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The Effect of Driving Experience on Hazard Perception in Relation to Visual Attention

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Abstract

In this study novice drivers (driver's license less than one year) were compared with experienced drivers (driver's license longer than three years). They were compared on their hazard perception with real-life video clips and this was measured with an eye tracker (a 'hit' indicated that the hazard was seen) and a potential hazard form (reporting the possible hazards on paper). The UFOV test was administered as well to compare visual attentional skills (processing speed, directed attention and selective attention). The sample consisted of 44 participants (*N* = 44). The novice group (*n* = 22) had an average age of 22.5 years (*SD* = 4.2, *Mdn* = 22). The experienced group (*n* = 22) had an average age of 25 years (*SD* = 4.9, *Mdn* = 24.5). The results were that there was a significant difference between the novice and experienced drivers on the amount of hazards seen with the eye tracker. There were no differences on the UFOV test and there were no differences between the amount of hazards seen with the eye tracker and the amount of hazards reported on paper. This suggests that in this study experienced drivers are better at seeing hazards than novice drivers and that the UFOV test might not be the right tool to compare these age groups. Participants were not better or worse when writing down the hazards compared to detecting the hazards with the eye tracker. The conclusion is that there was an experiential difference in detecting the hazards with the eye tracker, even with the small difference in age and driving experience. Future research could look at a better and more reliable way to differentiate between these two types of younger drivers.

The mortality rate for traffic in the Netherlands is low compared to 31 other European countries. This rate has declined in the last twenty years but fatal accidents still happen. Especially the drivers of motor driven bicycles and motorbikes have a relatively high risk for fatal accidents or to get severely injured (SWOV, 2013).

Furthermore, car drivers of 18-24 years and 75+ years have a higher risk compared to other age groups. This risk for younger drivers seems to be associated with little driving experience and their first foray in the world of traffic. Focusing on and understanding these groups could hopefully reduce this risk (SWOV, 2013).

The risk of involvement in traffic crashes for younger drivers can be age-related (for example personality traits) or experience-based. To acquire driving experience, one of the skills that is necessary is hazard perception. Hazard perception can also be called hazard awareness. It is the ability to read the road. This includes identifying and cognitively processing potentially hazardous situations (Borowsky & Oron-Gilad, 2013).

When driving a car, a driver can encounter different kinds of hazards. The types of hazards that are distinguished according to Vlakveld (2011) are acute hazards, like a child that suddenly crosses the road in front of a driver, and latent hazards. Latent hazards are possible hazards, a child could cross the road but it does not necessarily happen. There are four types of latent hazards. Covert latent hazards, the child is hidden from view but wants to cross (for example behind a bus or between parked cars). Overt latent hazards, the child is visible and could possibly cross the road in front of the driver. Precursors of hazards, for example seeing braking lights a couple of cars ahead on the highway that may result in the car in front of the driver braking. And the last kind of hazard is loss of control hazards and these are internal (e.g. distraction, being unwell) or external (e.g. rain, mist). In this study there will be an emphasis on covert and overt latent hazards (Vlakveld, 2011).

To study hazards it is useful to use a hazard perception test. A hazard perception test is a valid measure of crash-related driving performance. 25% of the drivers who failed the video-based hazard perception test in a study were more likely to be involved in crashes. There was an one year period following the participants after this test. 17% of the failing drivers were, prior to the test, more likely to have been involved with crashes as well (Horswill, Hill, & Wetton, 2015). To further study hazard perception it might be useful to look at driving experience and the UFOV (Useful Field of View). Driving experience (average of 7 months and 59 months of driving experience respectively for novice and experienced drivers) can reveal differences in hazard perception, especially when processing time is manipulated (Jackson, Chapman, & Crundall, 2009).

Driving Experience

Underwood and Crundall (1998) found that there were differences between experienced (mean experience 9.0 years) and novice (mean experience 0.2 years) drivers. This depended on the type of road. The study suggested that novice and experienced drivers use different visual strategies. This was in line with earlier studies that have shown decreased eye fixation durations for experienced drivers in increasingly demanding traffic situations (Shinar, McDowell, Rackoff, & Rockwell, 1987).

Novices may not have developed the right visual driving strategy that is required in traffic. Novices restrict their visual search and concentrate on novel, dangerous or difficult to process areas. This is in contrast to experienced drivers who expand their visual search to cover the dynamic situation (Underwood & Crundall, 1998). Borowsky, Shinar and Oron-Gilad (2010) suggested in their study that the drivers' awareness of potential hazards (or hazard perception) is improved by driving experience. Driving experience guides the eye movements of the drivers to locations with potential risks.

When explaining overt latent hazards earlier, an example of a precursor of a hazard was used, specifically the braking lights of a car far into the distance. It is suggested by Crundall (2016) that experienced drivers (license longer than three years) can get relevant information from precursors of the hazard earlier than novice drivers (license shorter than one year).

There are indications that important traffic skills are learnt during the first few months after drivers get their license. Drivers with a license for 1, 5 and 9 months and several years were tested for their hazard perception skills. Reaction times were measured with a video-based hazard perception test. There was no significance found in the decrease of reaction times with experience, but there was a tendency for this. There was still an indication of a possible effect of experience and reaction time (Sagberg & Bjornskau, 2005). It should be noted that according to Crundall (2016) an underlying possibility of the failure to identify group differences with reaction time measures is that reaction times of hazards have more components than is tested in the current paradigm.

When all of this is taken into account there are still questions that need to be answered. What is the effect of driving experience on the hazard perception test when you split the drivers in less than one year or more than three years of driving experience? The discussed research showed that there were differences between novice and experienced drivers (Underwood & Crundall, 1998; Shinar et al., 1987; Crundall, 2016; Sagberg & Bjornskau, 2005), but would these differences still show if there is a different distinction between years of driving experience.

Driving a car is a complex task that relies on multiple cognitive processes. One of the processes is attention. The link between attention and driving has been established from multiple studies (Strayer, Drews, & Johnston, 2003). Treat et al. (1989) concluded that inattention and improper lookout were the main causes of the 2,258 traffic accidents they evaluated. Furthermore, it was found in the laboratory that traffic accidents could be predicted with selective attention tasks (Arthur & Doverspike, 1992) and attention switching tasks (Elander, West, & French, 1993). Attentional strategies that focus on areas of expected hazards can be developed by drivers but at the expense of processing hazards that are less frequent. The visual scanning strategy that is developed concentrates on detecting the more major and frequent hazards and it ignores visual information on less frequent hazards (Summala, Pasanen, Raesaenen, & Sievaenen, 1996). Thus, there is a relation between driving and attention. A way to measure visual attention would be the Useful Field of View test.

UFOV (Useful Field of View)

Sanders (1970) was the first to describe the concept of the useful field of view. It was defined as a visual field area where a person could get information with just a brief glance, without eye or head movements. He called it the 'functional visual field', but later the term 'useful field of view' was used by Ball, Owsley and Beard (1990). This has become a computer-based test, the Useful Field of View test.

This test relies on visual sensory information as well as higher-order processing abilities. Visual attention is affected by the presence of distracters, central task difficulty, addition of secondary tasks, conspicuity and varying stimulus duration. Performance on this test was found to be age-related (Edwards et al., 2006; Scialfa, Kline, & Lyman, 1987). Because it relies on attentional processes the UFOV test exists of three subtests: processing speed, divided attention and selective attention.

The UFOV test is a tool that can successfully predict driving ability as well. As the name of the test indicates it is a test where the visual field is assessed by presenting stimuli centrally and peripherally. Deterioration in this task begins early in life (20 years), but is exacerbated among elderly people. This deterioration is a decrease in the efficiency of extracting information, not a shrinking field of view (Sekuler, Bennett, & Mamelak, 1999).

A meta-analysis confirmed that the UFOV assessment is important and a valid and reliable tool for measuring driving performance and safety for at-risk older drivers. A relationship between UFOV performance and future crashes has been confirmed by prospective studies. This supports the use of UFOV as a screening measure for older drivers and shows that processing speed, divided attention and selective attention are part of hazard perception (Clay et al., 2005).

Myers, Ball, Kalina, Roth and Goode (2000) found that the UFOV test, as a screening variable, was the best single predictor to predict the outcome of whether older drivers would pass or fail an on-road driving test. Furthermore, older drivers with an impairment on the UFOV test are more likely to have a crash and they are more likely to have crashes where they are at fault and injured (Owsley et al., 1998). The computer version of the UFOV test had high enough reliability and validity coefficients to use the test for evaluations. The participants of this study were 50 years or older (Edwards et al., 2005).

Ishimatsu, Miura and Shinohara (2010) found that in the peripheral-task the cost of divided attention was most evident and significantly greater for older adults (age ranging from 65 to 84 years) compared to younger drivers (age ranging from 19 to 28 years). Their results also suggest that the performance on UFOV might function as an indicator of accident risk for younger adults.

McManus, Cox, Vance and Stavrinos (2015) wanted to know if UFOV could be a predictive indicator of motor vehicle collisions for younger adults by using a driving simulator. They found that of the three subtests that the UFOV consists of, subtest three was the one that significantly predicted collisions in the simulated drive. This was the selective attention component of the test.

This raises the question whether this effect could be replicated with real traffic situations by using video clips and if driving experience plays a role as well. This could support the notion that it might be possible for UFOV (or a subtest of UFOV) to give an indication of hazard perception in younger adults. Besides driving experience and visual attention, it is important for this current study to look more at different cognitive processes as well. Drivers can be tested with an eye tracker to indicate whether they saw hazards but they can report hazards by writing them down as well.

Reporting Hazards on Paper

It could be useful to look at the similarity or discrepancy of the number of hazards reported between watching a traffic clip as measured with an eye tracker and a paper and pencil test in which the hazards detected are reported. These activities are part of different cognitive processes. With the use of an eye tracker the more or less unconscious, automatic process can be measured and with a hazard form that needs to be filled out there is reflective (conscious) thinking.

For a complex task such as driving visual search and perception are important characteristics of the visual allocation strategy. And for visual perception, attention is crucial. Information in unattended places is not processed at all or scarcely processed (Johnston & Dark, 1986). A way to measure what is seen is with an eye tracker. Eye tracker devices can be used in driving scenarios to measure eye movements, for example in visual scanning (McCarley, 2004) and button location (Dukic, 2005).

Furthermore, effortful, attentive scanning is necessary to avoid perceptual failures. This scanning is possible through top-down (knowledge-driven) as well as bottom-up (stimulus-driven) processes (Pringle, Irwin, Kramer, & Atchley, 2001). Seeing the hazards with the eye tracker seems a bottom-up process that relies on unfiltered visual information. However, this is the case when it is considered quick visual identification. If there is more time to look at the hazard, quick visual identification could turn into directed attention and make it a top-down process (Blackmore, 2012; Wickens, Lee, Liu, & Gordon-Becker, 2014).

The difference between an eye tracker and reporting the hazards on paper is that there is more time to think when writing the hazards down. Writing promotes reflective, critical thinking (Menary, 2007) and is partly connected to learning (Bangert-Drowns, Hurley & Wilkinson, 2004). These cognitive mechanisms are considered top-down processes.

It is, however, not likely that drivers become better at writing down hazards and thus better at seeing the hazards with the eye tracker in a short hazard perception test. Other factors are important to develop this skill. Feedback, for example, can enhance learning when it is used correctly (Hattie & Timperley, 2007). Not only that, but distributed practice (schedule of learning activities) and practice testing (self-testing) seem to be good learning techniques as well (Dunlosky et al., 2013).

Thus, writing down the hazards in this study seems to be a top-down process, which means it comes from a higher cognitive process. And with the use of scanning strategies and with more time to look at the hazard, seeing the hazards with the eye tracker is part of a top-down process as well. This means that there should be no difference between the amount of hazards reported on paper and the amount of hazards that were seen with the eye tracker.

In short, there are multiple questions this study wants to address. First, what is the effect of driving experience on this hazard perception test? Driving experience is divided between less than one year and more than three years of driving experience. Thus, the first hypothesis is: Experienced drivers are expected to perform better than novice drivers on the amount of hazards that were seen with the eye tracker.

Secondly, perhaps the UFOV test can indicate a difference in attentional skills (selective attention, divided attention and processing speed) between these novice and more experienced drivers. Accordingly the second hypothesis is: Experienced drivers are expected to have better visual attentional skills than the novice drivers (measured with the Useful Field of View test).

Thirdly, the hazards reported on paper and the hazards seen with the eye tracker should not significantly differ. Subsequently, the third hypothesis is: It is expected that there is no difference for all drivers (both novice and experienced drivers) between the amount of hazards reported on paper and the amount of hazards seen with the eye tracker.

The answers to these questions will give more insight into the experiential differences between two driver groups that are close in age and driving experience. Young, novice drivers are an at risk group for accidents in traffic and finding a way to lower this risk is valuable.

Method

Participants

The requirements to participate in this study were a valid driver's license and no background with psychological disorders (like ADHD or depression). Furthermore participants could not be in therapy for ADHD, depression, epilepsy, chronic pain, schizophrenia, psychosis, obsessive-compulsive disorder, bipolar disorder, anxiety disorder or a brain disorder. Medical treatments that can have influence on the reaction time or attention cannot be used either. These were for instance antidepressants, anxiolytics, antipsychotics, heavy painkillers or sleeping aids. Participants were recruited through SONA, a system used by Leiden University for research participation in the field of Psychology. The study was approved by the Ethics Committee of Leiden University and the experiment was conducted in accordance with applicable laws and guidelines (e.g. anonymity).

The participants were split in two groups depending on their years of driving experience. One group with less than one year of driving experience (novice drivers) and the other group with more than three years of driving experience (experienced drivers). Participants were asked in the questionnaire whether they still had visual disabilities when their vision was corrected with either contacts or glasses.

The sample consisted of 44 Dutch and international university students (N = 44). See Table 1 for an overview of the characteristics of the participants. The novice group (n = 22) had an average age of 22.5 years (SD = 4.2, Mdn = 22, Min = 18, Max = 38). The experienced group (n = 22) had an average age of 25 years (SD = 4.9, Mdn = 24.5, Min = 19, Max = 43). The novice group drove on average 14.4 kilometers per week (SD = 24.5, Mdn = 3, Min = 0, Max = 100) and the experienced group drove on average 86.2 kilometers per week (SD = 252, Mdn = 22.5, Min = 0, Max = 1200).

Table 1

An Overview of the Participants and their Gender

Participants	Male	Female	Total
Novice Drivers	5	17	22
Experienced Drivers	8	14	22
Total	13	31	44

Materials and Measuring Instruments

For this study the following materials and measuring instruments were used.

- Eye tracker (Gazepoint GP3). It had an accuracy of 0.5 – 1 degree of visual angle and a 60Hz update rate. It was 320 x 45 x 40 mm and weighs 250g. The movement was 25 cm x 11 cm (horizontal x vertical) and it had approximately 15 cm range of depth movement. It resembled a black, horizontal bar and was placed underneath the computer screen. The software that was used for this eye tracker was Gazepoint Analysis UX Edition – Software. It included a heat map, gaze fixation path, dynamic area of interests (AOIs) and image, video and statistics export (Gazepoint, 2014).
- UFOV test (Visual Awareness Research Group, 2009). This is the Useful Field of View test. It is a test for functional vision and visual attention and was administered by computer. It can be predictive of driving ability and can be administered in about 15 minutes. With both eyes participants had to detect, identify and localize targets that were presented for a short period of time. It consisted of three subtests:
    - Processing Speed. A target was presented in a centrally located place to determine the threshold for discriminating stimuli.
    - Divided Attention. A target had to be identified, but at the same time another target had to be localized. This second target was more on the periphery of the computer screen.
    - Selective Attention. This had the same set up as subtask two but now the distractors were added, making it more difficult.

  Each subtest provided a score in msec. Cut points for each subtest were in the UFOV User's Guide (Visual Awareness Research Group, 2009). Combinations of the subtests were automatically calculated and ranged in risk category (Very Low, Low, Low to Moderate, Moderate to High, High, Very High).
- GoPro Hero +. 1080p video capture at 60 frames per second. It can be remotely controlled and it was attached to the dashboard of the car to film traffic.
- Video clips (stimuli material). The clips were selected based on the kind of hazard it presented. One professor and two master students examined whether a hazard was overt or covert and if the clips were usable for the experiment. In the end, eight clips of approximately thirty seconds were used after indicating areas of interest with the eye tracker software. An area of interest was used to calculate eye movement quantitatively. A boundary was drawn around the hazard with the software. Within those lines of this chosen boundary the eye tracker measured for example fixation counts and durations. When the hazard (as indicated with an area of interest) was seen there was a 'hit'. In total, there were eight area of interests indicated as overt

hazards and seven area of interests as covert hazards. A short description of the clips, the kind of hazard it was and the area of interests can be found in Appendix A.

- Potential hazard form. A form made by the experimenters where participants report on paper how many (potential) hazards they saw and what the source and location of this hazard was. The source, for example, was a pedestrian and the location would then be on the left side of a zebra crossing. This potential hazard form can be found in Appendix B.
- Qualtrics Questionnaire. The questionnaire consisted of eight questions and it was administered on a computer with Qualtrics. The questions included age, sex, visual disabilities even with corrected vision, amount of kilometers driven per week, how frequently one drove and how long the participant had their driver's license.

Procedure

The experiment was conducted in the laboratory of Leiden University and the duration was 40 to 50 minutes. The procedure was the same for novice drivers as well as for experienced drivers. When participants entered the room they were greeted and asked to read the informed consent and to sign the form if they agreed. Then they were brought to the computer to start the experiment. There was a short explanation of the procedure of the experiment. This included what the participant had to do for the UFOV test and that the participant should open his/her door if there were questions or when he/she was asked to call the researcher. At that moment they did not have to do anything with the eye tracker, this would be explained by the researcher when the participant was ready for this part of the experiment. In this case, to start the part of the experiment with the eye tracker the researcher had to calibrate it first and make sure everything worked accordingly.

Thus firstly, the participants started with the UFOV test. The test was explained by the software, including a practice trial, but the researcher gave information about the duration of the test as well. This took about ten to fifteen minutes.

Secondly, the hazard perception test was administered. The participant had to call the researcher to set it up and after calibrating the eye tracker the researcher left the room. There was one practice clip where the researcher was present to explain the procedure if necessary. Afterwards the participant went through 8 clips of approximately 30 seconds (see Appendix A for descriptions of the video clips) and was asked to act as usual and to pretend to be the one driving. Between each clip the participant had one minute to write down the possible hazards on a form (see Appendix B for the potential hazard form). Each hazard was described by source (who or what) and location (where). They were told that the amount of hazards (0 to 5) could differ in clips. When the participant finished the researcher returned and started the questionnaire that asked the participant about age, sex and driving experience. Other questions like education and amount of kilometers they drove were asked as well. The experiment ended with a debriefing.

Lastly, the participant was asked after the debriefing if they had any questions. The participant had to sign a participation form with their signature and whether they wanted money or credits as payment for their contribution.

Statistical Analyses

The independent variable of the experiment was the driving experience. One group had less than one year of driving experience and the second group had three years or more of driving experience. The dependent variables were the amount of hazards seen with the eye tracker, the scores on the three subtests of the UFOV and the amount of hazards reported on the potential hazard form.

The experiment was initially tested as a trial with one participant and it was concluded that there were no complications. The data of this participant were not used in further analyses. The raw data were first organized in Microsoft Office Excel 2007. The data of the eye tracker were reorganized so that each participant had a 0 (not seen) or a 1 (seen) for each hazard. The potential hazard forms were coded by hand (again with 0 and 1) and this was recorded in Excel. Then the data from Qualtrics were included and finally all of the organized data were analyzed with SPSS (IBM Statistics 23).

Results

Two participants were excluded before analyzing the data. These two participants wore glasses and these glasses deceived the eye tracker by using the reflection on the glass instead of the pupil of the eye. No participants were excluded on behalf of the question on the questionnaire whether participants still had a visual disability even with corrected vision (contacts or glasses). After excluding the two participants with glasses, the sample consisted of 44 participants ($N = 44$), with 22 participants who had their driver's license shorter than one year (novice drivers) and 22 participants longer than three years (experienced drivers).

In this study there was independence of observations. There was no relationship between the novice drivers and the experienced drivers in each group. There were different participants in each group and each participant was tested independently of each other.

First Hypothesis: Driving Experience

The first hypothesis was that experienced drivers are expected to perform better than novice drivers on the amount of hazards that were seen with the eye tracker. The following results were found.

All Hazards

The results for the first hypothesis for all hazards (covert and overt).

Outliers. The total eye tracker scores (amount of hazards seen) were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. No outliers were detected.

Normality tests. A Shapiro-Wilk's test ($p > .05$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the total eye tracker scores (amount of hazards seen) were approximately normally distributed for both novice and experienced drivers. There was a skewness of -0.050 ($SE = 0.491$) and a kurtosis of -0.360 ($SE = 0.953$) for novice drivers and a skewness of -5.222 ($SE = 0.491$) and a kurtosis of 0.648 ($SE = 0.953$) for experienced drivers. The z-values were normally distributed.

Homogeneity of variances. For the total eye tracker scores (amount of hazards seen), the variances were equal for novice drivers and for experienced drivers, $F(1,42) = 3.30$, $p = .076$. Homogeneity of variance was assumed.

Independent-Samples T test. On average, experienced drivers saw more hazards with the eye tracker ($M = 9.5$, $SE = 0.39$), than novice drivers ($M = 7.73$, $SE = 0.61$). This difference, -1.77, 95% CI [-3.227, -0.319], was significant $t(42) = -2.46$, $p = .018$. It represented a medium-sized effect, *d* = 0.62. See Figure 1 for the difference between novice and experienced drivers on the amount of hazards that were seen with the eye tracker.

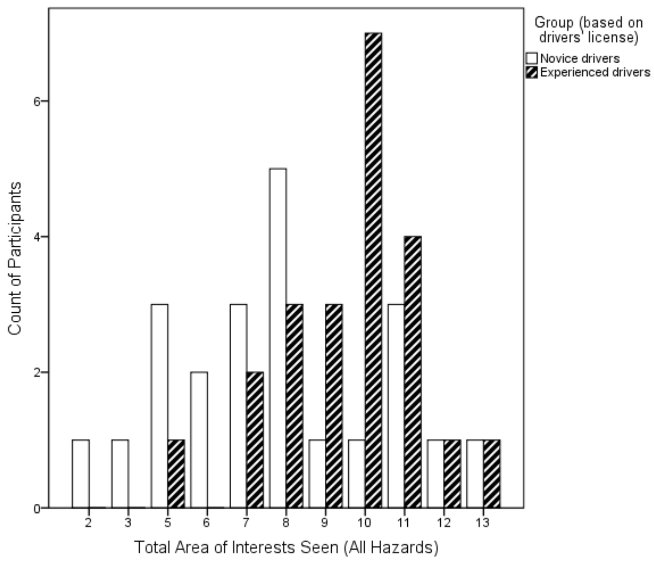

Figure 1.
Amount of hazards seen with the eye tracker. This figure illustrates the difference between novice and experienced drivers.

Overt Hazards

The hazards were distinguished between overt and covert hazards. Below the results of the overt hazards.

Outliers. The total eye tracker scores (percent of overt hazards seen) for overt hazards were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. No outliers were detected.

Normality tests. A Shapiro-Wilk's test ($p > .05$) and a visual inspection of their histogram, normal Q-Q plot and box plot showed that the total eye tracker scores (percent of overt hazards seen) for overt hazards were approximately normally distributed for novice drivers. The Shapiro-Wilk's test ($p < .05$) and the histogram for experienced drivers showed that these scores for overt hazards were not normally distributed. The normal Q-Q plot and box plot for experienced drivers showed an approximately normal distribution.

There was a skewness of 0.193 (*SE* = 0.491) and a kurtosis of -0.347 (*SE* = 0.953) for novice drivers and a skewness of 0.009 (*SE* = 0.491) and a kurtosis of -1.381 (*SE* = 0.953) for experienced drivers. The z-values for both novice and experienced drivers were normally distributed.

The K-S test *D*(22) = 0.141, *p* = .141, did not deviate significantly from normal for novice drivers on the total percent of overt hazards seen. However the K-S test *D*(22) = 0.215, *p* = .009 was significantly non-normal for the total percent of overt hazards seen for experienced drivers.

Homogeneity of variances. For the total eye tracker scores (percent of overt hazards seen) for overt hazards, the variances were equal for novice drivers and experienced drivers, *F*(1,42) = 0.567, *p* = .456. Homogeneity of variance can be assumed.

Mann-Whitney U test. Because of the violation of the assumption of a normal distribution for experienced drivers a non-parametric test was chosen. The Mann-Whitney U test. The total eye tracker scores (percent of overt hazards seen) for overt hazards for novice drivers (*Mdn* = 0.50) did not significantly differ from experienced drivers (*Mdn* = 0.625). The statistics were *U* = 162.00, *z* = -1.916, *p* = .055, *r* = -.29. This is a small to medium effect size (below the .3 criterion for a medium effect size). See Figure 2 for an illustration of the difference between novice and experienced drivers on the total percent of overt hazards seen with the eye tracker.

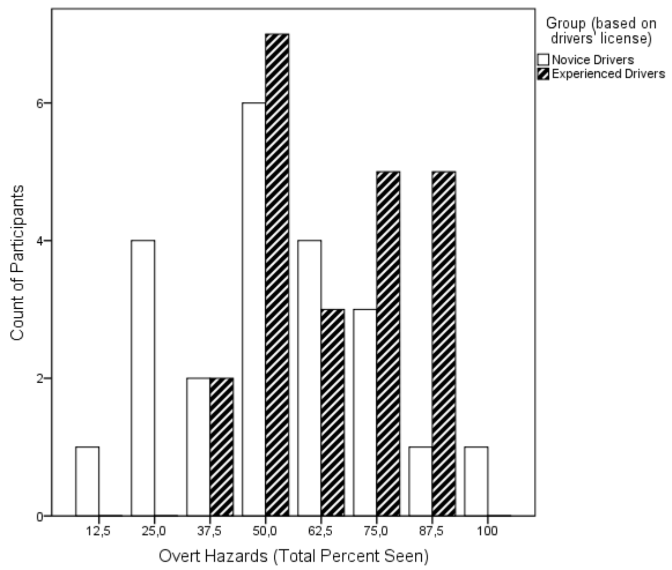

Figure 2.
The total percent of overt hazards seen with the eye tracker. This figure illustrates the difference between novice and experienced drivers.

Covert Hazards

The hazards were distinguished between overt and covert hazards. Below the results of the covert hazards.

Outliers. The total eye tracker scores (percent of covert hazards seen) for covert hazards were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. No outliers were detected.

Normality tests. A Shapiro-Wilk's test ($p > .05$) and a visual inspection of the histogram, normal Q-Q plot and box plot showed that the total eye tracker scores (percent of covert hazards seen) for covert hazards were approximately normally distributed for novice drivers. The Shapiro-Wilk's test ($p < .05$), the histogram and the box plot for experienced drivers showed that these scores for covert hazards were not normally distributed. The normal Q-Q plot for experienced drivers showed an approximately normal distribution.

There was a skewness of -0.185 (SE = 0.491) and a kurtosis of -1.055 (SE = 0.953) for novice drivers and a skewness of -0.391 (SE = 0.491) and a kurtosis of -0.932 (SE = 0.953) for experienced drivers. The z-values for both novice and experienced drivers were normally distributed.

The K-S test $D(22) = 0.152$, $p = .200$, did not deviate significantly from normal for novice drivers on the total percent of covert hazards seen. However the K-S test $D(22) = 0.192$, $p = .034$ was significantly non-normal for the total percent of covert hazards seen for experienced drivers.

Homogeneity of variances. For the total eye tracker scores (percent of overt hazards seen) for overt hazards, the variances were equal for novice drivers and for experienced drivers, $F(1,42) = 1.263$, $p = .267$. Homogeneity of variance was assumed.

Mann-Whitney U test. Because of the violation of the assumption of a normal distribution for experienced drivers a non-parametric test, The Mann-Whitney U test, was chosen. The total eye tracker scores (percent of covert hazards seen) for covert hazards for novice drivers (Mdn = 0.571) did not significantly differ from experienced drivers (Mdn = 0.643). The statistics were $U = 178.00$, $z = -1.529$, $p = .130$, $r = -.23$.This is a small to medium effect size (below the .3 criterion for a medium effect size). See Figure 3 for an illustration of the difference between novice and experienced drivers on the total percent of covert hazards seen with the eye tracker.

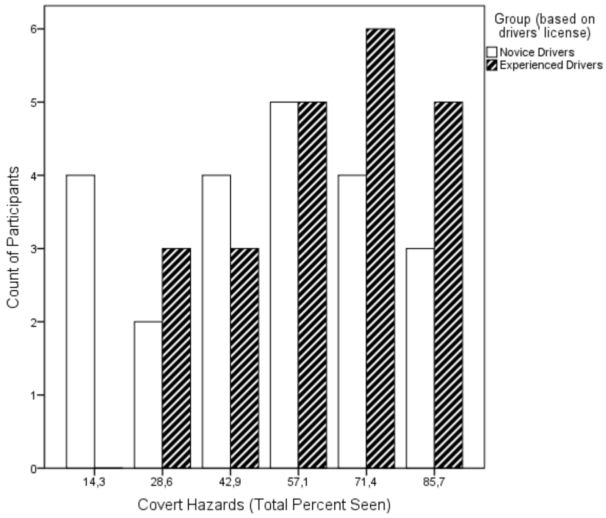

Figure 3.
The total percent of covert hazards seen with the eye tracker. This figure illustrates the difference between novice and experienced drivers.

Second Hypothesis: The UFOV
The second hypothesis was that experienced drivers are expected to have better visual attentional skills than the novice drivers (measured with the Useful Field of View test). The following results were found.

UFOV Processing Speed
The first subtest on the UFOV test was processing speed.

Outliers. The scores for the subtest processing speed on the UFOV were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. There was one ‘far out’ outlier (extreme outlier) detected in the novice drivers group but none in the experienced drivers group. The outlier still indicated a UFOV category of low to moderate risk.

Normality tests. A Shapiro-Wilk’s test ($p < .01$) and a visual inspection of the histogram, normal Q-Q plot and box plot showed that the scores for the subtest processing speed on the UFOV were not normally distributed for novice drivers. The Shapiro-Wilk’s test, the histogram and the normal Q-Q plot for experienced drivers could not be included because of constant data. The boxplot for experienced drivers did not show an approximately normal distribution either.

There was a skewness of 4.690 (*SE* = 0.491) and a kurtosis of 22.000 (*SE* = 0.953) for novice drivers. The z-values were not normally distributed for the novice drivers. The skewness and kurtosis was not computable for the experienced drivers due to constant data.

The K-S test $D(22) = 0.539$, $p = .000$, deviated significantly from normal for novice drivers on the scores for the subtest processing speed on the UFOV. The K-S test for experienced drivers for the scores for the subtest processing speed on the UFOV was not calculable due to constant data.

Homogeneity of variances. For the scores for the subtest processing speed on the UFOV, the Levene statistic could not be computed because of constant data for experienced drivers and because there were not enough unique spread/level pairs.

Test. No test could be computed. See Figure 4 for an overview of the scores on the UFOV subtest processing speed for both novice and experienced drivers. These scores were constant for experienced drivers.

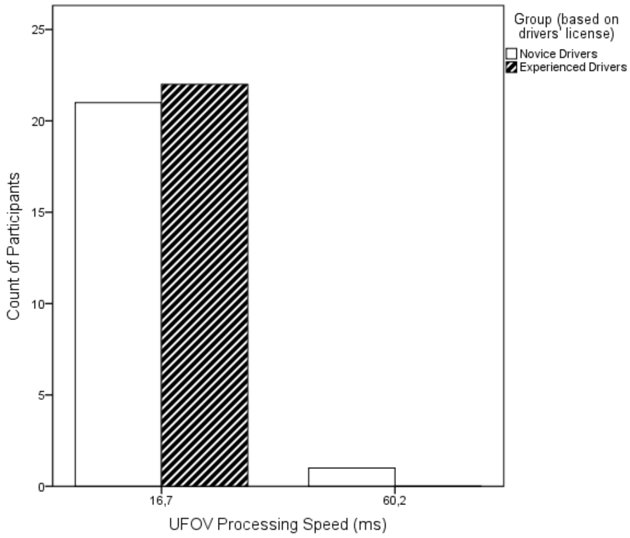

Figure 4.

Scores of the UFOV subtest processing speed in milliseconds. This is illustrated for both novice and experienced drivers.

UFOV Divided Attention

The second subtest on the UFOV test was divided attention.

Outliers. The scores for the subtest divided attention on the UFOV were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. There was one ‘out’ outlier detected in the novice drivers group and two ‘far out’ outliers (extreme outliers). The boxplot of the experienced drivers group showed four ‘far out’ outliers (extreme outliers).

Normality tests. A Shapiro-Wilk’s test ($p < .01$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the scores for the subtest divided attention on the UFOV were not normally distributed for novice drivers as well as for experienced drivers.

There was a skewness of 3.222 (*SE* = 0.491) and a kurtosis of 11.451 (*SE* = 0.953) for novice drivers and a skewness of 2.084 (*SE* = 0.491) and a kurtosis of 3.616 (*SE* = 0.953) for experienced drivers. The z-values were not normally distributed for both novice and experienced drivers.

The K-S test $D(22) = 0.389$, $p = .000$, deviated significantly from normal for novice drivers on the scores for the subtest divided attention on the UFOV. The K-S test $D(22) = 0.360$, $p = .000$ deviated significantly from normal for experienced drivers as well.

Homogeneity of variances. For the scores for the subtest divided attention on the UFOV, the variances were equal for novice drivers and for experienced drivers, $F(1,42) = 2.614$, $p = .113$. Homogeneity of variance was assumed.

Mann-Whitney U test. Because of the violation of the assumption of a normal distribution for novice and for experienced drivers a non-parametric test, The Mann-Whitney U test, was chosen. The scores for the subtest divided attention on the UFOV for novice drivers (*Mdn* = 16.7) did not significantly differ from experienced drivers (*Mdn* = 16.7). The statistics were $U = 232.500$, $z = -0.270$, $p = .787$, $r = -.04$. See Figure 5 for an overview of the scores on the UFOV subtest divided attention for both novice and for experienced drivers.

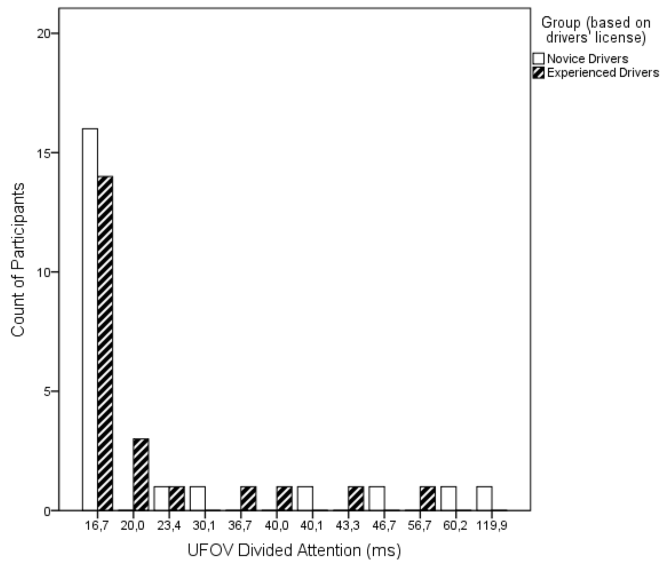

Figure 5.
Scores of the UFOV subtest divided attention in milliseconds. This is illustrated for both novice and experienced drivers.

UFOV Selective Attention

The third subtest of the UFOV test was selective attention.

Outliers. The scores for the subtest selective attention on the UFOV were visually inspected for outliers with box plots for both novice drivers as well as for experienced drivers. There was one ‘out’ outlier detected in the novice drivers group and one ‘far out’ outlier (extreme outlier). The boxplot of the experienced drivers group showed two ‘out’ outliers.

Normality tests. A Shapiro-Wilk’s test ($p < .05$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the scores for the subtest selective attention on the UFOV were not normally distributed for novice drivers as well as for experienced drivers.

There was a skewness of 1.469 (*SE* = 0.491) and a kurtosis of 2.745 (*SE* = 0.953) for novice drivers and a skewness of 1.192 (*SE* = 0.491) and a kurtosis of 1.436 (*SE* = 0.953) for experienced drivers. The z-values were not normally distributed for novice drivers. The z-value for the kurtosis in the experienced drivers group was normally distributed, but the z-value for skewness was not normally distributed.

The K-S test $D(22) = 0.201$, $p = .021$, deviated significantly from normal for novice drivers on the scores for the subtest selective attention on the UFOV. However, the K-S test $D(22) = 0.170$, $p = .099$ did not deviate significantly from normal for experienced drivers.

Homogeneity of variances. For the scores for the subtest selective attention on the UFOV, the variances were equal for novice drivers and for experienced drivers, $F(1,42) = 0.059$, $p = .809$. Homogeneity of variance was assumed.

Mann-Whitney U test. Because of the violation of the assumption of a normal distribution for novice and experienced drivers a non-parametric test, The Mann-Whitney U test, was chosen. The scores for the subtest selective attention on the UFOV for novice drivers (*Mdn* = 60.1) did not significantly differ from experienced drivers (*Mdn* = 58.4). The statistics were $U = 223.000$, $z = -0.446$, $p = .663$, $r = -.07$. See Figure 6 for an overview of the scores on the UFOV subtest selective attention for both novice and experienced drivers.

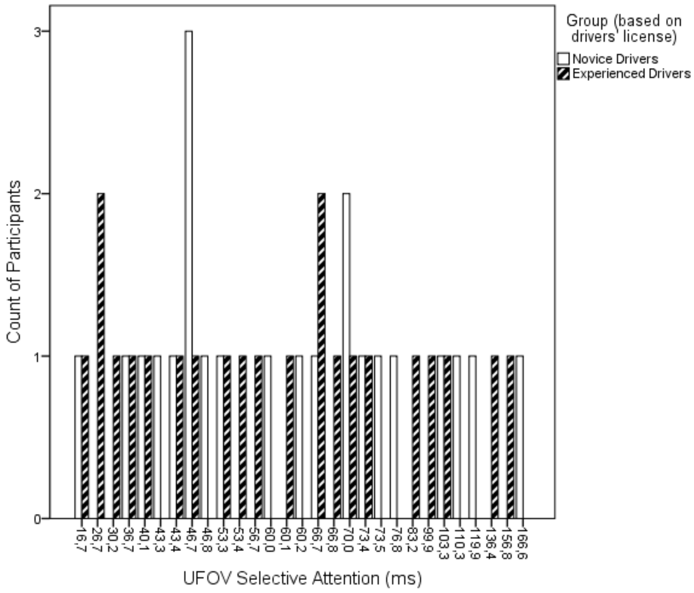

Figure 6.

Scores of the UFOV subtest selective attention in milliseconds. This is illustrated for both novice and experienced drivers

Overall UFOV Test Category

The UFOV Test gave a final test score of all subtests. This score was categorized in risk categories (Very Low, Low, Low to Moderate, Moderate to High, High, Very High) in which Very Low was category 1 and Very High category 6. See Table 2 for an overview of the novice and experienced drivers in each UFOV category. Most participants were in risk category Very Low and no participants were in risk category Moderate to High or higher.

Table 2

An Overview of Novice and Experienced Drivers in each UFOV Category

UFOV Category	Novice Drivers	Experienced Drivers	Total
Category 1	20	22	42
Category 2	1	0	1
Category 3	1	0	1
Category 4	0	0	0
Category 5	0	0	0
Category 6	0	0	0
Total	22	22	44

Third Hypothesis: Reporting Hazards on Paper

The third hypothesis was that there are no differences expected for all drivers (both novice and experienced drivers) between the amount of hazards reported on paper and the amount of hazards seen with the eye tracker.

To check normality the differences between scores of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were computed and this new variable was tested.

All Drivers

The results for all drivers, including novice and experienced drivers.

Outliers. The differences between scores of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were visually inspected for outliers with a box plot for all drivers. One ‘out’ outlier was detected.

Normality tests. A Shapiro-Wilk’s test ($p < .05$) and a visual inspection of the histogram and box plot showed that the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were not completely normally distributed for all drivers. The Q-Q plot looked approximately normally distributed. There was a skewness of 0.858 (SE = 0.357) and a kurtosis of 0.769 (SE = 0.702) for all drivers. For all drivers the z-value for kurtosis was normal but it was not normal for skewness.

The K-S test $D(44) = 0.162$, $p = .006$, deviated significantly from normal for all drivers on the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper).

Homogeneity of variances. For the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper), the variances were unequal for all drivers, $F(1,42) = 4.548$, $p = .039$. Homogeneity of variance cannot be assumed.

Wilcoxon Signed-Rank test. A non-parametric test, the Wilcoxon signed-rank test, was chosen. For all drivers the scores on the potential hazard form (Mdn = 10) were not significantly different than the scores on the eye tracker (Mdn = 9), $T = 443.5$, $z = 1.752$, $p = .08$, $r = .19$. See Figure 7 for an overview of the differences between the hazards reported on paper and the hazards seen with the eye tracker for all drivers.

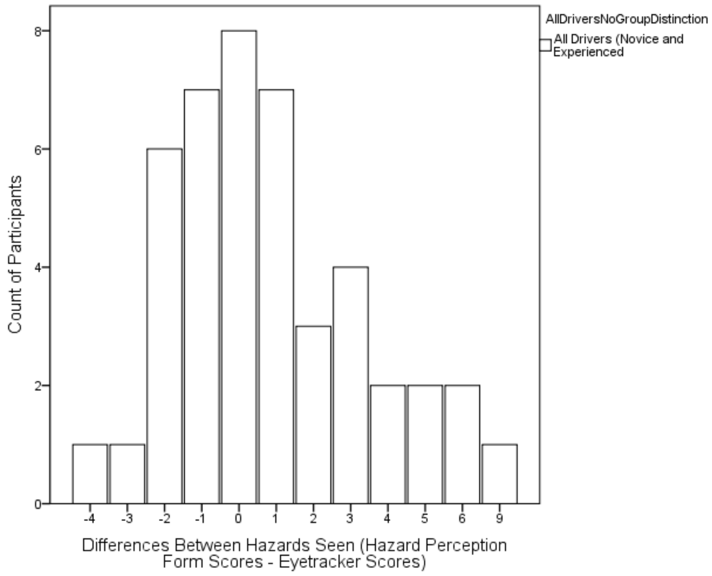

Figure 7.
The differences between the hazards reported on the potential hazard form and the hazards seen with the eye tracker. This is illustrated for all hazards (covert and overt) and all drivers (novice and experienced).

Comparing Novice and Experienced Drivers

Results for novice and experienced drivers in their respective groups.

Outliers. The differences between scores of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were visually inspected for outliers with box plots for both novice drivers and experienced drivers. No outliers were detected.

Normality tests. A Shapiro-Wilk's test ($p < .05$) and a visual inspection of the histogram, normal Q-Q plot and box plot showed that the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were not normally distributed for novice drivers. However, the Shapiro-Wilk's test ($p > .05$) and a visual inspection of the histogram, normal Q-Q plot and box plot showed that the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper) were normally distributed for experienced drivers.

There was a skewness of 0.883 (SE = 0.491) and a kurtosis of -0.128 (SE = 0.953) for novice drivers and a skewness of -0.189 (SE = 0.491) and a kurtosis of -0.445 (SE = 0.953) for experienced drivers. For novice drivers the z-value for skewness was normal but it was not normal for kurtosis and for experienced drivers the z-values were not distributed normally for either skewness or kurtosis.

The K-S test $D(22) = 0.218$, $p = .008$, deviated significantly from normal for novice drivers on the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper). However, the K-S test $D(22) = 0.129$, $p = .200$ did not deviate significantly from normal for experienced drivers.

Homogeneity of variances. For the scores for the differences of the total eye tracker scores (amount of hazards seen) and the total potential hazard form scores (amount of hazards reported on paper), the variances were unequal for novice drivers and experienced drivers, $F(1,42) = 4.548$, $p = .039$. Homogeneity of variance cannot be assumed.

Wilcoxon Signed-Rank Test. A non-parametric test, the Wilcoxon signed-rank test, was chosen. For novice drivers the scores on the potential hazard form (*Mdn* = 9) were not significantly different than the scores on the eye tracker (*Mdn* = 8), $T = 112$, $z = 1.69$, $p = .091$, $r = .25$. For experienced drivers the scores on the potential hazard form (*Mdn* = 10) were not significantly different than the scores on the eye tracker (*Mdn* = 10) either, $T = 113$, $z = 0.74$, $p = .462$, $r = .11$.

See Figure 8 for an overview of the differences between the hazards reported on paper and the hazards seen with the eye tracker for novice and for experienced drivers. The score -4 meant that there were four more hazards seen with the eye tracker than reported on the potential hazard form, the score 0 meant no difference and the score 9 meant nine more hazards reported on paper than hazards seen with the eye tracker.

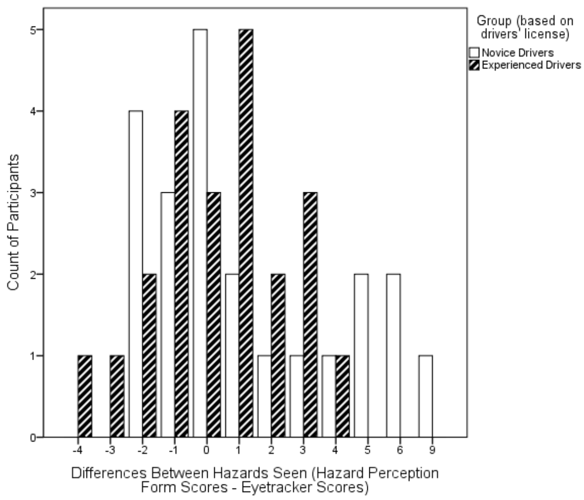

Figure 8.

The differences between the hazards reported on paper and the hazards seen with the eye tracker. This is illustrated for novice and experienced drivers for all hazards.

Discussion

This study expected to find that experienced drivers would perform better than novice drivers on the amount of hazards that were seen with the eye tracker. It was expected that experienced drivers would have better visual attentional skills (measured with the Useful Field of View test) than the novice drivers as well. Lastly, no difference was expected between the amount of hazards reported on the potential hazard form and the amount of hazards seen with the eye tracker for all drivers.

For the first hypothesis the test was significant and the hypothesis accepted, meaning that there was a difference between novice and experienced drivers. Experienced drivers saw significantly more hazards with the eye tracker than novice drivers. There was no significant difference between the type of hazards (covert or overt).

This is in line with the study of Underwood and Crundall (1998) that found a difference between novice and experienced drivers. It was suggested that novice drivers restrict their visual search and concentrate on novel, dangerous areas whereas experienced drivers expand their visual search to cover a bigger area. In another study (Sagberg & Bjornskau, 2005) a tendency was found for a decrease of reaction times when there was more experience. Although the current study that was done here did not take reaction times into account, since noticing a hazard does not necessarily mean a physical reaction in this study, experience did seem to matter.

Experienced drivers did not perform better than novice drivers on either covert or overt hazards. However, Vlakveld (2011) found that fixations on overt hazards were not a good indicator of the ability of younger drivers to detect the overt hazards. This could mean that there could still be a difference between the hazard types, but it was not measurable in the current study. Interestingly, Vlakveld (2011) found that fixations on covert hazards were a good indicator of the hazard perception ability of drivers. This was not found in this study either.

The second hypothesis, regarding the visual attentional skills of the drivers measured with the UFOV test, was rejected. The non-parametric tests for each subtest was not significant, meaning that there was no difference between novice and experienced drivers on processing speed, divided attention and selective attention. McManus et al. (2015) found that the selective attention component of the test significantly predicted motor collisions in a simulated drive. A difference on the selective attention test was not replicated in the current study.

Perhaps a reason for these results is that performance on the UFOV test was found to be age-related (Edwards et al., 2006; Scialfa et al., 1987). The biggest differences were found comparing younger drivers with much older drivers or elderly. For example Ishimatsu et al. (2010) found that in the peripheral-task the cost of divided attention was most evident and significantly greater for older adults (age ranging from 65 to 84 years) compared to younger drivers (age ranging from 19 to 28 years).

This could mean that the age difference and the difference in experience in the current sample was not big enough to find a significant difference on the UFOV test. The average age of the participants in the novice and experienced drivers group did not differ much. Moreover, all participants were in the lowest categories of the UFOV test, indicating that they all did well. Only one participant fell in risk category three (Low to Moderate), but this was still relatively low risk. Because of the small age and driving experience difference between the novice and experienced drivers the UFOV test might not have been the right tool to compare the participants in this study.

The third hypothesis, that there would be no difference between the amount of hazards reported on paper and the amount of hazards seen with the eye tracker for all drivers was accepted. There was no significant difference between these two variables. Drivers were not better at seeing the hazards or at reporting them on the potential hazard form. There were no significant differences found in each group either. The novice drivers were not better or worse at seeing the hazards and writing them down. This result was the same for the experienced drivers as a group.

This follows the reasoning that when there is more time to look at the hazard, quick visual identification could turn into directed attention and make it a top-down process (Blackmore, 2012; Wickens et al., 2014). Moreover Jackson et al. (2009) found that experiential differences in hazard perception could be revealed when processing time was manipulated. In this current study, processing time was not manipulated and consequently both the novice and experienced drivers had enough time to process the hazardous situation. Perhaps if processing time was manipulated a difference would show between seeing the hazards with the eye tracker and reporting the hazards on paper, because more reflective thinking could have occurred when reporting the hazards on the potential hazard form. Nonetheless, a difference between seeing the hazards with the eye tracker and reporting the hazards on paper was not demonstrated in this study. Naturally, this study had limitations and these limitations are important to consider.

One of the limitations was first and foremost the demographics of the participants. Most participants were female and there was a mix of Dutch and international university students. This means that the results cannot be generalized.

Another limitation was that while the set-up of this study tried to be realistic with real-life video clips it was still a simulated environment. Participants knew they were looking for hazards and they probably directed their attention to this task. Driving in real life is more complex, with a lot more distractions (e.g. radio, phone). However this study did show that if a difference would be found in more naturalistic driving it would probably not be because of not being able to see the hazards or not having the visual attentional skills (tested with the UFOV).

On top of that, the set-up had only one computer screen. When driving a car the perceived worldview is bigger. For example, three computer screens with an approximately 180 degrees perceived worldview would give a wider field of view. It includes more environmental cues regarding the hazardous situation and it would increase the ability to detect hazards (Shahar, Alberti, Clarke, & Crundall, 2010). The current study did not use sound either to give a more naturalistic driving experience. Drivers do not only rely on their visual skills, but on a complex set of skills that includes auditory information.

Considering the reporting of the hazards on paper, the possibility that writing down the hazards enhanced the ability to detect hazards with the eye tracker cannot be excluded. Perhaps participants became better at detecting hazards because they wrote it down. However this study was very short compared to what is needed to become better at seeing hazards. A lot of factors are needed to facilitate learning. Factors like feedback and distributed practice (Hattie & Timperley, 2007; Dunlosky et al., 2013) were not present in this study which makes a training less likely. However, it cannot be ruled out that reflective thinking facilitated more directed attention.

In conclusion, it is interesting that while there was a difference between novice drivers and experienced drivers on the eye tracker, there were no differences between the type of hazards (covert or overt). There were no differences in visual attentional skills (measured with the UFOV test) either. Thus an unanswered question is why the novice and experienced drivers did not differ that much. Future research could also investigate other tools to predict driving ability specifically for younger drivers. Perhaps there is a tool that can differentiate the nuances between younger drivers even with their smaller differences in age and driving experience. Perhaps it is interesting to focus more on how to successfully change the attitudes of younger drivers as well. This could possibly lead to different driving behaviors. Even so, this study demonstrated that even with a small difference in age, there was an experiential difference in the amount of hazards seen with the eye tracker. This suggests that driving experience does matter.

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