

## **TRAINING HAZARD PERCEPTION OF YOUNG NOVICE DRIVERS - A DRIVING SIMULATOR STUDY**

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Number of words: 7,168

Number of figures: 3

Number of tables: 2

Words counted: 8,418

Paper submitted:

August 1<sup>st</sup> 2012

## ABSTRACT

*Objective:* The goal of this driving simulator study was to determine whether young novice drivers that were trained in hazard perception performed better than young novice drivers that did not receive training, immediately after training and two to four weeks after receiving the training. *Participants:* young novice drivers between the ages of 17 and 25 that held their temporary or permanent driver's license. *Training design:* the pretest, training or control intervention, and the posttest were all conducted on the first test day. The follow-up test was conducted two to four weeks later to study the persistence of the training effect over time. Eye tracking data served as dependent variables of interest. More specifically, hazard detection variables (i.e. correct hazard detection and detection time) and a hazard handling variable (i.e. rear mirror use). *Results:* The hazard handling scores were significantly higher for the trained group, as indicated by a significantly higher percentage of rear mirror use, and this effect persisted over time. The trained group performed significantly better in terms of detection time and correct hazard detection both during the posttest and retention test. Together, the content and design of the training importantly contribute to the current literature. As for the content, the trainability of a hazard handling component (i.e., rear mirror use) was explored. As for the design, the study employed a randomized controlled design in which the program design of the control group resembled the program design structure of the trained group, which guarantees valid conclusions. Additionally, there was both a pre- and posttest evaluation and the short-term effects of the training were reassessed in a retention test.

**Keywords:** Hazard perception, young novice drivers, eye-movements

## 1. INTRODUCTION

In 2008, Belgium was ranked 15<sup>th</sup> out of a total of 27 European member states with respect to the number of fatalities per million inhabitants [1]. In 2009, Belgium ( $\pm 11$  million inhabitants) had a total of 944 traffic deaths, and 17% of these fatalities were young drivers between the age of 18 and 24 [2]. Although their participation in traffic is relatively low when compared to other age categories, young drivers between the age of 18 and 24 are overrepresented in the accident statistics in all countries [3–9]. Especially young inexperienced drivers have a high risk of crash involvement [10,11]. This higher risk for young novice drivers can be attributed to different causes [12,13]. Beside the age factor, the present study focuses on experience and hazard perception.

Drivers need to monitor other road users, various elements from the environment and the traffic situation as a whole. By doing this, they can detect elements and traffic situations that could form a threat, also referred to as hazards. "A hazard is a situation or activity in which danger will occur with some probability" [14].

Different studies have depicted the importance of hazard perception for traffic safety [15]. The failure of appropriate visual search was identified as a leading cause for crashes [16] and according to a British study [17] hazard perception abilities represent the most promising perceptual or cognitive predictors of road-traffic-accident involvement. The high crash rate of young drivers has been attributed to their poor hazard perception abilities involving not only the ability to detect and recognize potential hazards, but also the skills to respond appropriately to those hazards in comparison with more experienced adult drivers [18]. Experience plays an important role in the development of driving skills [10] and hazard perception skills improve with experience [16,19]. It has been shown that experienced drivers detect and predict hazardous situations better than novice drivers [15,17,20-23]. Furthermore, experienced drivers perceive hazards more holistically than novice drivers and this holistic perception improves with knowledge and experience [21-22].

Driving a vehicle can be seen as a hazardous activity, but it will not always evolve into a hazardous situation or a crash. It can therefore take some time to experience different types of hazards in different traffic situations. To speed up this process of gaining experience in hazardous situations

and the process in which hazard perception is learned, hazard perception can be trained [24,25]. There have been numerous attempts to improve hazard perception through various methods of training.

## **2. THEORETICAL BACKGROUND**

### **2.1 Hazard perception model**

In the model of Grayson et al. [18], hazard perception is subdivided into four components: hazard detection, threat appraisal, action selection and implementation. According to this model, hazard perception starts with the detection of a looming hazard. The process of hazard detection is followed by an evaluation of the importance of the hazard in which the driver assesses the potential need for an evasive action. It is speculated that the contribution of threat appraisal to the capacity of a driver to detect and respond to a hazard will decline with an increase of experience. Once the driver has decided whether to respond or not, he or she will have to select a suitable action within the range of his/her skills. Once the action has been selected, it still has to be correctly implemented. Thus it is not sufficient to detect a hazard; necessary skills need also to be implemented after detection (i.e. the final step of the perception process), in order to obtain a safer driving behavior (i.e. hazard handling).

### **2.2 Hazard perception training studies**

Simulator-based training interventions can have some advantages over a pc-based or video-based training method. Simulator-based studies provide the opportunity to experience hazardous situations and their consequences more realistically, whilst the safety of the drivers is preserved [24,26–28]. Furthermore, cognitive resources have to be allocated to the driving task which means that they cannot focus merely on hazard perception [13]. Also, a wider field of view includes more environmental cues that are related to a hazardous situation and increases their ability to detect hazards [29]. Chapman et al. [30] already stressed the need for scanning multiple locations in the visual scene for sources of potential danger, which can hardly be achieved with only one screen.

Past studies have implemented different training methods that revealed some positive effect on hazard perception. They have shown that driving simulators are useful in differentiating the behaviors of drivers, with varying levels of experience, in hazard anticipation [4]. Also, the use of a simulator in combination with an eye tracker plays an important role in the assessment of drivers' risk recognition, because eye movements provide clear evidence of detection of risks [31]. Some training methods were based on providing or receiving verbal comments on a scenario. Crundall et al. [15] provided the training group with comments from a qualified instructor while driving. Others provided comments during video clips [30,32,33], or commented on the participants driving performance by comparing it to that of an experienced driver [34]. Rather than focusing on hazard detection, the study of Wang et al. [34] looked at the hazard handling performances of young novice drivers, although they mainly focused on collisions. All of these training methods found an overall improvement of the hazard perception and safe driving skills of a trained group, including an increase in horizontal scanning [30]. Some studies also found a speed reduction when approaching hazards [15,34]. The retention effects of these training methods were rarely assessed. Retention is, like transfer, one of the most important elements for the evaluation of training. It is important to estimate if the effects of training persist over time [13]. Transfer is the degree to which the participants apply what they have learned during training in on-road driving. Two components can be distinguished: near transfer and far transfer. Near transfer occurs when the trained participants apply what they have learned in situations that contain hazards that are conceptually identical to the training situations. In far transfer, participants apply what they have learned in situations with hazards that conceptually differ from that of the trained situations [13,22,35]. Another, frequently applied, training method was developed by Fisher [35]. He evaluated the trainability of novice drivers to scan for information, making use of an eye-tracker. The training was a pc-based risk awareness and perception training (RAPT) program which consisted of three RAPT experiments. Fisher [35] stated that "RAPT not only presents a scenario which is risky, but also explains to the novice driver why it is risky and what areas of the

visual field are obstructed”, which is best for learning transfer [35,13]. The RAPT program has been used in other studies as well [13,36-37]. One of the most recent studies in the field of simulated hazard perception training was conducted by Vlakveld [13]. This training intervention, based on the RAPT program, consisted of three components: (a) a hazard detection drive, (b) an error drive: which was the same as the hazard detection drive, except that the hazard did materialize and (c) an improvement drive. The effect of this training intervention was assessed in a posttest, in which a distinction was made between far and near transfer scenarios. The study found positive results on gaze directions, especially in near transfer scenarios.

To summarize, simulator-based training methods have advantages over other training methods (i.e., realistic experience of hazardous situations and their consequences, safety of participants, allocation of cognitive resources and a wider field of view). Training techniques that are based on giving instructions have shown positive effects in the training of novice drivers to enhance hazard perception skills [15,30,32,33]. Aforementioned studies mainly focused on training either hazard detection skills or hazard handling skills. Finally, in previous studies, retention of the training effects over time has also rarely been investigated [30,36]. The present study will take the positive and missing aspects of the aforementioned studies into account, to create an instructional and plan view-based training technique. Given the recentness and relevance, the training procedure of the study of Vlakveld [13] will serve as a framework for the current study. In evaluating training programs, there are two important components: transfer and retention [13,25]. In ideal conditions, transfer is assessed in an on-road evaluation. Since it is not always possible to assess transfer in on-road situations, the transfer of training could be assessed in a driving simulator. This simulator transfer assessment was also carried out by Vlakveld [13] and was referred to as ‘quasi transfer’ assessment. The evaluation of retention is important to estimate if the effects of training persist over time. When there is an effect immediately after training but after a period of time this positive effect is no longer found, retention is low. Beside focusing on the hazardous location, mirror use could also be worth analyzing when looking at glance behavior. Since Chapman et al. [30] already acknowledged that checking of mirrors can be of importance and that it would be of interest to develop an intervention that evaluates this and Klauer et al. [38] recognized the importance of rear mirror use as a safety-enhancing behavior, it could be interesting to examine mirror use as a component of hazard handling skills. Since hazard handling (i.e. the way participants deal with a hazard after detecting it) has not been clearly analyzed as an isolated subject nor in combination with hazard detection analysis, it will be explored by evaluating rear mirror use as a sub-component of hazard handling.

There will be two important additions to the training intervention design of the study of Vlakveld [13]: retention of the effects of the training will be assessed and a pretest will be conducted. Together these changes will enable the assessment of (1) the magnitude of the training effect in a pretest-posttest evaluation, (2) possible initial differences between a training group and control group and (3) the retention of training effects in a posttest-retention evaluation. A control group procedure will be developed allowing participants from the control group to undergo a similar procedure as the training group. This will enable us to rule out any differences in the results due to fatigue or other factors, such as suspicion regarding possible group division.

### **3. OBJECTIVE AND RESEARCH QUESTIONS**

The main research question is if hazard detection and hazard handling skills of young novice drivers can be trained, by using a driving simulator. The study will focus on the glance behavior of the drivers. In order to answer the main question, the effects of an instructional training intervention on the glance behavior of young novice drivers will be assessed. The following four hypotheses provide the framework for the assessment of trainability:

- After the training intervention, trained young novice drivers will be more successful in searching for hazards than untrained young novice drivers (Hazard detection: measured by means of dependent variables collision, detection time and correct hazard detection).

- After the training intervention, trained young novice drivers will use their rear mirror more accurately than untrained ones (Hazard Handling component: measured by means of the dependent variable rear mirror use).
- After the training intervention, the increased level of hazard detection and hazard handling performance of the trained young novice drivers is larger in near transfer scenarios than in far transfer scenarios.
- An increased level of hazard detection and hazard handling performance of the trained young novice drivers in the posttest, persists during the retention test.

## 4. METHOD

### 4.1. Participants

The group of participants consisted of young novice drivers between 17 and 25 years old who either possessed a temporary or permanent driver's license:

**TABLE 1 Description of participant data**

T = Training group; C = Control group

Group	N	Gender		Age		License					
		Male	Female	Mean	SD	Temporary	Mean	SD	Permanent	Mean	SD
T	15	33%	67%	19.5	1.92	53%	12.1	6	47%	5.4	3.6
							months			months	
C	14	29%	71%	19.4	1.1	50%	11.8	7	50%	11.8	2.9
							months			months	

### 4.2. Apparatus

The tests were conducted on a STISIM M400 fixed-base driving simulator with a force-feedback steering wheel, an instrumented dashboard, brake and accelerator pedals and with a 135 degree field of view. The visual environment of this simulator is presented on three computer screens (each with 1280 x 800 pixels resolution and 60Hz refresh rate). The eye movements of the participants were recorded while driving through the simulation, making use of a camera-based eye-tracking system (FaceLab<sup>TM</sup>).

### 4.3 Training material and scenarios

During the different tests, participants encountered various types of hazardous scenarios. These scenarios were based on frequently used hazardous scenarios such as a pedestrian crossing, a car overtaking, diversions, divided attention, reduced visibility, hidden hazards and varying speed limits. These scenarios were encountered in several environments such as parking scenarios, intersections, roundabouts, build-up areas and high way environments.

The training procedure is based on the existing RAPT training procedure [36], as used in the study of Vlakveld [13]. This training intervention combined the principals of active learning through errors, inducement of arousal to promote memory consolidation, and the natural way drivers learn to anticipate hazards in real traffic [13]. For the training intervention of the present study, instruction slides were created with a plan view of ten hazardous situations and a simulator picture from the driver's perspective. On the plan view the normal cone of view was depicted and divided into visible and invisible areas. The simulator pictures portrayed the focus points of the hazardous situation presented. This was accompanied by instructions of what to look at in these types of situations and what to do to handle the hazards correctly. These instructions were provided by a qualified driving instructor. For the replacement task of the control group, traffic question slides were composed. The slides contained twenty traffic related questions, two for each of the ten scenarios. This was to ensure an equal test time of both the training and control group. The answers to these questions were not analyzed.

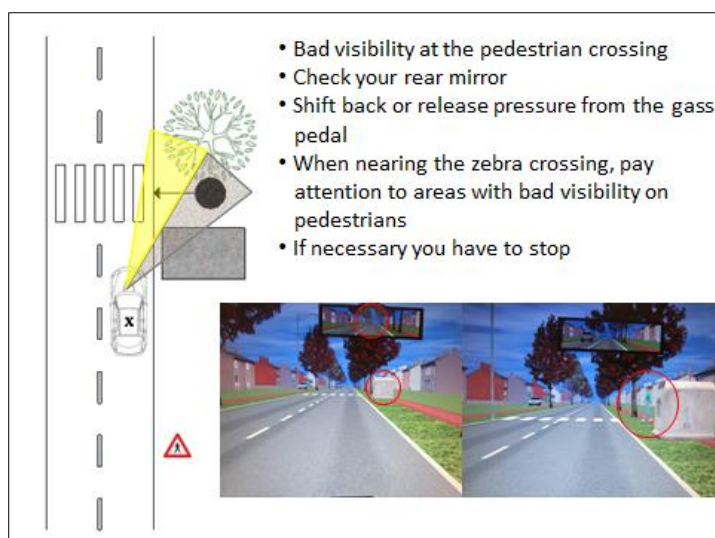


FIGURE 1 Training material - training intervention slide

#### 4.3.1. Training procedure

**Training - first scenario ride** In the first ride of the training intervention, the participant drives through a scenario with ten potential hazardous situations, in which the actual hazard does not occur. At the end of this simulated ride the participants are asked to indicate any moments during the ride were they had expected something to happen. This question is asked in order to promote self-reflection after a crash or near crash and minimize the tendency to attribute the cause of crashes to other road users or elements [13].

**Training – second scenario ride** The second part of the training intervention consists of three components:

- Hazard drive: During the ride whenever the participant has encountered one of the hazards, independent of how it was handled, they are asked to pull aside.
- Training intervention: They will then receive the plan view explanation as described in the training material paragraph. The participant is given a clarification of the elements of the plan view picture and is asked to study the plan view and the simulator picture as the instructions are read out.
- Improvement drive: After the instructions, the participant is asked to proceed in the simulator drive. They will then encounter the same hazard allowing the participant to apply the previously received instructions. This process will be repeated for each of the ten hazards that were selected for training.

The procedure for the control group is similar to that of the training group. The main difference however is that, in the first scenario ride, they will not be asked to indicate any moments during the ride were they had expected something to happen. Furthermore, in the second scenario ride, the control group will not come into contact with the actual hazardous situations when driving through the scenario and they will receive the general traffic questions.

#### 4.4. Test procedure

The simulator tests were spread over two days (2-4 weeks in between;  $M=22.89$ ,  $SD=4.88$ ). The first testing day consisted of a pre-training test, the training intervention and a post-training test which took approximately 2 hours to complete. The second testing day contained a retention test which took about 40 minutes to complete. Before starting, basic information and instructions were given to each participant with regard to the experiment. The participants first did a familiarization drive of five minutes. Participants then undertook the pre-training drive throughout a scenario in which they

encountered ten hazards. After this pre-training drive 29 participants who were randomly assigned to the training group (n=15) and to the control group, received the training or replacement task (by means of random binary number generation). After the training intervention, all participants continued in the post-training test. In this posttest, they encountered 16 hazardous situations. On the second test day, they all drove through the retention test in which the participants encountered 54 hazards. The hazards that were encountered during training were not identical to those of the pre-, post-, or retention test. During the pretest, posttest and retention test, there was no one present in the simulator room to ensure the driving behavior would not be affected.

#### 4.5. Design and data analysis

The study employed a mixed design. The between-subjects factor was the group to which the participant was randomly assigned (a training group and a control group). The within-subjects factors were the time of assessment (pre-training test versus post-training test and post-training test versus retention test) and transfer (near transfer and far transfer).

##### 4.5.1. Dependent variables

The dependent variables can be subdivided into hazard detection and hazard handling parameters. Hazard detection parameters consist of (1) collision, (2) detection time, and (3) correct hazard detection. A collision was defined as a crash with the hazard or an element from the surroundings due to detection failure or failure in the evasive action that was carried out. For detection time, the time of the first glance on the hazard was selected measured from the onset of the hazard in the simulator. In case of bad eye tracking due to blinking the last documented eye-movement towards the hazard was recorded as the participants detection time. In order to score the parameter of correct hazard detection, a description of visual search points was made for all the hazards. The participant had to direct her or his eyes towards these points in order to correctly detect the hazard. If more than one glance was required in order to detect the hazard, a score was given to that hazard (e.g. TABLE2: In order to correctly detect this hazard, four visual search points were defined. When a participant looks at three out of four points he or she will be given a score of 0.75 for this particular hazard). The hazard handling parameter was (4) rear mirror use. Correct hazard handling was defined based on the driving instructor's comments.

**TABLE 2 Determining hazard detection and rear mirror scores - Example**

<b>Hazard description</b>	<b>Critical visual search</b>
Two children suddenly cross the road from behind a parked bus. A zebra crossing is present 5 meters further down the road.	<p><u>Correct hazard detection (visual search points)</u></p> <ul style="list-style-type: none"> <li>• Glance at traffic sign pedestrian crossing</li> <li>• Glance at the front of the bus while passing</li> <li>• Glance at crossing children (= detection time)</li> <li>• Glance at children at the other side of the road</li> </ul> <p><u>Rear mirror use</u></p> <ul style="list-style-type: none"> <li>• Glance at rear mirror after detecting traffic sign or crossing children, before braking.</li> </ul>

##### 4.5.2. Data analysis

To analyze the training effect, for three dependent measures (i.e., two hazard detection parameters: detection time, correct hazard detection; one hazard handling parameter: rear mirror use), a 2 (group: control, training) by 3 (time: pre, post, retention) repeated measures ANOVA was carried out in SPSS. In case of a significant interaction effect of group and time, (1) a between group comparison (one-way ANOVA) was made for each of the three time levels, and (2) a within group comparison (dependent t-tests) of the pre-post time levels and post-retention time levels was made. This analysis was carried out on 10 hazards that occurred in both pre-, post-, and retention test. Given the binominal distribution of the variable collision and the small number of crashes that occurred, previously

mentioned analysis was carried out by means of the Fisher's Exact Test. The 16 hazards that occurred both in the posttest and retention test were subdivided in the categories of near and far transfer. To analyze the transfer effect a paired sample t-test of these 16 transfer hazards was carried out in the training group, using the post- and retention test results of the variables detection time, correct hazard detection and rear mirror use. In case of non-normal distribution (i.e. the variable collision), the Wilcoxon signed rank test was used.

#### *Eye movement analysis*

For analyzing the eye movements of the participants, a video overlay was made in MATLAB r2007b for each assessment drive. The video overlays of each hazard were monitored frame by frame. This way, all glances could be analyzed in detail and first glances on the hazard could be identified which both led to correct detection times and hazard detection scores.

## **5. RESULTS**

### **5.1. Analysis of collision**

#### *Training effect*

The results of all the participants were considered in the analysis. Results from the post-training showed that two participants from the control group versus none of the participants from the training group experienced a collision (FET,  $p = .224$ ). During the retention test there were no crashes in the control group or the training group. Compared to the pretest ( $n = 3$  collisions), the training group did have an elimination of crashes during the posttest, whereas the number of crashes in the control group remained constant ( $n = 2$  collisions), yet low.

#### *Transfer effect*

The results of the Wilcoxon signed rank test show that in the posttest, the training intervention did elicit a significant change in the number of collisions between the near transfer and far transfer hazards ( $Z = -2.45$ ,  $p = .014$ ). However, the number of collisions was higher in the near transfer hazards ( $n = 6$ ) than in the far transfer hazards ( $n = 0$ ). In the retention test, the training intervention did not elicit a significant change in the number of collisions between the near transfer and far transfer hazards ( $Z = -1.00$ ,  $p = .317$ ).

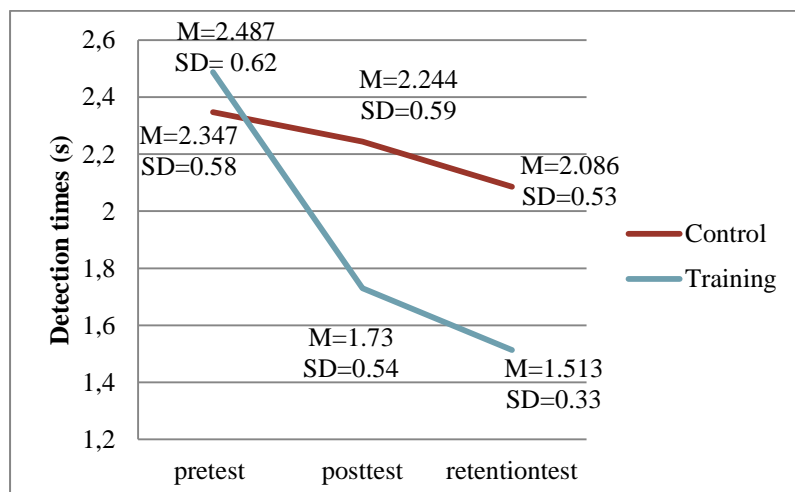
### **5.2. Analysis of detection time**

#### *Training effect*

See Figure 2 for an overview of the results of detection time. Due to missing values and after deletion of outliers ( $\pm 2.5$  SDs from the mean), detection times of twenty participants (training:  $n = 11$ ) remained.

The results showed a significant main effect of test time ( $F(2,36) = 10.96$ ,  $p < .01$ ,  $\eta_p^2 = .378$ ). The main effect of group was non-significant ( $F(1,18) = 3.77$ ,  $p = .068$ ,  $\eta_p^2 = .173$ ), although the mean detection time of the control group was higher ( $\bar{X} = 2.226$ s) than that of the training group ( $\bar{X} = 1.91$ s). Importantly, the results revealed a significant interaction effect ( $F(2,36) = 4.29$ ,  $p = .021$ ,  $\eta_p^2 = .192$ ) between group and test time. The between-group analysis, carried out with a one-way ANOVA, confirmed that there was a significant difference in detection times between the trained and untrained group in the posttest ( $F(1,25) = 8.17$ ,  $p < .01$ ,  $\eta_p^2 = .246$ ) and the retention test ( $F(1,22) = 5.43$ ,  $p < .05$ ,  $\eta_p^2 = .206$ ). The results from this analysis also showed that the difference in detection time in the pretest was not significant ( $F(1,2) = .02$ ,  $p > .05$ ,  $\eta_p^2 = .001$ ). The trained group had the greatest reduction in detection time between the pretest and posttest, compared to the control group (30.45% as opposed to 4.39%). In the retention test, the trained group had a further and steeper decline (12.54%), with respect to the control group (7.04%).





**FIGURE 2** The difference in mean detection time between the trained and control group throughout the different periods of testing

#### *Transfer effect*

A paired sample t-test compared the differences in detection time of the training group between 16 near and far transfer scenarios in the posttest and retention test. The results showed that in the posttest and retention test there was a significant difference in detection time between the near transfer and far transfer scenarios ( $t(13) = -5.93, p < .01$ ) and ( $t(11) = -4.01, p < .01$ ), with near transfer scenarios showing lower average detection times (posttest = 0.93s; retention = 0.75s) than far transfer scenarios (posttest = 1.76s; retention = 1.54s).

### **5.3. Analysis of correct hazard detection**

#### *Training effect*

See Figure 3 for the results of the correct hazard detection analysis. Due to missing values and after deletion of outliers ( $\pm 2.5$  SDs from the mean), correct hazard detection of twenty participants (training:  $n = 11$ ) remained.

The results revealed a significant main effect of time ( $F(2,36) = 7.54, p < .01, \eta_p^2 = .295$ ) and group ( $F(1,18) = 8.87, p < .01, \eta_p^2 = .33$ ). The interaction effect between group and test time was not significant ( $F(2,36) = 2.99, p = .063, \eta_p^2 = .142$ ). The training and control group had approximately equal hazard detection scores in the pretest. In the posttest both groups had an increase in hazard detection scores, although the scores of the trained group were 9% higher than that of the control group. This smaller difference in the posttest could explain the non-significant interaction effect. The positive effect on the scores of the trained group remained and even increased in the retention test, whereas the control group had a decrease in hazard detection scores. In the retention test, the trained group had 18.8% more accurate hazard detection compared to the pretest. The control group had a total increase of 3.49%.

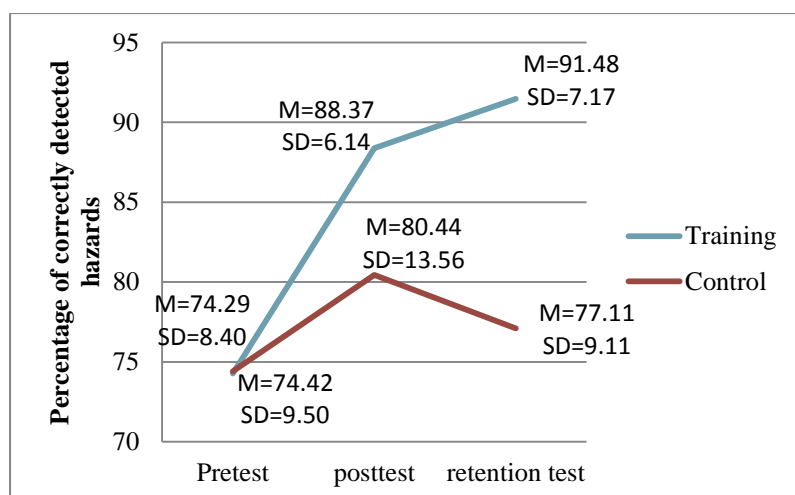


FIGURE 3 Percentage of correct hazard detection of the training and control group across the three testing times

#### *Transfer effect*

A paired sample t-test compared the hazard detection scores of the training group between near and far transfer scenarios in the posttest and retention test. The results showed that in the posttest and retention test there was a non-significant difference in hazard detection scores between the near transfer and far transfer scenarios ( $t(14) = -1.09, p > .05$ ) and ( $t(13) = -.06, p > .05$ ). In fact, the mean hazard detection scores were slightly greater in the far transfer scenarios (posttest = 89.15; retention = 92.70) than in the near transfer scenarios (posttest = 86.20; retention = 92.08).

#### **5.4. Analysis of mirror use**

##### *Training effect*

Twenty-four participants (training:  $n = 13$ ) remained in the sample for the mirror use analysis. The analysis revealed a significant main effect for both test time ( $F(2,42) = 6.65, p < .01, \eta_p^2 = .24$ ) and group ( $F(1,21) = 32.6, p < .01, \eta_p^2 = .608$ ). The results also revealed a significant interaction effect ( $F(2,42) = 33.69, p < .01, \eta_p^2 = .62$ ) between group and test time. The between-group analysis confirmed that there was a significant difference in mirror use between the trained and untrained group in the posttest ( $F(1,27) = 35.32, p < .01, \eta_p^2 = .567$ ) and the retention test ( $F(1,23) = 38.92, p < .01, \eta_p^2 = .629$ ). The results also showed that the difference between the training and control group in the pretest was non-significant ( $F(1,26) = .98, p > .05, \eta_p^2 = .036$ ). The percentage of mirror use of the trained group strongly increased (from 23.7, to 69.3, to 81 percentage points), whereas that of the control group mildly decreased (from 38.7, to 24.7, to 24.2 percentage points).

##### *Transfer effect*

A paired sample t-test compared the differences in mirror use of the training group between near and far transfer scenarios in the posttest and retention test. The results showed that in the posttest and retention test there was no significant difference in mirror use between the near transfer and far transfer scenarios ( $t(14) = -.43, p > .05$ ) and ( $t(11) = -.96, p > .05$ ). As in the hazard detection variable, the rear mirror scores were greater in the far transfer scenarios (posttest = 67.87; retention = 80.11) than in the near transfer scenarios (posttest = 65.73; retention = 71.10).

#### **5.5 Discussion**

The training intervention had a positive effect on the drivers' general eye scanning behavior. The trained group had a strong reduction in mean detection time between the pretest and the posttest and a further reduction during the retention test. There was a significant interaction effect indicating that the

training intervention had a positive effect on reducing the detection time and that the reduction in detection time from pretest to posttest and retention test was greater for the training group than for the control group. In total, the trained group decreased their detection time with 39.2% whereas the control group had a total reduction of 11.12%. The total mean detection time of the trained group was 16.5% lower than that of the control group and there was a significant interaction effect. Therefore it can be assumed that a significant result of the main effect might have been found with a larger sample size. The decrease in detection time of the control group could result from the fact that by undergoing the pretest hazards, they also had some expectation of what would happen in the following tests and adapted their usual eye-scanning behavior. In the analysis of near and far transfer on detection time, the results indicated that the trained group clearly performed better in the near transfer than in the far transfer scenarios.

The hazard detection analysis results showed that there was a difference in correct hazard detection between the training and control group and the trained group had a notably higher mean in the percentage of correct hazard detection. Although it was expected, the interaction effect was not significant. Still, the results of the training effect revealed a clear trend. The control group had an initial but smaller increase during the posttest, which could explain the absence of the significant interaction effect, but it declined during the retention test. This initial increase of the control group could be due to the fact that the posttest occurred on the same day as the pretest and that due to the recent hazard experiences this group increased their search for hazards as well. However they did not receive any training intervention and when the fresh memory trace of the hazards diminished, the advantage of simple exposure decreased during the retention test. On the contrary, the fact that the training group kept and even increased their gain during the retention test can be explained by neuroplasticity-based learning theories that a good time delay is needed for learning consolidation [39]. Even though there was no interaction effect between group and time, with the significant main effect of group and the steep increase of the hazard detection scores of the trained group it is assumed that the training intervention had a positive effect on this variable. This relates to the findings of Fisher et al. [35], that trained young novice drivers perform better in scanning the road for relevant hazard related information.

A significant positive result was found on the rear mirror use of the trained drivers. Their rear mirror use drastically improved from the pretest to the posttest and retention test. These significant results do suggest that the training intervention succeeded in increasing the rear mirror use of the trained group and that this positive effect persisted over a two to four-week period of time. The decrease in mirror use of the control group could be explained in relation to the decrease in detection time as noted earlier. The control group was not notified about the importance of mirror use, as opposed to the trained group, and might have paid less attention to this by focusing more on searching for hazards. The near and far transfer analysis of both correct hazard detection and rear mirror use were inconclusive.

The effects of the training intervention on the number of collisions are inconclusive. Although there was an immediate reduction in the number of crashes in the trained group during the posttest, this reduction was not significantly different from that of the untrained group. However, as argued by Klauer et al. [38], crashes are related to failure in looking towards the right directions or objects at the right time. The non-significant effect of the present training on the number of collisions should therefore not be discarded. A larger dataset might give more insight in the effect of the current training intervention. In the far and near transfer analysis of collision the results showed that the number of collisions was higher in the near transfer hazards than in the far transfer hazards. A selection bias in the training intervention hazards could explain these counterintuitive results. The near transfer hazards are the hazards that are conceptually the same as the hazards that were chosen for training. It is possible that the training and near transfer hazards are more aggressive than the far transfer hazards and that therefore the number of collisions is higher in the near transfer scenarios.

## 6. CONCLUSION AND RECOMMENDATIONS

With respect to the first hypothesis, concerning the hazard detection variables, the trained drivers were more successful in searching for hazards than the untrained drivers and these results remained during retention, although the results of the occurrence of collision were inconclusive. The significant results on the correct rear mirror use, give an insight in the trainability of mirror use in general. The trained young novice drivers used their rear mirror more accurately than the untrained ones and this between-group difference even increased during the retention test. Given the importance of mirror use in hazard perception and general traffic safety [30,38] it could be of interest to incorporate overall mirror use in future hazard perception training studies. With respect to the third hypothesis, in the analysis of far and near transfers only the variable detection time gave a positive and conclusive result. In retrospect, it can be argued that due to a selection bias, the types of hazards that were selected for the purpose of training had an effect on the results of far and near transfer analysis of mirror use and correct hazard detection. In the results of the variable 'number of collision', the significantly higher number of crashes in the near transfer scenarios could also be attributed to the type and aggressiveness of the near transfer hazards. As described by Crundall et al. [40], participants can react differently towards different types of hazards. In their study they made a clear distinction between Behavioral Prediction, Environmental Prediction and Dividing and Focusing attention hazards and the fixations differences between those types. In the study of Vlakveld [13] another distinction was made between latent overt-, latent covert- and imminent hazards. These differences in hazard types could be further examined and used as a basis for selecting training hazards.

With respect to the fourth hypothesis, looking at the retention effect of the variables that showed a positive effect, the trained group did not have a fallback during the retention test and there even was a further improvement during this retention test..

The present study showed support for the trainability of hazard perception skills. It will be of interest for further research to expand the sample size and conduct an on-road experiment to validate the results that were found. As noted before, near and far transfer should also be assessed in on-road driving to make statements about the transferability of the training intervention. With regard to the testing times of the current study, it is suggested by Fisher et al. [41] that it should be examined if the effect of training persist for six months, since this is the critical window of vulnerability. In future studies, the retention test could therefore be carried out six months after training to get a full grasp on the retention effects. Given the positive result of the current training interventions and the training interventions that were carried out by others [13,15,34,35], future research may also consider examining the trainability and testability of hazard perception in the context of the Belgian driving education system. In relation to this it could also be examined whether the simulator-based training programs, although costly and perhaps more difficult to implement in the education system, are preferable to pc-based methods that also have shown positive results [30] and are less expensive. One could, for instance, argue that elements such as mirror use cannot realistically be trained or analyzed in a pc-based environment or that the realistic representation of a simulator will lead to better results in an on-road evaluation. It could therefore be interesting to compare the effectiveness and implementability of both types of training methods.

## REFERENCES

- [1] Casteels Y, Nuyttens N. Statistieken verkeersveiligheid 2008. Brussel, Belgisch Instituut voor de Verkeersveiligheid; 2010.
- [2] BIVV. Kerncijfers verkeerveiligheid. M. Van Houtte; 2011.
- [3] Bos K, Willems B, Dreesen A. Ongevalbetrokkenheid van jongeren Deel I - Internationale literatuurstudie naar oorzakelijke en/of bijdragende factoren. Belgium: Provinciale Hogeschool Limburg, UH, VUB, Vito; 2006. Report No.: RA-2006-91.

- [4] Chan E, Pradhan AK, Pollatsek A, Knodler MA, Fisher DL. Are Driving Simulators Effective Tools for Evaluating Novice Drivers' Hazard Anticipation, Speed Management, and Attention Maintenance Skills. *Transp Res Part F Traffic Psychol Behav.* 2010 Sep 1;13(5):343–53.
- [5] Daniels S. Verkeersveiligheid voor jongeren in Vlaanderen [Internet]. Steunpunt Verkeersveiligheid, Universiteit Hasselt; 2007. Available from: [https://doclib.uhasselt.be/dspace/bitstream/1942/10591/1/Jongeren\\_en\\_Verkeersveiligheid\\_\\_een\\_moeilijke\\_combinatie\\_.pdf](https://doclib.uhasselt.be/dspace/bitstream/1942/10591/1/Jongeren_en_Verkeersveiligheid__een_moeilijke_combinatie_.pdf)
- [6] OECD, ECMT. Young Drivers: The Road to Safety [Internet]. 2006. Available from: <http://trid.trb.org/view.aspx?id=794214>
- [7] Safetynet. Novice Drivers [Internet]. 2009. Available from: [http://ec.europa.eu/transport/road\\_safety/specialist/knowledge/pdf/novice\\_drivers.pdf](http://ec.europa.eu/transport/road_safety/specialist/knowledge/pdf/novice_drivers.pdf)
- [8] SWOV. SWOV - Factsheet: Young novice drivers. SWOV; 2010.
- [9] Vidotto G, Bastianelli A, Spoto A, Sergeys F. Enhancing hazard avoidance in teen-novice riders. *Accident Analysis & Prevention.* 2011;43(1):247–52.
- [10] Harrison WA. Role of experience in learning to drive: a theoretical discussion and an investigation of the experiences of learner drivers over a two-year period - Monash University [Internet]. Monash University Accident Research Centre; 1999. Report No.: 156. Available from: <http://www.monash.edu.au/miri/research/reports/muarc156.html>
- [11] Berg HY. Reducing crashes and injuries among young drivers: what kind of prevention should we be focusing on. *Injury Prevention.* 2006;12(suppl 1):15-18.
- [12] Arnett JJ. Developmental sources of crash risk in young drivers. *Injury Prevention.* 2002;8(suppl 2):ii17–ii23.
- [13] Vlakveld W. Hazard anticipation of young novice drivers: Assessing and enhancing the capabilities of young novice drivers to anticipate latent hazards in road and traffic situations. [Leidschendam, Nederland]: Rijksuniversiteit Groningen; 2011.
- [14] Michon JA. Dealing with danger. The Netherlands: Traffic Research Centre, University of Groningen; 1978. Report No.: VK79-01.
- [15] Crundall D, Andrews B, van Loon E, Chapman P. Commentary training improves responsiveness to hazards in a driving simulator. *Accident Analysis & Prevention.* 2010;42(6):2117–24.
- [16] Pradhan A, Simons-Morton B, Lee S, Klauer S. Hazard Perception and Distraction in Novice Drivers: Effects of 12 Months Driving Experience. 2011. Available from: <http://trid.trb.org/view.aspx?id=1112898>
- [17] Chapman P, Underwood G. Visual search of driving situations: Danger and experience. *Perception.* 1998;27:951–964.
- [18] Grayson GB, Maycock G, Groeger JA, Field DT. Risk, hazard perception and perceived control. *Risk, hazard perception and perceived control.* 2003;1(1):1–50.

- [19] Underwood G, Chapman P, Brocklehurst N, Underwood J, Crundall D. Visual attention while driving: sequences of eye fixations made by experienced and novice drivers. *Ergonomics*. 2003;46(6):629–46.
- [20] Borowsky A, Oron-Gilad T, Parmet Y. Age and skill differences in classifying hazardous traffic scenes. *Transp Res Part F Traffic Psychol Behav*. 2009;12(4):277–87.
- [21] Borowsky A, Shinar D, Oron-Gilad T. Age, skill, and hazard perception in driving. *Accident Analysis & Prevention*. 2010;42(4):1240–9.
- [22] Deery HA. Hazard and Risk Perception among Young Novice Drivers. *Journal of Safety Research*. 1999;30(4):225–36.
- [23] Taylor T, Masserang K, Pradhan A, Divekar G, Samuel S, et al. Long-Term Effects of Hazard Anticipation Training on Novice Drivers Measured on the Open Road. Olympic Valley - Lake Tahoe. Available from: <http://trid.trb.org/view.aspx?id=1107685>
- [24] Allen W, Cook M., Park GD. Chapter 7: Novice driver performance improvement with simulator training. In L. Dorn (Ed.). *Driver behaviour and training*. Ashgate Publishing, Ltd.; 2005.
- [25] SWOV. SWOV - Factsheet: Training hazard perception. SWOV; 2010.
- [26] Brooks JO, Goodenough RR, Crisler MC, Klein ND, Alley RL, et al. Simulator sickness during driving simulation studies. *Accident Analysis & Prevention*. 2010;42(3):788–96.
- [27] Kaptein N, Theeuwes J, Van Der Horst R. Driving Simulator Validity: Some Considerations. *Transportation Research Record: Transportation Research Record*. 1996;1550(1):30–6.
- [28] Riener A. Assessment of Simulator Fidelity and Validity in Simulator and On-the-road Studies. *International Journal On Advances in Systems and Measurements*. 2011;3(3 and 4):110–24.
- [29] Shahar A, Alberti CF, Clarke D, Crundall D. Hazard perception as a function of target location and the field of view. *Accident Analysis & Prevention*. 2010;42(6):1577-84.
- [30] Chapman P, Underwood G, Roberts K. Visual search patterns in trained and untrained novice drivers. *Transp Res Part F Traffic Psychol Behav*. 2002;5(2):157–67.
- [31] Pradhan AK, Hammel KR, DeRamus R, Pollatsek A, Noyce DA, Fisher DL. Using eye movements to evaluate effects of driver age on risk perception in a driving simulator. *Human Factors*. 2005;47(4):840–52.
- [32] Isler RB, Starkey NJ, Williamson AR. Video-based road commentary training improves hazard perception of young drivers in a dual task. *Accident Analysis & Prevention*. 2009;41(3):445–52.
- [33] McKenna FP, Horswill MS, Alexander JL. Does anticipation training affect drivers' risk taking? *J Exp Psychol Appl*. 2006;12(1):1–10.
- [34] Wang Y, Zhang W, Salvendy G. Effects of a Simulation-Based Training Intervention on Novice Drivers' Hazard Handling Performance. *Traffic Injury Prevention*. 2010;11(1):16–24.

- [35] Fisher DL. Can novice drivers be trained to scan for information that will reduce their likelihood of a crash? *Injury Prevention*. 2006 Jun 1;12(suppl\_1):i25–i29.
- [36] Fisher DL, Pradhan AK, Pollatsek A, Knodler MA. Empirical Evaluation of Hazard Anticipation Behaviors in the Field and on Driving Simulator Using Eye Tracker. *Transportation Research Record*. 2007 Dec 1;2018(-1):80–6.
- [37] Pollatsek A, Narayanaan V, Pradhan A, Fisher DL. Using Eye Movements to Evaluate a PC-Based Risk Awareness and Perception Training Program on a Driving Simulator. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. 2006 Fall;48(3):447–464.
- [38] Klauer SG, Dingus TA, Neale VL, Sudweeks JD, Ramsey DJ. The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data , [Internet]. Washington D.C.: National Highway Traffic Safety Administration (NHTSA); 2006. Report No.: DOT HS 810 593. Available from: <http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/PDF/DriverInattention.pdf>
- [39] Doyon J, Benali H. Reorganization and plasticity in the adult brain during learning of motor skills. *Curr. Opin. Neurobiol*. 2005;15(2):161–7.
- [40] Crundall D, Chapman P, Trawley S, Collins L, van Loon E, et al. Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accident Analysis & Prevention*. 2012;45(0):600–9.
- [41] Fisher DL, Laurie NE, Glaser R, Connerney K, Pollatsek A, et al. Use of a fixed-base driving simulator to evaluate the effects of experience and PC-based risk awareness training on drivers' decisions. *Hum Factors*. 2002;44(2):287–302.