The effect of Leftward Bias on Visual Attention for Driving Tasks

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Abstract
The leftward bias of driving visual attention has been found to explain the role of driving experience in the visual attention strategy; even though the results reported in the literature are not always consistent. This study aims to explore the driving attention characteristics and the eye movement patterns by using a simulated driving experiment in conjunction with an eye-tracker device. 31 young inexperienced drivers (undergraduate students, average age 21) and 30 old experienced drivers (taxi drivers, average age 36) took part in the experiment. Results show that the eye movement patterns of the drivers have certain similarity in the occurrence of subtle asymmetries of visual attention favouring left space (the direction of the driving in the experiment was right-side) and that they are related to the right hemisphere specialization for spatial attention. However, in the more experienced drivers the leftward eye movement tends to shift toward the centre or even rightward to pay attention to the hazard events on road. These results suggest that inexperienced drivers are initially aroused by natural biological leftward visual attention and likely to develop central and rightward eye movement strategy for safety diving purpose. The implications of this study suggest that, despite the existence of natural visual attention bias, the left asymmetries in visual scan in inexperienced drivers still can be modified by driving trainings that focus on the hazard situation on road.

Keywords: leftward visual bias, eye movement, driving visual attention, simulator, eye tracker

1. Introduction
The term “pseudoneglect”, usually defined as ‘bias of spatial attention’, refers to the subtle bias of visual attention in healthy individuals who show a tendency to favour the left side of space, making leftward errors in line bisections and starting visual search slightly from the left of their true centre. This concept was first proposed by Bowers and Heilman in 1980 and its existence was confirmed over the last 30 years by empirical research on the perspectives of individual behaviour, eye movement, cranial nerves, and brain structure (Benwell, Harvey & Thut, 2014; Cicek, Deouell & Knight, 2009; Newman, O'Connell & Bellgrove, 2013; Sacchetti, Goedert, Foundas & Barrett, 2015). A summary of the main cognitive factors (such as cognitive load, cognitive task, and task time) and exogenous factors (such as properties of stimulus materials and visuospatial properties) that influence the pseudoneglect can be found in the literature review carried out by Jewell & McCourt (2000), Zheng, Yang & Easa (2015), Nicholls, Hobson, Petty, Churches & Thoms (2017). The main findings from this literature is that a slightly left-attention bias exists regardless of the nature of the task performed and regardless of which hand is dominant. However, these studies also note that using the left hand to respond to stimuli may
significantly increase the degree of pseudoneglect compared to using the right hand. The effect on visual bias is stronger in presence of higher cognitive loads, and the cognitive load in turn has an effect on the pseudoneglect. Moreover, inexperienced drivers tend to show higher level of cognitive load than experienced drivers do, because their limited driving experience may be less likely to generate the confidence needed to drive safely. Many researchers discovered that inexperienced drivers have higher risk of having accidents than experienced drivers, due to lack of hazard perception (Chapman & Underwood, 1998; Neyens & Boyle, 2008). This suggests that inexperienced drivers need more processing time to capture hazard scenes on the roads, while experienced drivers are able to perceive the hazard immediately.

Over the past 50 year, pseudoneglect has been investigated within several research paradigms, such as line bisection tasks, chimeric-faces stimuli, judgements of brightness, numerosity and size, and navigation tasks (Jewell & McCourt, 2000). All these paradigms are consistent with the fact that exploratory visual scanning behaviour typically starts from the left side more than the right side or the center. The specific neural structure and the mechanism of the pseudoneglect are unknown yet. However, the activation-orientation hypothesis has contributed to the explanation of pseudoneglect, suggesting that asymmetries in hemispheric activation, namely a right hemisphere dominance, are associated with an unbalanced speed of visuospatial processing and with more attention to the contralateral left hemi space (de Schotten et al, 2011).

In recent years, studies on traffic safety psychology showed that traffic accidents are mainly caused by drivers’ space-based attention. The analysis of traffic accidents revealed that 93%–94% of the accidents are caused by human factors (Stanton, Young & Walker, 2007; Parnell, Stanton & Plant, 2018) and, among these, 12%–25% are caused by drivers’ spatial attention bias (Lee, 2008). These human factors, leading to traffic accidents, mainly result from failure to pay sufficient attention to traffic information, such as movement of pedestrians, non-motor vehicles, and traffic street signs. Moreover, since drivers tend to pay more attention to the left side than the right side, analyses conducted on traffic collision (Divekar, Pradhan, Masserang, et al, 2013; Hatin, Tottenham & Oriet, 2012) show that there is a higher probability of rightward than leftward collision. This phenomenon is known as leftward bias of visual attention in driving (Benedetto, Pedrotti, Bremond, et al, 2013).

In the field of transport research, eye-movement measurement is one of the major techniques adopted to understand the mechanisms of leftward bias of spatial attention in driver’s visual scan. To the best of our knowledge, there have been mainly two schools dedicated to study drivers’ eyes movement. The first school is in the field of traffic safety (Konstantopoulos, Chapman, & Crundall, 2010) and focuses on the visual attention of driving using either simulated experiments (i.e. with driving simulators) or real-world driving experiments. In the past research history, several important conclusions have been reached. First, in terms of Azimuth (horizontal scans), inexperienced drivers have a narrower visual field compared to experienced drivers (Underwood, Chapman, Brocklehurst, Underwood & Crundall, 2002, 2003; Crundall, Chapman, Trawley, et al, 2012). Second, inexperienced drivers tend to visually scan only a near space outside the driving cabinet while experienced drivers scan a wider space (Divekar, Pradhan, Masserange, et al, 2013). Third, inexperienced drivers are likely to have biased visual attention, favouring inside driving cabinet compared to experienced drivers who more likely favour outside driving cabinet. Fourth, researchers have also found differences in left and right bias of spatial attention among drivers with different driving experiences. Specifically, researchers found that young inexperienced drivers prefer to repeat scanning from centre to far left, while young experienced drivers prefer to repeat scanning from middle right to middle left and back to middle right spaces with wider
scanning range and longer scanning time. A number of studies pointed out that young inexperienced drivers tend to have a bias in the middle-left space of the vision search; but after gaining more driving experiences, they develop a proper safe driving vision-searching pattern (Charlton & Starkey, 2011) and the leftward bias appears mitigated (Scott, Hall, Litchfield, & Westwood, 2013). The second school (Lust, Geuze, Groothuis, et al, 2011; Longo, Trippier, Vagnoni, Lourenco, 2014) is in the field of cognitive psychology, which has mainly explored the behaviour of visual attention and its neural basis with the purpose to verify whether attention theories such as inhibition and spatial attention can be adopted to explain driving behaviours. These researches have used various methods and techniques, such as ERP (Event-Related Potential) and fMRI (Functional Magnetic Resonance Imaging). Cognitive psychologists have studied the bias of spatial attention for more than 30 years, and they have found that the visuospatial bias is associated with physiological neural basis: the lateralization of brain functions (Loughnane, Shanley, Lalor, & O'Connell, 2015). Note that the bias of spatial attention is a form of endogenous allocation of spatial attention (a top-down cognitive process), and is influenced by functional lateralization of the brain. However, like other forms of attention, visuospatial attention is easily affected by cognitive or other exogenous factors (tasks, complexity of situation, etc.). Recently, cognitive psychologists (e.g. Benedetto et al., 2013) have studied attentional leftward bias in a driving context with a simulated driving task (Lane Change Test–LCT) in spatial symmetry conditions. The LCT required driving along a straight traffic-free three-lane road and changing lanes according to the information provided by two identical road signs displayed concurrently on both left and right sides of the road. Results revealed that drivers were more aware of the left-hand traffic signs and in this case completed the lane-changing task quickly. Results showed also that 90% of the gaze points of the eye movement fell on the left signs, and only 10% on the right signs. Later on, drivers were asked to perform two tasks simultaneously: changing the driving lane and performing simple cognitive tasks with the right hand. The simple task required participants to locate a target among distractors, and then to double-click as fast as possible, with the right hand, the portion of screen where the target (larger circle) was located among several distractors (smaller circles). This simple task had to be performed continuously: every manual response was followed by the appearance of a new stimulus on the screen. The results showed that the percentage of gaze points falling to the left dropped to 67%, and those falling to the right raised to 33%, illustrating that the leftward bias is attenuated by introducing a secondary simple cognitive task.

A study from Kennedy and Bliss (2013) showed an opposite result. They conducted a driving simulator test with undergraduate students as drivers. One of the driving tasks consisted in following GPS instructions to turn left while a “no-left-turn” sign was placed on the left side of the road. The results showed that 79.5% of the drivers followed the GPS to turn left and overlooked the sign on the left. The authors concluded that leftward bias of visual attention could not explain why the signs were overlooked, and they believed that this was caused by “inattentional blindness”. However, looking at the GPS is not equivalent to performing other cognitive tasks. It is in fact a particular task that can be considered as “substituting” the signs on the road. In this sense, even if the main task of the drivers in this experiment was to search the signs on the road and follow the transport rules and the second task to follow the GPS, it is possible that respondents used the GPS as a substitute for the road signs, which would explain the opposite results compared to previous studies.

The above review seems to show that high levels of cognitive load and driving experience force drivers to attenuate the leftward bias of spatial attention. In addition, there seems to be also a
near-space attention bias (Aimola, Schindler, Simone, & Venneri, 2012). Drivers’ attention tend to lean toward near space with the increase of road condition complexity; but it shifts to a farer space in case of experienced drivers when the habitual vision search pattern is formed by bottom-up attention. It should be noted that the study from Kennedy and Bliss (2013) failed to show the leftward bias of spatial attention and that few experiments have provided solid evidence with detailed explanations to support the above observations. Thus, this paper aims to verify the above research hypothesis by performing the simulated driving experiment in the lab with the specific aim of exploring the effect of drivers’ experience on the visuospatial attention. The hypothesis in this research is that the visual scan pattern, in terms of eye movement measures, such as eye fixation, pupil size, and visual angle, depends on the degree of driving experience. More specifically, the hypothesis is that inexperienced drivers are more leftward visually biased than experienced drivers. As it is known, the driving simulator uses a controlled cause-effect design; it represents then the most suitable environment to test if the visual leftward bias is primarily relevant to the driving experience. At the same time, even though the simulator is able to reproduce realistically driving conditions, the difference in the naturalistic intensity of the stimuli can induce lower brain activation than in the real context, resulting in users using different neural mechanisms in their driving behaviour (Camerer & Mobbs, 2017). Finally, the driving simulator represents also a safe environment for the drivers who participate in the study, which makes it suitable for inexperienced drivers.

2. Experimental descriptions

2.1 Participants

A total of 62 male drivers participated in the simulated driving experiment, of which 31 were young inexperienced drivers and 31 adult experienced drivers. The sample of inexperienced drivers was formed by undergraduate students 18-22 years old (average age 21, ± 1.02), holding the driving licence only for one year. The sample of experienced drivers was formed by taxi drivers 32-52 years old (average age of 36, ± 5.01) and holding the driving license for an average of 16 years (± 6.07). The two groups are statistically different in age and driving experience at 0.01 level of significance. One experienced driver quit, due to vertigo caused by the driving screen. The experiment was completed by all the remaining 61 drivers.

All participants received a small payment of 100 Chinese currency (equivalent to 16USD) after completion of the experiment.

2.2 Experiment condition and implementation process

Respondents were asked to drive in a driving simulator for half an hour. A non-contact infrared eye tracker named FaceLab manufactured by Australian Group “Seeing Machines” was used to track the eyes movement of the participants. This eye tracker is widely used to measure the eye movement in driving research. It is based on two separate cameras with emitters that can take different positions in order to fit the research environmental conditions. The accuracy of the gaze orientation used in our study was set at 0.5 degrees. This eye tracker does not require participants to wear helmets or eyeglasses, which makes the experiment more realistic. However, it takes half an hour to calibrate each participant’s eye pupil, as required by the eye-tracker compulsory procedure. The eye tracker registers gaze points, gaze duration (unit: ms), and pupil diameters of both (left and right) eyes (unit: mm). Since driving is a continuous action, our study uses “unit gaze points” (gaze points per second) and “unit gaze duration” (gaze duration per second) to describe the eye movement.
The driving simulator was equipped with “DSR-1000TS Driving Simulation Platform”, which is a virtual simulation product designed specifically for the comprehensive research in the field of “human-vehicle-road-environment”. The platform is able to provide real-world driving experience and can be used for close-loop design of traffic systems under lab-controlled conditions (Figure 1).

![Figure1: The schematic representation of the simulator experiment.](image)

The simulated road section used in our experiment is a double-lane 28 km long street with speed limit of 60 km/hr, from Baizhongliyang to Chiyuanpanting, Minqing County in the city of Fuzhou in the Fujian Province in China. Road scenes were generated directly from the design file and roadside landscape was added later, complying with Chinese national codes [JTG B01-2014]. Compared to real roads, the simulated road is better in terms of surface condition, traffic signs, ground marks and basic traffic conditions. Finally, to avoid confounding factors in the experiment, the frequency of the oncoming vehicles in the simulator was set at the lowest default level implemented in the driving simulator. Before the main driving experiment, all participants were given about 5-minute to familiarize themselves with the driving simulator. After that, they were instructed to drive for half an hour along the simulated road with the traffic signs. Figure 1 reports an example of the driver simulator setting used in our experiment. The distance between the driver and the simulated screen was set at about 0.8 meters, which is the standard setting, meaning that the driver should be able to drive as she usually does in the real world.

2.3 Data processing

The EyeWorks analysis software (provided as part of the FaceLab eye tracking) was used to analyse the data collected with the driving simulator experiment. The drivers’ visual field was divided into left, middle, and right zones, called Area of Interest (AOI). The left zone covers an area from the vision left to the middle line that includes 2% of the image; the right zone covers an area from the vision right to the middle line that includes 2% of the image (Foulsham, Gray, Nasiopoulos & Kingstone, 2013). Since the visual field in the real environment is wider than in the simulated experiment, in terms of eye measures there are more missing data in the real world than in the driving simulator.

The data were analysed as follows: we first looked at the gaze points, gaze duration and pupil diameter, which allow analysing the differences in the basic visual scan pattern as a function of the driver’s skills. We then looked at the driving Azimuth and elevation Horizontal and Perpendicular Visual Angles, which allow comparing driving related visual scan patterns. We used
paired-samples t-tests to test for differences between AOIs. We used independent-samples t-tests to test for differences between driving experience. All eye-movement data were collected using the eye tracker during experiment with the driving simulator.

We defined “one gaze point” when the gaze duration held for 80 millisecond or above, meaning that the cognitive processing in visual task requires a minimum time of 80 millisecond. The gaze duration is the total time of gaze in the area of interest (AOI) in both the left view zone and the right view zone. Therefore, gaze points and gaze duration have a different meaning and allow different analyses of the cognitive loads of the mental process and the mental effort. The pupil diameter is affected by many factors such as emotions, attention, target detection, decision making and others (Zenon, Sidibe, Olivier, 2014), but the level of cognitive load when processing information is arguably the most widely recognized cognitive factor influencing pupil size (Verney, Garnholm, Marshall, 2004). A large pupil dilation reflects high processing information load or mental effort. In general, the pupil diameter is the same in both eyes (right and left). However, the mean pupil diameter of the dominant eyes is slightly smaller than that of the non-dominant eyes. In the majority of the population, the right eye is the dominant one.

3. Results
3.1 Gaze Point, Gaze Duration and Pupil Diameter

Table 1 shows the difference in the eye movement parameters (gaze point, gaze duration, right-eye pupil diameter and left-eye pupil diameter) between left and right zones for both experienced and inexperienced drivers while using the driving simulator.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Eye Movement Parameter</th>
<th>AOI Parameter (M±SD)</th>
<th>Paired sample T-Test</th>
<th>P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Left zone</td>
<td>Right zone</td>
<td></td>
</tr>
<tr>
<td>Experienced</td>
<td>Unit Gaze Point</td>
<td>2.0944±1.68076</td>
<td>0.00186±0.00106</td>
<td>6.466</td>
</tr>
<tr>
<td>Drivers</td>
<td>Unit Gaze Duration</td>
<td>0.0043±0.00056</td>
<td>0.00421±0.00051</td>
<td>1.923</td>
</tr>
<tr>
<td></td>
<td>Right-Eye Pupil Diameter</td>
<td>0.0038±0.00044</td>
<td>0.00378±0.00126</td>
<td>0.367</td>
</tr>
<tr>
<td></td>
<td>Left-Eye Pupil Diameter</td>
<td>0.0038±0.00039</td>
<td>0.00350±0.00136</td>
<td>1.295</td>
</tr>
<tr>
<td>Inexperienced</td>
<td>Unit Gaze Point</td>
<td>2.0953±1.62817</td>
<td>0.0236±0.042202</td>
<td>6.806</td>
</tr>
<tr>
<td>Drivers</td>
<td>Unit Gaze Duration</td>
<td>0.0124±0.00092</td>
<td>0.00032±0.00025</td>
<td>5.408</td>
</tr>
<tr>
<td></td>
<td>Right-Eye Pupil Diameter</td>
<td>0.0043±0.00055</td>
<td>0.00434±0.00062</td>
<td>-0.327</td>
</tr>
<tr>
<td></td>
<td>Left-Eye Pupil Diameter</td>
<td>0.0042±0.00048</td>
<td>0.00417±0.00053</td>
<td>1.201</td>
</tr>
</tbody>
</table>

*P* is the probability to reject the hypothesis H₀ that the two population means are equal.

Table 1 shows that for the inexperienced drivers the unit gazing points and the unit gaze duration are significantly bigger in the left AOI (0.0124 VS 0.00032) than in the right AOI. For experienced drivers, instead, the unit gazing points is significantly bigger in the left AOI (2.094 VS 0.00187) than in the right AOI, while the difference in the unit gaze duration between left and right AOI is not statistically significant. In addition, there is no significant difference between left and right AOI for pupil diameters for both groups of drivers.

Table 2 reports the same parameters as in Table 1, but it compares experienced and inexperienced drivers, allowing testing if these two groups are significantly different.
Table 2 Differences in the Eye movement parameters between experienced and inexperienced drivers

<table>
<thead>
<tr>
<th>Eye Movement Parameter</th>
<th>Parameter Level (M±SD)</th>
<th>T-Test</th>
<th>Effect Size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experienced Drivers</td>
<td>Inexperienced Drivers</td>
<td></td>
</tr>
<tr>
<td>Unit Gaze Point</td>
<td>2.1271±1.5528</td>
<td>2.1453±1.6712</td>
<td>0.068</td>
</tr>
<tr>
<td>Unit Gaze Duration</td>
<td>0.00187±0.00106</td>
<td>0.00183±0.00106</td>
<td>0.039</td>
</tr>
<tr>
<td>Right-Eye Pupil Diameter</td>
<td>0.00372±0.00080</td>
<td>0.00433±0.00055</td>
<td>3.312**</td>
</tr>
<tr>
<td>Left-Eye Pupil Diameter</td>
<td>0.00368±0.000763</td>
<td>0.00420±0.00050</td>
<td>3.211**</td>
</tr>
</tbody>
</table>

**P<0.01

Table 2 shows that there is no significant difference in the unit gaze points and unit gaze duration between experienced and inexperienced drivers. However, the left and right pupil diameters of inexperienced drivers are significantly greater than that of experienced drivers. The eye movement heat-map and trajectory are illustrated in Figure 2. As it can be seen, the gaze pattern is different between experienced and inexperienced drivers. The former tend to focus ahead of the road and have less eye-tracing path, while the latter tend to scan a larger portion of the road and have messy eye tracing paths, suggesting that inexperienced drivers have less eye searching skills when driving in the simulator. It seems that inexperienced drivers did not know where and what to look at. Their visual pattern is not relevant for the driving itself, but it indicates the natural visual scanning patter that goes from left side to right site.

![Figure 2. Eye Movement Heatmap and Trajectory of Experienced and Inexperienced Drivers](image)

3.2 Driving Horizontal Visual Angle and Perpendicular Visual Angle

The horizontal (α) and perpendicular (β) visual angles from the test were used to analyse the drivers’ eye movement. As sketched in Figure 3, these two parameters describe the maximum angle formed by the eyeball with respect to the head (assumed still) when moving horizontally and perpendicularly to watch objects. The visual angle location of the gaze points indicates the direction of the space-based attention of the test subject with the progress of the experiment.
The range of the horizontal and perpendicular visual angle of the drivers during the simulation experiment is summarized in Table 3.

Table 3 Range of the Visual Angle from Simulation Driving of Experienced and Inexperienced Drivers

<table>
<thead>
<tr>
<th></th>
<th>Inexperienced Drivers</th>
<th>Experienced Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Angle (α)</td>
<td>-53.61567°~ 45.62543°</td>
<td>-66.83532°~ 48.29438°</td>
</tr>
<tr>
<td>Perpendicular Angle (β)</td>
<td>-68.47361°~ 60.25797°</td>
<td>-70.83477°~ 61.83532°</td>
</tr>
</tbody>
</table>

As it can be seen from the table above, the range of the visual angle of the experienced drivers is larger than that of the inexperienced drivers, both horizontally and perpendicularly. This study focuses in particular on the range between ±60° because we analysed the accumulated time percentage of the range of the visual angle and we found that over 99% of all participants’ visual angles on both planes were within this range.

Figure 4 shows that the horizontal visual angles are mostly between -30° and 30° for both groups of drivers. For the experienced drivers, the range of the visual angle of the right visual
field is bigger than that of the left (64%:35%, Chi-square test=48.32, P <0.05), and it is also bigger than the range of the right vision of the inexperienced drivers (64%:41%, Chi-square test = 37.7, P<0.05). For the inexperienced drivers, instead, the range of the visual angle of the left vision is bigger than that of the right vision (58%:41%, Chi-square test=36.72, P<0.05), and it is also bigger than the range of the left vision of the experienced drivers (58%:35%, Chi-square test=35.32, P<0.05). Moreover, the left side of the driving vision is larger in the inexperienced drivers than in the experienced drivers (58.5%:35.5%, Chi-square test=35.32, P<0.05), while the experienced drivers paid more attention than the inexperienced drivers on the right side of the driving vision (64.3%: 41.3%, Chi-square=37.83, P<0.05). We note that the negative numbers represent the left area of the driving vision, i.e. the part above the horizontal plane, while the positive numbers represent the right area of the driving vision, i.e. the part below the horizontal plane.

Figure 5 shows the ranges of the perpendicular visual angle that, as for the horizontal angles, are mostly in the range ± 30°.

![Figure 5. Perpendicular Angle Range of Experienced and Inexperienced Drivers](image)

Figure 5 shows that the perpendicular visual angles are mainly focused around the horizontal midline, slightly below the horizon. Inexperienced drivers pay more attention to the lower area (79.6%:69.4%, Chi-square test=23.37, P<0.05), while experienced drivers pay relatively more attention to the higher area, which means that they prefer looking further and high (13.57%:29.41%, Chi square test=24.02, P<0.05).

4. Discussion

This study was designed to explore the possible differences in the visual scan pattern between experienced and inexperienced drivers by using driving simulator and eye-tracker. According to the results of the driving simulator experiment, we can conclude that both groups of experienced and inexperienced drivers pay more attention to the left area than the right area. The possible explanation for such results is related to theory of “pseudoneglect” and reflects an underlying desire to engage the right hemisphere by viewing more of the stimulus in the left visual field and less error detection than in the right visual field (Nicholls et al, 2017). Moreover, previous

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1 We note that the Chi-square statistics is particularly high, probably because the frequency of timing in the different angle is accumulated across all participants. However, the raw frequency, which is often used instead of the Chi-square (e.g. Kennedy and Bliss, 2013), is in line with previous works.
research have supported the argument that “pseudoneglect” for visual scan is driven, at least part of it, by a biological mechanism related to cerebral asymmetry and cannot be solely attributed to a cultural mechanism related to reading habits and scanning eye movements (Rinaldi, Luca, & Girelli, 2014). What is more interesting is that for experienced drivers there is no significant difference in gaze duration between left and right search areas, while for inexperienced drivers, the visual attention search time on the left area is longer than on the right area. This result suggests that there might be different cognitive strategies between experienced and inexperienced drivers on visual attention search. More specifically, the experienced drivers are likely to have more driving-relevant visual scan strategy, equally dividing the visual attention to both sides of the visual area for driving safety. On the other hand, inexperienced drivers tend to have an asymmetric visual bias with visual attention more on the left side. Such result is consistent with previous studies (e.g. Benedetto, et al. 2013) suggesting that drivers direct most of the attention to the left side unconsciously or naturally. It is interesting to note that our experiment was carried out in China where drivers seat on the left, while Benedetto et al. experiment was carried out in France where drivers seat on the right. Similar results regarding the position of the driving seat i.e. left or right, stressed that drivers’ visual scan pattern obeys to the natural leftward bias, and it might be shifted to the centre and right side of the visual view as the cognitive mental load decreases. Experienced drivers are considered to have lower cognitive mental load than inexperienced drivers.

In line with this behaviour, our results also show that the pupil diameter of both eyes of the experienced drivers is significantly smaller than that of the inexperienced drivers, which confirms that inexperienced drivers had more cognitive loads (i.e. they needed more mental effort to drive safely) than experienced drivers. One possible explanation for this finding is that inexperienced drivers with lower driving skills actively and routinely process driving stimuli before assessing if the information is irrelevant. Thus, the smaller pupil diameter in the experienced drivers with higher driving ability may reflect faster automatic driving behaviour with lower mental load, while the larger pupil diameter in the inexperienced drivers with lower driving skills may reflect a failure in automatic driving behaviour with heavier mental load involved. This result is in line with the theory of processing information, according to which larger pupil diameters reflect greater mental loads. A study by Verney, Granholm and Marshall, (2004) demonstrated that smaller pupillary response in individuals with higher cognitive abilities might reflect greater or faster automation of tasks detection.

Regarding the gaze parameters, we found that inexperienced drivers show more attention to the left area, according to the gaze points and the gaze duration time. By using these two parameters of gaze, we found that our results could be the reflection of the characteristics of “pseudoneglect” attention at certain levels. The literature on “pseudoneglect” space-based attention shows that this phenomenon is of traits of endogenous attention, and when an individual initiates original space-based attention, a slight preference to the left side is shown, which is caused by the fact that the right brain sphere dominates the space-based attention, an effect termed lateralization of brain function (Szczepanski & Kastner, 2013). From the gaze results of the experienced drivers, we found that only gaze points showed obvious difference between the left and the right area, while there is no difference on gaze duration time between the two areas. This result shows that experienced drivers’ attention-scanning strategy is likely to consist in broadly scanning the road information for safe driving. Results show also that the experienced drivers, as expected, have developed much better visual attention strategy for safety purpose than inexperienced drivers. Such results are similar to what found in previous studies (Jang, Ku, Na,

The third major eye parameter is the visual angle. Our results show that the horizontal and perpendicular visual angles of the experienced drivers are much wider than that of the inexperienced drivers. This result shows that there is an obvious difference in the attention-scanning ranges between experienced drivers, who have an established strategic driving visual attention with wider visual scan both horizontally and perpendicularly, and inexperienced drivers, who do not have developed yet a driving visual attention strategy and tend to have a narrower visual scan. These results are consistent with those in previous studies. For example, a study conducted by Konstantopoulos, Chapman et al. (2010) recorded eye movements of driving instructors and driving learners while driving in three virtual routes in a driving simulator. Their results showed that driving instructors had shorter processing time and broader scanning of the road than driving learners. Another study (Underwood, Chapman, Bowden, & Crundall, 2002) found that novice drivers had longer gaze to the hazard situation than experienced drivers, indicating that novice drivers have not developed the experience needed to recognise quickly hazard situations and to process them to take a decision. They need more time to see the hazard and have longer fixation times of the objects.

5. Conclusion

In the experiment presented in this paper, we found that experienced and inexperienced drivers are likely to pay left-space attention while driving in a simulator. However, experienced drivers have a wider attention range, and require lower cognitive processing level than inexperienced drivers. The horizontal visual angle is wider on the right side for experienced drivers and wider on the left side for inexperienced drivers. On the perpendicular direction, experienced drivers pay more attention to middle and far visions, while inexperienced drivers scan closer and narrower. These results show that pseudoneglect will present itself differently for different vision distances.

In conclusion, left bias of spatial attention does exist, but the left-shifting visual attention will gradually change to right side as the driving experience increases. In addition, experienced drivers have a wider range of visual attention than inexperienced drivers do. These results seem to suggest that future interventions aimed at training driver’s visual attention strategies should therefore include sections where participants practice applying an evenly distributed search across all the visual areas and should include tasks designed to develop the visual scan skills. To be concrete, young inexperienced drivers have initially left-shifting space-based attention, but through eye movement training, the range of their vision angle can be enlarged to improve the space-scanning ability for safe driving. However, data on driving performance of inexperienced drivers as related to the gaze behaviour are needed to confirm these recommendations. Future work is also needed to integrate training of visual scan strategies into novice driver training interventions. We carried out some small sample tests to study the effect of different driving conditions on real roads and found that the higher the complexity of the road, the bigger the driver’s mental load, leading to less left-bias visualization. Our pilot study suggests that the left-spatial visualization might be initially rooted in the biological base and it can be subject to adjustments. Future research is needed in this area.

The current study has some limitations. First, the drivers were not selected according to their eye dominance. Even though the majority of the population is right eye dominant, we cannot assume that everybody is like that. This may cause slightly bias in the eye movement
measurement. Second, all participants involved in the study were male. It is expected to recruit female in future research involving driving experiment. Third, the study is expected to consider driving behaviour performance such as brake depth, refuelling times, and driving angle deviation in future. Since driving behaviour performance was not recorded, it is not possible to discuss differences in driving behaviour as linked to eye movements, namely if the younger group was worse at driving than the older and experienced group. Finally, since subjective measures were also not recorded, it is not possible to know if the inexperienced drivers were not just going very slowly, or were crashing every few minutes. However, previous studies found that driving experience is one of the key predictors of crash rates, with young novice drivers being particularly at risk (Chapman & Underwood, 1998; Neyens & Boyle, 2008). An earlier study (Maycock, Lockwoodd, Lester, 1991) reported that a newly qualified driver has been estimated to be approximately three times more likely to be involved in a road traffic accident than one with five additional years of age and driving experience.

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