Using Eye-Tracker to Assess the effectiveness of a 3D Riding Simulator in increasing Hazard Perception Skills

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Using Eye-Tracker to Assess the effectiveness of a 3D Riding Simulator in increasing Hazard Perception Skills

Concetta F. Alberti, Luciano Gamberini, Anna Spagnolli, Diego Varotto, Luca Semenzato

Human Technology Lab. Department of General Psychology University of Padova

Running title:

Eye-tracker to assess hazard perception

Corresponding author:

Luciano Gamberini
Dipartimento di Psicologia Generale
Università di Padova
Via Venezia, 8
35131 Padova
Italy
Tel: +390498276957
Fax: +390498276600
Email: luciano.gamberini@unipd.it
Abstract

A crucial factor contributing to the high rate of road accidents involving young people is inexperience, in particular the inability to perceive hazards. The aim of this study is to test the effectiveness of a fixed-base riding simulator in improving this skill in young people without previous motorbike driving experience. A group of 14 participants was asked to ride in a virtual urban area in which other passing vehicles were programmed to create risks of collision. Participants’ hazard perception was measured through an eye tracking machine as the first fixation latency, i.e. the time interval between hazard onset and the first fixation on the hazard. Results show that a four session training (16-24 minutes) can significantly affect hazard perception, decreasing the time needed to orient the eyes to the hazard from the first to the last session (t=1.92, df=13, p=0.038).

KEYWORDS: training, hazard, virtual simulator, fixation, riding.
1. Introduction

1.1 Gaining Road Experience with Simulators

Young drivers are the most involved population in road accidents. Although 16 to 24 years old people in 2005 represented 11.5% of the whole European population, they underwent 21.1% of all road fatalities.\(^1\) The lack of experience seems to be a key factor undermining their safety on the road, in addition to personal factors such as risk-seeking behavior and social factors such as group affiliation, role expectation, or social dependence.\(^2\) Experienced drivers show a richer repertoire of driving practices, a refined capability of self-assessment, an increased automatization of drive-related actions with a consequent reduction in the request for cognitive (mainly attentive) resources and a diminished mental workload during driving tasks.\(^3\)

A rich opportunity to train users in these tasks is provided today by driving/riding simulators. Using a set of controls such as steering wheel and pedals, simulators allow users to interact with a vehicle and drive it real-time on a virtual road. One advantage of this training technique over practicing with real cars is obviously a safer training environment both for the trainee and for the other road users. Interactivity is a second advantage that distinguishes simulator-based training from class-based training with visual material and lectures, where there is no possibility to practice risk-preventing behaviors. The potential of driving simulators, in term of active processing during training, has been investigated by Ivancic and Hesketh\(^4\). The authors compared the relative effectiveness of an active training (where participants make their own errors) and a guided training (where participants are shown video-clips of errors): the number of traffic offences occurred in a subsequent trial with a simulator was smaller in the first group than in the group trained with video-clips.

A third class of advantages pertains to the flexibility of the learning environment; a simulator makes available several different scenarios, with varying levels of difficulty, environmental conditions and...
vehicles, allowing stepwise training and knowledge transfer from one setting to the other. The system can include additional feedback sources, e.g. task replay from different perspectives.

Simulators can be considered as persuasive technologies, namely tools designed (and able) to change behaviors and attitudes\(^5\) by showing in a few sessions the consequences of hazards that would have taken longer in real life in order to be experienced. To this, the simulator adds other persuasive aspects including the attractiveness of a game-like tool, and the intuitiveness that can make them a suitable and effective interface also for elderly people not used to new technologies.\(^6\)

A review of the recent developments in the design of simulators, including a chart summarizing the features of recent driving simulators and their pro and cons, has been recently provided by Pinto, Cavallo and Ohlmann\(^7\). While the authors promote a multisensory stimulation (visual, motion, tactile-kinesthetic, and acoustic) as the ideal equipment for research purposes, common computer-based simulators offer a more affordable solution to be adopted in schools and training centers and are then most likely to impact the actual learning practices in the next years. Common simulators also allow to overcome the current lack of standards that, due to the deployment of different simulator prototypes, prevents the generalization of results on the efficacy and efficiency of these systems. We decided to adopt in this study the Riding Trainer manufactured by Honda\(\textsuperscript{®}\) (HRT) which is distributed worldwide and whose efficacy as a tool to improve hazard perception and awareness has been recently demonstrated\(^8,9\).

### 1.2 Hazard Perception while Driving

The concept of hazard perception is defined as either the ability to perceive, understand and anticipate risky situations, or the ability to quickly perceive and respond to potentially dangerous events. According to Sagberg and Bjørnskau\(^10\) hazard perception is composed by two separable aspects: “the degree of perceived hazard associated with the situation” and “the perception/reaction time to the perceived hazard” (p. 407). Also Deery\(^11\) introduced a two-component model based on a
subjective experience, such as the evaluation of danger potential, and on driving skills, such as hazard perception latency.

The recognition of dangerous traffic events as they arise represents a human factor of extreme relevance in safe driving. Endsley\textsuperscript{12} identifies a multi-level structure consisting of “perception” (level 1), “comprehension” (level 2) and “projection” (level 3); level 1 is considered the most important one since, as was pointed out by Jackson, Chapman and Crundall, “without seeing and perceiving the necessary information it will be difficult, perhaps impossible, to achieve level 2 and 3” (p. 156).\textsuperscript{13} Treat et al.\textsuperscript{14} found out after a five year long study of 2258 automobile accidents that only a very small percentage of them could be ascribed to mechanical fault (2.4%) or environmental factors (4.2%) whereas human error was a contributing factor in 92.6% of the cases and the sole cause of accident in 57% of them. Considering only these latter cases, 90% depended on “perceptual” errors and 10% were categorized as caused by human response errors. According to Nagayama\textsuperscript{15} 50% of all collisions in road traffic arise from a missing or delayed hazard perception. The drivers’ failure to perceive road-traffic hazards is often due to the fact that they overlook certain areas of the street, because of their lack of experience and because their mental resources are focused elsewhere. Also according to the analysis of McKnight and McKnight of 2000 police crash reports, the largest fraction of accidents involving young drivers is due to failures of attention and visual search, not to high speed and risky behaviours.\textsuperscript{16}

Eye tracking have been proposed as a strategy to measure the drivers’ identification of a risk when it appears, and then to assess the improvement in his/her hazard recognition skill as a consequence of training. Eye tracking systems allow to locate which part of the visual scene attracts attention by connecting certain pre-defined information present in the virtual scene to the distribution of visual fixations.\textsuperscript{17}

In the work presented here, the measure of hazard perception is the first fixation latency, i.e. the time taken by the observer since the danger’s appearance to first fixate (with his/her eyes) the visual
area containing the danger. Hazards appearing in a peripheral area of the screen are considered, since they require to move the gaze away from the central area of the screen where the user is controlling the road. The hypothesis is that if the simulator can improve the ability to identify hazards, then the latency of the first fixation on the hazard should decrease from the first to the last training session.

2. Method

Participants

A group of 14 students from the University of Padua voluntarily took part to the experiment. Participants were 20 to 25 years old (7 females and 7 males; \( M = 23.28, \ SD = 1.59 \)). They were selected because they reported no driving experience on scooters or other motorcycles and did not have any motorcycle riding license. Participants had normal or corrected to normal visual acuity. The experiment was undertaken with the written consent of each participant. None of the participants needed to be discarded, as good eye tracking data were obtained from all of them.

Eye tracking apparatus

Eye movements were recorded with a remote eye tracker (Tobii® 1750) based on combined pupil and corneal reflection analysis. The system integrates the camera and the near-infrared LEDs into a TFT 17” monitor (1024x768 resolution) and has an accuracy of 0.5°, a sampling frequency of 50 Hz and a reacquisition time inferior to 100 ms. The system permits a relatively high freedom of movements as the camera has a recording field of 20x16x20 cm; thus a chinrest is not necessary. A 9-point calibration of the eye tracker was performed for each participant. The ClearView® 2.7.0 software was used to manage the eye tracking data. Fixations were estimated from x and y gaze coordinates clustering the gaze-points that were closer than 1.58° of visual angle for at least 100
ms. A replay visualization of fixations positions on the screen was exported in .avi format and analysed frame-by-frame.

Driving simulator

The Honda Riding Trainer (HRT, Figure 1), is a fixed-base driving simulator with the commands of a real scooter. Different traffic situations are proposed in the interactive environment of the HRT; it is possible to select the road type, i.e. “Avenue” (main street), “Path” (secondary street) or “Touring” (extra-urban road), and the visibility conditions, i.e. daylight, night or fog. The HRT allows to choose between different motorcycle categories and between automatic and manual riding mode. For this experiment participant had to ride a scooter in automatic mode, urban main streets and daylight. Urban main streets were usually single-carriageway roads with different kinds of vehicles, bicycles and pedestrians using it. We also consider the role of the social context of the training situation, adopting the most favourable setting as suggested in a recent work\(^{18}\): the training was undertaken in an isolated environment where no other people were present apart from the experimenter.

[Figure 1 here]

Figure 1. The experimental apparatus, with the Honda Riding Trainer and the Tobii 1750 eye-tracker

Stimuli

The virtual roads were shown on the 17” monitor of the Tobii eye-tracker and located at a distance of approximately 60 cm away from the participant’s eyes. The screen was subtended by a visual angle of 31,6 x 25,3 degrees. The video frame-rate was 24 Hz.

The speedometer and the wing mirrors were visualized at the bottom and on both sides of the screen respectively.
As explained at the end of section 1.2, the hazard considered for the analysis had to emerge from the periphery of the scene and to be heading across the rider’s projected trajectory. The periphery of the scene was defined as the area comprised between 3.57° from the central vertical axis of the screen and the lateral borders of the screen. Two routes containing an equal number of hazards filling this criterion (four hazards each route) were used as first and last routes in the training in a counterbalanced order; the measures were taken on these routes.

**Experimental procedure**

Participants were seated in front of the screen and received instructions on how to accelerate, decelerate and brake, about the engine ignition and signalling. They were told that they would have one practice route followed by four assessment routes during which their eye movements would have been recorded. After this explanation the practice ride started on roads without traffic and where no other vehicle or pedestrian was present in order to get acquainted with the HRT commands. Participants were asked to try to accelerate, brake, to turn and signalling. After this practice ride, participants took four assessment sessions with as many routes. They were told that directions were provided vocally by the system, and were warned that each time they incurred in an accident, the simulator would stop, show a replay of the accident and then re-start the ride from the accident position. When this happened, they simply had to start the scooter engine and continue the assessment. Participants were instructed to keep an eye out for hazards and, if a hazard was encountered, to try and avoid collisions. After these instructions and the eye tracker calibration, the series of 4 assessment routes started and eye movements were recorded. In case speed exceeded 40Km/h, the participant was requested to decelerate. At the suggested speed (30-40 Km/h) the completion of one route took approximately 4-6 minutes. Each route was presented once to each participant.
Design and data

A pre-post experimental design was used in which riders underwent four assessment sessions. Only the data from the first and last assessment routes were analyzed, as they contained an equal number of hazards matching the above mentioned criterion. The measures taken were the number of hazards fixated, the latency of the first fixation and the number of crashes occurred in the first and last routes with the selected hazards.

The first fixation latency for each hazard was calculated with respect to the hazard onset. The hazard onset was its actual appearance on the screen or – in case the object was already present on the screen – the moment at which it started moving across the trajectory of the scooter. As a consequence of individual driving style, the time at which hazards appeared could vary across participants.

Figure 2 shows a hazard appearing from the periphery of the screen marked with a white rectangle; this area helped defining fixations on the hazard: fixations had to be enclosed in this area to be considered as possible fixations on the hazard. Fixations closer than 3.57° to the central vertical axis of the screen were most probably directed to the driving direction than to the hazard and therefore were not included in the analysis. The figure also shows the sequence of fixations of a participant after hazard’s onset; only the first was considered in the analysis.

[Figure 2 here]

Figure 2. A hazard appearing at the periphery of the screen and directed across the scooter. The first fixation on the hazard is highlighted with a red circle. The white rectangle helps defining fixations on the hazard as fixations had to be comprised within this area to be considered in the analysis.
We expected that the first fixation latency decreased from the first to the last assessment session, suggesting an improved timing in hazard perception. Finally we considered the number of hazards that were followed by an accident.

Results

A first analysis checked whether participants actually considered the selected hazards, which were supposed to be fixated sooner or later regardless of their previous real or virtual experience, given that “hazardous objects” crossed the scooter’s trajectory on the street. The analysis confirmed that participants fixated all hazards in both controlled sessions [94% of the hazards in the first, and 98.11% in the last session; a Wilcoxon matched-pairs, signed-rank test showed that there is not a difference between these two sessions in the number of hazards fixated (exact p>.05, one-tailed)].

After this preliminary control, the latency of the first fixation on the hazards in the first and last session was compared. Figure 3 shows the mean values for the first (M= 2909.43 milliseconds, SE= 1022.18) and for the last session (M= 1022.56 ms, SE= 121.46). A paired-samples t-test demonstrated that the time required to spot an approaching hazard was significantly shorter in the last session than in the first session (t=1.84, df=13, p=0.04). The Cohen’s $d$ measure of effect size suggests that the training has an effect on the first fixation latency and that after four riding sessions (16-24 minutes) the hazard perception improves (Cohen’s $d = 0.49$).\(^{19}\)

![Figure 3 here]

Figure 3. The mean value of first fixation latency on hazards in the first and last sessions.

Regarding the results on the number of crashes with the selected hazards, there was no difference between the first (14% of hazards determined an accident) and the last session (9.43%; Wilcoxon matched-pairs, signed-rank test >.05).
Discussion

This experiment shows that after a relatively short practice with a riding simulator the time needed to spot a hazard decreases. A previous experiment demonstrated that the ability to fixate the hazard area within an appropriate time window can be trained with a PC-based training program.\textsuperscript{20} In that work, the training program adopted plan views (top down) of traffic scenarios and coached trainees where they should be looking at in order to reduce risks. In the current study we confirm this result by asking participants to interact with a simulator, without explicitly training them to look at specific areas of the street. This research suggests that simulators could be not only a precious instrument for improving coordination and motor skills and/or a valid assessment instrument\textsuperscript{9} as previously found in other research, but also a tool for ameliorating the hazard perception abilities in young users before their first real riding experience.

We did not find any difference in the number of crashes between the first and the last session. However, the virtual accident rate per se is not a reliable indicator of the training effectiveness\textsuperscript{21} as it might be related to factors not considered during the training or due to causes that were not controlled in the study...

At a higher level, our results confirm the insightfulness of focusing on visual/attentive resources related with the processing of information in studies of hazard perception. Previous experiments adopting eye movements measurements showed that gaze position can indicate the drivers/riders’ visual source of information and more specifically which parts of their visual field attract attention according to their skills and experience level.\textsuperscript{17} Our experiment extends these results showing that eye tracking technique is a suitable tool also to obtain a direct time-related measure of hazard perception more solid that manual response-time previously used for testing hazard perception skills.\textsuperscript{22} The ocular response is independent from possible answer criterion/strategies adopted by the participant in manual response-time experiments\textsuperscript{28}. Finally, the results show that when experience
is gained by participants, hazards are fixated earlier. This suggests that trained drivers start to adopt strategies to visual monitor “risky” areas and that eye movements are more closely related with drivers predictive ability than reaction effort.

Acknowledgments

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All authors equally contributed to this paper.

Author Disclosure Statement

No competing financial interests exist.

References


Figure 1
197x212mm (300 x 300 DPI)
Figure 2
279x187mm (72 x 72 DPI)
Figure 3
133x99mm (300 x 300 DPI)