linear regression model within the framework of GLMM. The independent variables group and hazard type and their interaction were included as fixed effects and participants were included as a random effect. Applying a backwards elimination procedure, the final model's results are summarized in Table 2. Estimated means were transformed back to the original values of the dependent variable (that is, before the LN transformation).

Table 2 - A summary of the final normalized response time model's fixed effects

Source	F	DF1	DF2	Sig	Estimated Medians (CI) of the normalized RTs
Group	6.38	2	1119	0.02	C=0.48 (0.35-0.60), NLR= 0.27 (0.12-0.48), ELR=0.67 (0.57-0.76) ELR > NLR ($P_{adj}=0.03$), C = ELR, C=NLR
Hazard Type	5.58	2	1119	0.04	VP=0.58 (0.48-0.67), HP=0.34 (0.22-0.50), VM=0.48 (0.37-0.60) VP>HP ($P_{adj}<0.01$); VM=VP, VM=HP
Group*HazardType	15.22	4	1119	<0.01	See Figure 2 right panel

Figure 2 right panel describes the interaction between group and hazard type. Post hoc pairwise comparisons analysis revealed several patterns. First, experienced LRDs were significantly slower to respond to hidden-potential hazards compared to novice LRDs ($P_{adj}<0.01$) and compared to the control group ($P_{adj}<0.01$). No differences between the groups were found for materialized hazards. Second, while experienced LRDs displayed significantly slower RTs for hidden hazards compared to visible hazards (HP>VP: $P_{adj}<0.01$; HP>VM: $P_{adj}<0.01$), novice LRDs displayed an opposite pattern, that is, a faster RTs towards hidden hazards compared to both visible-potential hazards and visible-materialized hazards (HP<VP: $P_{adj}<0.01$; HP<VM: $P_{adj}<0.01$).

5 DISCUSSION

This study examined LRDs ability to anticipate road hazards as this is one of the greatest challenges of LRDs (Naweed et al., 2017). The results of this study revealed several patterns. Because the types of hazards according which the hazards were classified were a prominent factor in affecting participants' response the discussion will be organized accordingly. First, with respect to materialized hazards, there were no significant differences between experienced LR, novice LR and control drivers either in terms of the probability to respond or in the time to respond. This pattern is consistent with previous studies showing that even novice drivers have no problems in detecting materialized hazards and respond to them at the same speed as experienced drivers (Vlakveld et al., 2011; Borowsky et al., 2010). This pattern is not surprising because responding to a materialized hazard where the hazard instigator is visible (e.g., a pedestrian crossing the tracks in front of the LR) is independent of driving experience and does not require any anticipation capabilities. Typically, and consistent with our findings, these types of hazards induce the largest number of responses among all types of hazards.

Second, with respect to visible-potential hazards, two patterns emerged. First, experienced LRDs (0.68) and novice LRDs (0.52) were significantly more likely to respond to visible-potential hazards than the control (0.24) drivers. This is interesting because it shows that with LR training and driving experience drivers' sensitivity to the potential hazards increases. In contrast, the control group who had no experience in LR driving was much less sensitive to visible potential hazards. Thus, an observer who is unfamiliar with the context of the LR driving environment cannot really evaluate the likelihood that a pedestrian walking along the tracks or a construction worker who stands beside the tracks will enter the LR path of travel. With accumulating LR driving experience, drivers learn that other road users in the near surroundings of the tracks may oftentimes be unexpected. For this reason, experienced LRDs tend to monitor these hazards more closely and are more sensitive to respond to these types of hazards. RT analysis showed that the control group were also much slower to respond to these hazards compared to experienced LRDs and novice LRDs (who did not differ from each other).

Third, and perhaps the most intriguing finding was the difference between experienced LRDs and novice LRDs in identifying hidden-potential hazards. It was hypothesized that experienced LRDs will identify these types of hazards better than novice LRDs. Our findings, however, revealed an opposite pattern. Novice LRDs were more likely than any other group to respond to hidden-potential hazards (0.66) followed by Experienced LRDs (0.18) followed by the control (0.09). In addition, the RT results revealed that experienced LRDs were significantly slower (MRT=0.88) to respond to hidden hazards compared to both the control (MRT=0.26) and the novice LRDs (MRT-0.06). However, given the fact that the novice LRDs consisted of only 4 people, more research should be done before drawing any conclusions.

To summarize, this study was an initial step toward establishing a HPT for LRDs; one that will hopefully be used by LR trainers as well as other stakeholders. Since the number of LRDs was limited, especially with respect to novice LRDs, more research is needed.

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