The effect of driving experience on hazard perception and its relation with attention
Abstract

This study investigated the differences between experienced and novice drivers in their performance on detecting potential on-road dangers and its relation with attention. The participants underwent both of the hazard perception (HP) task and the Useful Field of View (UFOV) test. The measures taken in HP task included the accuracy of fixating the hazards, time taken to first fixate a hazard, and the fixation durations, while the dependent variable of UFOV was participants’ perceptual threshold. Differences were found between experienced drivers and the novices in their overall HP performance and visual behaviours, as well as in the different lengths of clips. Hazard types did not show a strong influence in hazard perception, yet the performance on detecting covert hazards was still inferior to that of overt hazards. The correlation suggested that selective attention is the most crucial ability under high demanding driving situation (i.e. the short length clip condition), while the novices are not yet able to transfer this ability to real-life driving scenarios.
Introduction

Hazard perception is an ability to detect developing traffic situations that requires a driver to take actions such as steering or braking, and this ability is a key component to driving safety. Most of the hazard perception tests contain a series of on-road clips taken from the driver’s perspective. Each clip contains one or more potential hazards, and participants are instructed to identify them by pressing buttons or directly looking at, pointing at or clicking on them. Typical developing hazards include, for instance, pedestrians who are about to cross the road, a parked vehicle which is pulling out of parking space, or another vehicle that obstructs part of the sight of the road.

Many studies have shown an association between hazard perception and collision risk (e.g. Horswill, Anstey, Hatherly, & Wood, 2010; Boufous, Ivers, Senserrick, & Stevenson, 2011). For example, Boufous et al. (2011) found that among 17 to 24 years old holding first-year provisional driving license, who failed the hazard perception test at least twice had higher chance of collision involvement than those who passed on the first attempt. Similarly, Horswill et al. (2010) have investigated the relationship between self-reported crash risk and hazard perception in older participants who were aged 65 and over. They revealed that participants who had slower response time to hazardous situations were more likely to have been involved in self-reported collision than fast response participants.

Although nowadays driving is a common behaviour in our daily life, there is still chance that drivers get into accidents that involve events in terms of financial costs, injury or death, especially novice drivers, they are found to have inferior hazard perception performance (e.g. Wallis & Horswill, 2007; Scialfa, Deschenes, Ference, Boone, Horswill, & Wetton, 2011; Crundall, 2016), and are more likely to have an accident than experienced drivers (McKnight & McNight, 2003). The hazard perception skill explains part of the differences in accident involvement between
novice and experienced drivers (Sagberg & Bjørnskau, 2006). For instance, the study of Ahopalo, Lehikoinen, Summala (1987) showed a negative correlation between driving distance and hazard perception latencies. In the same manner, Sagberg and Bjørnskau (2006) did find a pattern of response times decreasing with experience yet not statistically significant.

Experienced drivers are found to have more successful and accurate predictions in developing hazards than novice drivers (Jackson, Chapman, & Crundall, 2009; Crundall, 2016). One of the possible explanations of this experience-related deficiency is that experienced drivers have better understanding of the contextual structure of traffic situation (Crundall, 2016; Chi, Feltovich, & Glaser, 1981), and thus could extract much valid cues from the environment compared to novice drivers.

The difference among novice and experienced drivers could also be seen in visual behaviour. Studies mainly focused on the time taken to spot the stimuli, the mean fixation durations on potential hazards, the differences of visual scanning patterns, and/or the use of peripheral vision. Multiple studies showed that novice drivers tend to have longer fixation time compared to their experienced counterpart (e.g., Mourant & Rockwell, 1972; Chapman & Underwood, 1998; Underwood, Crundall, & Chapman, 1998), and this phenomenon could be interpreted as increasing time of information processing to meet with novel and complex stimuli. Intriguingly, Crundall, Chapman, Trawley, Collins, van Loon, Andrews and Underwood (2012) had the opposite findings; the novices appeared to give the least attention to the hazards when comparing to the experienced group and their speed suggested that they also failed to capture adequate information from the relatively short dwell time. Moreover, Crundall and Underwood (1998) found that there was an interaction among experience, fixation durations and road types in which novice and experienced drivers tend to have opposite responses. In the most demanding and highest complexity dual carriageway experienced drivers had
shorter fixation durations while novice driver spent more time fixating, suggesting either dual carriageway was least demanding to experienced drivers, or they reduced fixation durations to sample more of the traffic scene, a strategy that novices have not yet developed (Crundall & Underwood, 1998). Besides, experienced drivers expanded their visual search area while driving on most demanding road type whereas novice drivers did not vary the size of sampling across different roadways. This finding also suggests that novices have not yet developed a flexible approach in viewing dynamic traffic situations (Crundall & Underwood, 1998).

Does the heterogeneity of the hazards also play a role in the hazard perception skills? Various studies categorized the hazards in different terminologies. For instance, Crundall et al. (2012) divided the hazards into two main types: behavioural prediction (BP) hazards environmental prediction (EP) hazards. The BP hazards emphasize the direct relationship between the precursor and the hazard; in other words, the precursor and the hazard share the same stimulus, only the hazard is the future status of the precursor. For example, the right front vehicle which is flashing the left turn signal may evoke the prediction that it will change the lanes. In this scenario the vehicle is the precursor as well as the hazard, allowing the driver to project the future behaviour (changing the lanes) directly from current behaviour (flashing the turn signal). The second type of hazard, as Crundall et al. (2012) proposed, has a more subtle and indirect connection between the precursor and the hazard. The EP hazards require the drivers to examine the relationship between two distinct stimuli and to use the environment to predict potential hazard. For instance, a parked van (the precursor) could obscure a potential child (the hazard) behind it. The driver needs the understanding of contextual structure to project a potential pedestrian from a parked van. This classification of types of hazards is similar to the overt and covert latent hazards used by Vlakveld, Romoser, Mehranian, Diete, Pollatsek and Fisher (2011).
Not only are the overall hazard perception skills the function of driving experience, but also are the responses to the different hazard types. The study of Crundall et al. (2012) showed that inexperienced drivers were more inaccurate in detecting BP precursors when compared to the other drivers but they spotted the same amount of BP hazards as their counterpart, suggesting the novice drivers did not make use of the direct link between BP precursors and hazards. Moreover, the analysis of the time needed to first view the stimuli revealed that it took more time for novice drivers to fixate the BP hazards. Crundall et al. (2012) believe that the experienced drivers fixating the BP precursors may help reduce the time needed to spot the BP hazards.

There is a contradictory findings on how an effortful hazard perception test might influence experienced and inexperienced drivers (e.g., McKenna & Farrand, 1999; Crundall, 2016). Beside a hazard perception task, McKenna and Farrand (1999) added a secondary task of generating random letters to increase drivers’ attentional resource demand. One might expect experienced drivers experience less detrimental effect than novices since they have stored sufficient hazardous templates in long term memory which helps them predicting upcoming danger in a less effortful manner (Crundall, 2016). However, the evidence from Mckenna and Farrand (1999) suggests the opposite; the secondary task reduced performance in both groups to the same level.

On the other hand, Crundall (2016) argues that different driver groups might develop systematically different strategies because of the use of artificial secondary tasks, and varying the length of hazard clips is a more naturalistic alternative to manipulate the attentional resources demand. Crundall (2016) found that the longer clips have a detrimental effect on hazard perception test performance in novice drivers but not in experienced drivers, which suggests the latter driver group is less susceptible to the time-on-task decrement.

Apart from the ability to detect hazards, another factor that plays a role in driving
safety is the attention skills of drivers. Driving on road requires drivers to process various stimuli simultaneously. Continuously detecting and evaluating the dynamic traffic conditions as well as predicting possible outcomes of taking or not taking certain actions. With amounts of attentional resources needed in driving behaviour, insufficiency of attention and incompetency of information processing capacity may result in accidents (Shinar, 1993). Measuring useful field of view is one of the ways to examine an individual’s visual attention. Useful field of view means a visual field area where the individual can effectively and efficiently extract information without moving his/her head or neck, and the size of the field acts as a critical role in driving safety. A narrow useful field of field results in lesser information acquired and thus slower information processing, which increases the risk of crash.

The ability to process stimuli in peripheral visual field might be a crucial component in driving performance. For instance, the study of Allahyari, Saraji, Adl, Hosseini, Younesian, and Iravani (2007) suggested that there was a negative correlation between driving performance and peripheral task score in divided attention, and this finding was in line with the conclusion of Roge and Pebayle (2005) that crash risk should be estimated only based on localization task. Similarly, studies also found that the selective attention subtest of UFOV, which requires participants to localize the peripheral targets, is the better predictor of driving performance and the ability to detect hazards (Chaparro, Groff, Tabor, Sifrit, & Gugerty, 1999; Wood, Chaparro, Lacherez, & Hickson, 2012).

Most of the studies examine useful field of view to differentiate younger and older drivers (e.g. Chaparro et al., 1999; Roge et al., 2005; Allahyari et al., 2007; Wood et al., 2012) since cognitive capabilities like attention and information processing speed decreases with age (Roge et al., 2005). However, with the evidences of increasing experiences may free participants from perceptual narrowing (e.g., see Williams (1995)
for the comparison between aviators and non-aviators) and that of increasing processing demands leads to inferior peripheral detection (Lee & Triggs, 1976). Crundall, Underwood, & Chapman (1998) concluded that varying experience may as well impact the effective size of peripheral field.

**The present study**

The main goal of the present study are twofold: First, we investigate the effect of experience in hazard perception, namely examining the differences between novice and experienced drivers in their performance of identifying developing hazards. There are ample studies showing that experienced drivers have more successful and accurate predictions in developing hazards than their counterpart (Jackson, Chapman, & Crundall, 2009; Crundall, 2016); therefore we expect to find the similar result that experienced drivers perform better than novices on hazard perception task. Second, we further assess its relation with attentional processing by using the Useful field of View test (UFOV®). To our knowledge, there have not been many studies focusing on the effect of experience on hazard perception and its relation with UFOV® performance. Based on the concept Crundall et al. (1998) proposed, we predicted that people who have less experience in driving may have higher perceptual threshold than their counterpart on processing peripheral stimuli, and this result may negatively correlate with their hazard perception performance. In addition to that, we are interested to find out whether two groups of drivers will perform differently in shorter and longer length of video clips. As Crundall (2016)’s experiment suggested, we expect to see experienced drivers perform equally well on both length of clips while novice drivers show a degradation in performance with longer clips, and the former is better than the latter overall.
Method

Participants: Forty-five adults in total were recruited from Leiden University and were divided to two groups based on how many years they have held their driving license. Twenty-two (17 female, mean age = 22.5, $SD = 4.2$) were classed as novice drivers who have held their driving license for less than a year ($M = .62$ years, $SD = .59$). Twenty-three participants (15 female, mean age = 25.0, $SD = 4.8$) were classed as experienced drivers who have held their license for a minimum of 3 years ($M = 6.02$ years, $SD = 2.73$). However, the data of a participant in the experienced group was excluded from further analyse because the eye tracker wrongly captured the light reflections on her glasses instead of her pupils. The remaining 22 experienced participants had the mean age of 25.1 ($SD = 4.9$) and the mean driving years of 6.08 ($SD = 2.78$). All the participants gave their written consent prior to taking part in the study and received monetary reward or credits after finishing the experiment. All drivers had normal or corrected-to-normal vision.

Materials and apparatus:

Useful field of view test

The useful field of view test we administered was the UFOV© software developed by Visual Awareness Research Group, Inc (2009). The test consisted of three subtests: processing speed, divided attention and selective attention. The first subtest (i.e., processing speed) required participants to identify the object in the white box in the centre of the screen, which was either a car or a truck. The second (i.e., divided attention) and third subtests (i.e., selective attention) required the same as the first, but the participants had to simultaneously locate the object presented in the periphery as well. The second and the third subtests were identical except for that there were 47 distracter (triangles) embedded in the periphery in the selective attention subtest.
Hazard perception task

Eight video clips were taken by GoPro Hero from a moving car, placed in the centre of dashboard, right below the rear-view mirror, thereby providing a footage of the view of windshield (see Appendix B). The clips were taken in the Netherlands, consisted of various road types and different traffic situations. The clips lasted from 22 to 86 seconds, containing only genuinely occurring hazardous situations; there were not any staged situations. The potential hazards were selected by researchers, dividing into two categories, namely overt and covert hazards. Each clip contain 1 to 3 developing hazards. Clips were edited to be either long (with a mean length of 70.25 seconds) or short (with a mean of 27.25). During the experiment participants’ eye movements were record by Gazepoint GP3 eye tracker, measuring their scanning patterns, numbers of fixations, fixations durations, and if participants successfully fixate on areas of interest.

Design:

Useful field of View

The study first employed a 2 x 3 mixed design where the between-participants factor was experience (novice, experienced) and the within-participants variable was useful field of view (processing speed, divided attention and selective attention). The dependent variable was the perceptual threshold. The program measured the point at which participants were unable to see the presented targets accurately, represented as in millisecond. Thus a low number reflects a lower perceptual threshold and a higher sensitivity, and a higher number represents a higher threshold and a lower sensitivity. Since the ability to process stimuli in peripheral visual field was a crucial component of driving safety, we predicted that the divided attention and selective attention might be able to differentiate novices and experienced drivers.
Hazard perception task

We employed an independent *t*-test to assess if there exist a difference between novice and experienced groups in the overall hazard perception performance. A 2 x 2 mixed design was then conducted where the between-subject factor is experience (novice, experienced) and the within-subject variable is hazard type (overt, covert). The main dependent variable was the accuracy of detecting the potential hazards in the traffic clips, which was calculated by whether participants fixate on areas of interest, namely where the potential hazards might occur, in certain time windows. Time window of a hazard started from when a hazard could first be seen, and ended at the time when the hazard could no longer be seen on the screen. It was predicted that experienced drivers would identify potential hazards faster and more accurate than novices since they have already developed a more constructed mental model of hazardous situations and deeper knowledge in traffic context structure. The second factor, hazard type, is within-subject variable with two levels: overt and covert hazards. We expected to see both groups perform equally well on overt hazards, and experienced drivers would outperform novices in recognizing the more subtle covert hazards.

Lastly, we employed a 2 x 2 mixed design with the between-group factor of driving experience (novice, experienced) and the within-group factor of clip length (short and long). We predicted that experienced group would perform equally well on both length of clips and novice drivers would show a degradation in performance with longer clips.

*Procedure:* Participants were tested in a single session lasting 45 minutes approximately. Upon arrival the experimenter introduced the purpose of the study and the procedure of the entire experiment, and participants signed the informed consent
The practice trials of the Useful Field of View test (UFOV) followed right after the introduction to make sure participants fully understand how the test works. The UFOV test consists of three subtests, namely central identification/processing speed, divided attention, and selective attention task. The test was administered in around 15 minutes. The UFOV test was followed by the hazard perception task. Participants were instructed to pay attention on traffic situations that contain potential or developing dangers that require drivers to take action to avoid any conflicts. Afterwards, participants filled out the demographic questionnaire and received the debriefing of the study.

**Result**

Useful field of view test

A 2 x 3 mixed-measured ANOVA was conducted. The between-participants factor was experience (novice and experienced drivers) and the within-participants factor was useful field of view test (processing speed, divided attention and selective attention). A main effect of UFOV was found, $F(2, 84) = 17.03, p < .001, \eta^2_p = .289$. Neither the effect of experience nor the interaction between UFOV and experience reach the significance, indicating the two groups of drivers were on par in their perceptual thresholds of three subtests. Pairwise comparisons revealed that selective attention ($M = 65.57$ msec) subtest had significantly higher threshold than processing speed ($M = 25.04$ msec), $p < .001$, and divided attention ($M = 28.44$ msec), $p < .001$. See the upper half of Table 1 in Appendix A for the mean accuracy and standard deviation of the three subtest of UFOV among two groups of drivers (note Table 1 also contained participants’ performances on the hazard perception task).
Hazard perception task

In accordance with previous studies, we anticipated that the experienced drivers would outperform the novice drivers in the overall hazard perception performance. An independent $t$-test with two groups of participants on mean accuracy showed that there was a significant effect of experience, $t(42) = -2.46, p = .018$. See the lower half of Table 1 for the mean accuracy and standard deviation of the overall performance on hazard perception task among the novice group and the experienced group.

We then analysed the time-related variables, namely the time taken to the first view and the fixation durations. Adopted from Crundall et al. (2012) the time-related variables were expressed as a percentage of the time that the stimuli were available on screen in order to compare across different time courses (see the section Hazard perception task of Table 1). The independent $t$-test showed that the mean time the experienced drivers taken to the first view was significantly faster than the novices (63% v.s 71%), $t(42) = 2.13, p = .039$. Similarly, the independent $t$-test revealed a significant difference between two groups in the fixation durations, $t(42) = -2.06, p = .045$. During the hazards presenting the novice group spent 8.91% of time in average viewing the hazards while the experienced spent 11.68% of time. The further correlation analysis (see Table 2) revealed that the time taken to the first view was negatively correlated with the overall hazard perception performance ($r = -.89, p < .0001$), suggesting the faster an individual spotted the hazards the better hazard perception performance the individual had. On the contrary the time participants spent on viewing hazards was positively correlated with their overall performance ($r = .80, p < .0001$), indicating the longer they spent on viewing the higher accuracy they performed.

Furthermore, studies suggest that different hazard types might also have an impact on the accuracy of hazard detection (Crundall et al., 2012; Crundall, 2016); therefore,
we further examined whether the mean accuracy would differ as a function of hazard types. A 2 (driving experience: novice, experienced) x 2 (hazard type: overt, covert) mixed-measured ANOVA showed that that there was a significant main effect of experience, $F(1, 42) = 5.96, p = .019, \eta_p^2 = .124$, while neither the effect of hazard type nor the interaction between experience and hazard type was significant, $F(1, 42) = 3.34, p > .5$ and $F(1, 42) = .03, p > .8$, respectively. Judging from the overall performance, the experienced group outperformed their counterpart in detecting the overt hazards as well as the covert hazards (see the Hazard type in the section Hazard perception task of Table 1). Although the effect of hazard types failed to reach the statistical significance, the accuracy of two driver groups both degraded when facing more subtle on-road dangers. Both of the time taken to the first view and the fixation durations failed to show a main effect of hazard types, $Fs < 1$.

Lastly, we employed a 2 x 2 mixed-measured ANOVA with driving experience (novice and experienced) as between-participants variable and clip length (short and long) as within-participants variable. The main effect of clip length was significant, $F(1, 42) = 32.88, p < .001, \eta_p^2 = .439$, as well as the main effect of experience, $F(1, 42) = 6.04, p = .018, \eta_p^2 = .126$. The interaction between them was not significant, $F > .5$. See the Length of clip in the section Hazard perception task of Table 1 for the mean accuracy and standard deviation, the novice group was inferior to their experienced counterparts on the hazard perception performance on both the short length clips and the longer clips.

Relation between UFOV and hazard perception

To examine whether the three subtests of useful field of view test, namely processing speed (PS), divided attention (DA) and selective attention (SA), have any relations with the hazard perception performance of the two driver groups, we
conducted a correlation analysis among the three subtests with the overall hazard perception task accuracy, the accuracy of two hazard types and the accuracy of two clip lengths. The full set of correlation analyses applied to all three UFOV subtests and measures of hazard perception task are listed in Table 3. Note that the experienced drivers have all reached the minimum threshold in the processing speed subtest of UFOV therefore the variable was constant.

We first correlated the aforementioned variables regardless of experience. As can be clearly seen from Table 3 top panel, all the three subtests did not correlated with the remaining variables, all $p > .05$. We next examined the correlations among three subtests and measurements of hazard perception tasks for novice and experienced drivers respectively. For the novice group, the results were similar with those of two groups combined. We failed to find any correlations among three subtests and hazard perception performance, all $p > .05$. However, for the experienced drivers, the selective attention subtest was negatively correlated with the accuracy of short clip length ($r = -.44$, $p < .05$).

**Discussion**

The main goal set forth for the present study was to utilize the eye tracking device to assess whether the drivers of varying experience perform differently to the hazard perception task. Moreover we inspect the relation between attentional capabilities and the abilities to detect hazard by correlating the useful field of view test and hazard perception task. We predicted that the experienced drivers outperformed the novices in overall hazard perception performance, they were able to detect more subtle covert hazards than the novices and to immune from the length of clips, and that the hazard perception task might reveal a negative correlation with the measurements of useful field of view test.
Studies suggest that experienced drivers have developed a wider and deeper mental schema of traffic situation and thus have better knowledge of on-road potential dangers (Crundall, 2016; Chi, Feltovich, & Glaser, 1981). As expected, the results of overall hazard perception performance showed that the drivers with greater experience in driving were more likely to fixate potential hazards than the less experience drivers, which was in line with previous studies.

The more sensitive time-related analyses, i.e. the time taken to first view the hazards and the fixation durations, supported that there is a distinction between novice and experienced drivers in perceiving potential hazards as well. The deeper knowledge of on-road contextual structure allows the experienced drivers to better predict upcoming dangers and to spot the hazards faster than the novices; the results regarding the time taken to first fixate accord well with this concept. With regard to fixation durations, however, the present study failed to find the result of shorter fixation durations of the experienced drivers as previous studies reported (e.g., Mourant & Rockwell, 1972; Chapman & Underwood, 1998; Underwood, Crundall, & Chapman, 1998). On the contrary, we found that the experienced drivers produced significantly longer fixation durations than the novices, which was similar to the study of Crundall et al. (2012) where they reported that the experienced group gave more attention to the stimuli than the least experienced group. Besides, the mean fixation durations was positively correlated with the performance of the hazard perception task, indicating that the longer an individual spend on viewing the stimuli the better accuracy the individual may have. What does the opposite finding suggest? One possible explanation is the different response patterns of two groups of drivers toward various road types. The research of Crundall and Underwood (1998) suggested that inexperienced drivers seemed to increased fixation durations on more demanding road type while experienced drivers increased durations on less demanding of the roads.
The roadways used in the present study were mainly in suburban where the experienced drivers may find them less demanding and thus increase the time of viewing. If that is the case, the longer fixation durations are not necessarily represent the time needed to process the information. Nevertheless, the failure of the novices to perform equally well as the experienced drivers suggests that they are not capable of utilizing their relatively short fixation durations and they fail to extract sufficient information as efficiently as their experienced counterpart.

When we included hazard type as the within-participants factor in the analysis we failed to find the effect of hazard type and the interaction between experience and hazard types as Crundall et al. (2012) reported. However, both of the groups experienced a slight degradation in performance when detecting the more indirect covert hazards, suggesting the more obscure danger does have, to some degree, impact on hazard perception. In addition, the experienced drivers successfully detected more covert hazards than the novices, indicating the drivers do benefit from the increased experience which helps them construct a more sophisticated schema of traffic hazards.

Another aim of the present study was to examine how various levels of effortful traffic clips might affect drivers of different experiences. As suggested by Crundall (2016) that varying the length of hazardous clips is a more naturalistic manipulation to assess the usage of attentional resources, we edited the clips to be either short or long. The experienced drivers outperformed the novices in both lengths of clips; contrary to the findings of Crundall (2016) however, the novices were more likely to spot the hazards in the long length traffic clips instead of the shorter clips.

Despite of the similar manipulation of the length of clips, the paradigm used in the current study differs from the previous experiment (see Crundall (2016) experiment 1) in terms of the number of the hazards each clips contained and the way
of presenting the hazards. Crundall (2016) employed the methodology of using occluded hazard clips where the clip ends prior to the hazard. Limited to the methodology there was only one hazard per clips in the experiment. While in the current study the amount of hazards varied across each clips and the clips did not end prior to the hazards. One might imagine that the shorter length of clips reflex a less effortful demand because the attentional resources have not yet depleted; this is not the case in the present study however, the more hazards contained in the shorter length of clips induce more effortful attentional demands in which drivers have to encode the information from multiple sources and predict the likelihood of certain conflict happens based on myriad elements in the scene in a short period of time. On the other hand, the longer length of clips which contain same amount of hazards may not require as much resources as the shorter clips do.

In spite of the differences between the paradigms that used in the current study and that of the experiment done by Crundall (2016), we successfully discriminate the experienced drivers and the novices by manipulating the attentional demands. The findings of the study show that the past experiences did help the drivers perceiving the hazards in the more demanding short clips condition. The on-road hazards schema that constructed by years of driving experiences might facilitate the process of predictions so that the experienced drivers still managed to detect more than half of the hazards under high demanding condition. On the other hand, the novices detected only 44.8% of hazards in shorter clips and performed greatly inferior to their counterpart in the least demanding longer clips (see Table 1 bottommost panel). The degradation of accuracy of the novices between the short and long length of clips was not as acutely as that of the experienced drivers. Does that mean the novices are less susceptible to the effects of changes in demands? One possibility is that the relatively
small reduction may be due to a floor effect that they would detect 40-50% of hazards regardless of the demanding or less demanding hazardous conditions.

The relationship between hazard perception task and UFOV subtests indicated that, only selective attention subtest in the experienced drivers had a negative correlation with their hazard perception performance, especially with the performance in the short length of clips. The findings are, to some extent, in accordance with Wood et al. (2012) that, selective attention subtest of UFOV is the most predictive of driving performance under complex driving conditions. One could imagine the importance of the selective attention in hazard-detecting driving scenarios. The on-road visual complexity requires the drivers to be able to filter out non-dangerous and/or non-urgent information and focus on one that may develop to a hazard. The ability to distinguish dangers from non-dangers is cultivated by experiences, which the novices have not yet fully developed.

The correlation patterns are corresponding to the results of the short length clips. As we discussed, the same amount of hazards contained in a shorter length of clip requires drivers to accelerate the process of identifications and predictions, and the lower perceptual threshold of selective attention subtest represents the higher sensitivity to distinguish peripheral target from embedded distracters. These results demonstrate that the experienced drivers are able to quickly select relevant information (i.e., the hazards in hazard perception task and the target in UFOV test) and inhibit irrelevant distracters (i.e., the non-dangerous elements in hazard perception task and the embedded distracters in UFOV test) in a short period of time. On the other hand, even though the novices did have a slightly higher perceptual threshold than the experienced, the result that the correlation only happened in the experienced group supports the concept that the novices had encountered a floor
effect where they were not able to utilize their abilities to distinguish a target from the
distracters in real-life driving scenarios.

The correlations are slightly different from the results of Allahyari et al. (2007). They reported that it was the divided attention subtest that had a negative correlation with driving performance. However they have not looked specifically at the ability to detect on-road hazards. The driving components they focused on were speed, using indicator and stop before junction and so on which did not assess participants’ ability to actively select relevant and ignore irrelevant elements. As Wood et al. (2012) stated, divided attention may be the better predictor for the inability to see and react in complex situations like encountering intersections.

In conclusion, the results of our study demonstrated that the discrepancy of hazard perception performance between experienced and novice drivers are related to their visual behaviours (i.e. the time taken to first view the hazards and the fixation durations). As previous studies suggested, the hazard templates that stored in the experienced drivers’ long term memory did help them process and predict dangers more efficient than the novices. Yet the result of fixation durations differ from the common expectation. Based on the evidence that drivers of varying experience tend to have different response patterns toward various road types (Crundall & Underwood, 1998), we suspect the overall roadways used in the current study may be a possibility of this finding. Although the difference between overt and covert hazards did not reach statistical significance, the overall performance pattern revealed that the covert hazards were harder than the overt hazards and the novices were inferior to the experienced drivers.

Furthermore, due to the different experiment design we found an opposite result from Crundall (2016) that, in the current study the shorter clips were in fact more effortful than the longer clips. The correlation only occurred in the experienced group
between selective attention and the performance of short length clips might suggest
the sensitivity to distinguish a target from the distracters is crucial under complex and
high demanding scenarios, and yet the novices have not fully equipped the ability to
transfer this kind of sensitivity to real-life situation.
References


Appendix A.

Table 1. The mean and SD (in parentheses) in the three subtests of UFOV (processing speed, divide attention and selective attention) and each of the measurements of hazard perception task among experienced (N = 22) and novice (N = 22) drivers.

<table>
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<tr>
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<th>Experienced</th>
<th>Novice</th>
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<tr>
<td><strong>UFOV</strong></td>
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<tr>
<td>Processing speed</td>
<td>16.70 (.00)</td>
<td>33.37 (78.20)</td>
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<tr>
<td>Divided attention</td>
<td>24.26 (18.07)</td>
<td>32.62 (40.46)</td>
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<tr>
<td>Selective attention</td>
<td>64.27 (34.98)</td>
<td>66.87 (33.32)</td>
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<td><strong>Hazard perception task</strong></td>
<td></td>
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<tr>
<td>Overall</td>
<td>63.33 (12.12)</td>
<td>51.52 (18.99)</td>
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<tr>
<td>Time taken to first view</td>
<td>63.27 (10.61)</td>
<td>70.77 (12.70)</td>
</tr>
<tr>
<td>Fixatio durations</td>
<td>11.66 (4.22)</td>
<td>8.85 (4.80)</td>
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<tr>
<td><strong>Hazard type</strong></td>
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<tr>
<td>Overt hazard</td>
<td>64.77 (17.09)</td>
<td>52.27 (22.37)</td>
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<tr>
<td>Covert hazard</td>
<td>61.69 (19.41)</td>
<td>50.65 (24.04)</td>
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<tr>
<td><strong>Length of clip</strong></td>
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<td>Short clip</td>
<td>54.55 (10.47)</td>
<td>44.81 (19.86)</td>
</tr>
<tr>
<td>Long clip</td>
<td>71.02 (16.99)</td>
<td>57.39 (22.05)</td>
</tr>
</tbody>
</table>
Table 2.
Correlation among overall performance on hazard perception tasks and measures of visual behaviour.

<table>
<thead>
<tr>
<th>Overall performance</th>
<th>Time taken to first view</th>
<th>Fixation durations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall performance</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Time taken to first view</td>
<td>-.89**</td>
<td>1</td>
</tr>
<tr>
<td>Fixation durations</td>
<td>.80**</td>
<td>-.73**</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01
Table 3.
Correlation among three subtests of UFOV and measures of hazard perception task for all participants (top), experienced ($N = 22$) (middle) and novice ($N = 22$) (bottom) drivers.

<table>
<thead>
<tr>
<th>Hazard perception task</th>
<th>UFOV</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Processing speed</td>
<td>Divided attention</td>
<td>Selective attention</td>
</tr>
<tr>
<td>ALL participants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall performance</td>
<td>-.10</td>
<td>-.20</td>
<td>-.20</td>
</tr>
<tr>
<td>Overt hazard</td>
<td>-.06</td>
<td>-.11</td>
<td>-.23</td>
</tr>
<tr>
<td>Cover hazard</td>
<td>-.09</td>
<td>-.21</td>
<td>-.09</td>
</tr>
<tr>
<td>Short clip</td>
<td>.07</td>
<td>-.05</td>
<td>-.17</td>
</tr>
<tr>
<td>Long clip</td>
<td>-.20</td>
<td>-.28</td>
<td>-.20</td>
</tr>
<tr>
<td>Experienced drivers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall performance</td>
<td>.a</td>
<td>-.31</td>
<td>-.37</td>
</tr>
<tr>
<td>Overt hazard</td>
<td>.a</td>
<td>-.07</td>
<td>-.40</td>
</tr>
<tr>
<td>Cover hazard</td>
<td>.a</td>
<td>-.35</td>
<td>-.10</td>
</tr>
<tr>
<td>Short clip</td>
<td>.a</td>
<td>-.25</td>
<td>-.44*</td>
</tr>
<tr>
<td>Long clip</td>
<td>.a</td>
<td>-.28</td>
<td>-.26</td>
</tr>
<tr>
<td>Novice drivers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall performance</td>
<td>-.06</td>
<td>-.13</td>
<td>-.10</td>
</tr>
<tr>
<td>Overt hazard</td>
<td>-.02</td>
<td>-.08</td>
<td>-.10</td>
</tr>
<tr>
<td>Cover hazard</td>
<td>-.07</td>
<td>-.14</td>
<td>-.07</td>
</tr>
<tr>
<td>Short clip</td>
<td>.14</td>
<td>.04</td>
<td>-.03</td>
</tr>
<tr>
<td>Long clip</td>
<td>-.20</td>
<td>-.25</td>
<td>-.15</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01

a. Experienced drivers have all reached the minimum threshold of the subtest *processing speed* therefore the variable is constant
Appendix B.

The hazards used in current study.

1. A car on the right with its lights on

2. A reversing car
3. Space behind a parked van with flashing turn signal

4. Parked yellow van with its lights on
5. Cyclist crossing

6. Pedestrian crossing
7. Pedestrian with dog crossing

8. Man getting in car
9. Cyclist crossing

10. Cyclist’s leg
11. Space behind car on sidewalk

12. Child running across
13. Child standing between cars

14. Car reversing
15. Man crossing