Are experienced drivers more likely than novice drivers to benefit from driving simulations with a wide field of view?

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Abstract

This study aimed to further our understanding of the impact of a restricted field of view on visual search and hazard perception, by comparing novice and experienced driver performance in a driving simulator as a function of the available field of view. Participants encountered a series of virtual hazards during their drive while viewing the world under narrow or wide field of view conditions. The results showed that all drivers were more likely to avoid the hazards when presented with a wide view, even though the hazards only occurred in an area of the screen that was visible in both the wide and narrow view conditions. Experienced drivers also tended to have fewer crashes, and this appeared to be related to a greater speed reduction 10 metres before the hazard. This speed reduction was greatest in the wide field of view condition suggesting that additional information from wider eccentricities was useful in safely navigating the hazardous events. Gaze movement recording revealed that only experienced drivers made overt use of wider eccentricities, and this was typically in advance of any visual cues that might help identify the hazard. This suggests that either early overt attention to wider eccentricities, or continuous covert attention to these extra-foveal regions on approach to the hazard, is responsible for the safer behaviour of experienced drivers when presented with a wide field of view. We speculate about the possible underlying mechanism and discuss possible consequences for HP tests.

Keywords: Driving, Simulator, Gaze, Hazard perception.

1. Introduction

Hazards are dangerous events that require a reaction (e.g. to brake or to swerve) to avoid an accident when driving. Early detection and processing of hazards is related to accident liability and is therefore a substantial component contributing to traffic safety (e.g., Deery, 1999; Elander, West & French, 1993; Horswill & McKenna, 2004). From a variety of driving skills this ability has been argued to be one of, if not *the*, best predictor of accident involvement (Horswill & Mckenna, 2004). Hazard perception (HP), the ability to detect hazardous situations on the road, is usually assessed by recording button responses to hazardous situations presented in short video-clips taken from a driver's perspective in a moving vehicle.

Using this simple method for testing HP, researchers have successfully shown that drivers who have not had an accident respond more quickly to hazards than drivers who have (e.g., McGowan & Banbury, 2004; McKenna, Horswill & Alexander, 2006; Wallis & Horswill, 2007) and in addition, researchers have successfully discriminated between drivers of varying levels of experience, typically demonstrating that experienced drivers detect hazards more quickly than drivers that are less experienced (McKenna & Crick, 1991, 1994; Wallis & Horswill, 2007).

The typical hazard perception test is however designed as much on the basis of pragmatics as theory. Initial hazard perception studies used relatively immersive settings; Watts and Quimby (1979) placed participants in a car shell and had them watch film clips projected onto a large screen. Later research however reduced the apparatus to a standard computer screen display (McKenna & Crick, 1991, 1994), perhaps with an understanding that, if any HP test was to be introduced as part of the national licensing procedure, apparatus would have to be reduced to a minimum while still retaining validity. Many academic studies have since adopted this simple single-screen approach to hazard perception without questioning the impact that it might have on the ability to accurately measure hazard perception skill. Theories of *spatial presence* argue that immersion is key to evoking and training real-world skills in artificial environments (e.g. Wirth et al., 2007), yet such theories are rarely discussed in the hazard perception literature.

Certainly there are reasons to believe that the provision of a more immersive visual environment may have differential effects on drivers of varying levels of experience both at the behavioural and eye-movements level (Di Stasi, Contreras, Candido, Canas & Catena, 2011; Alberti, Gamberini, Spagnolli, Varotto & Semenzato, 2012). For instance it has been found that novice drivers fail to look at critical elements on the road (Pradhan et al., 2005), that they fail to appropriately scan the mirrors (Underwood, Crundall & Chapman, 2002), and they scan the road less widely than experienced drivers (Mourant & Rockwell, 1972; Underwood, Chapman, Bowden & Crundall, 2002; Crundall & Underwood, 1998). On this basis one can predict that simply increasing the field of view of a hazard perception test should create a more realistic scanning pattern in experienced drivers, while novices may still restrict themselves to a relatively central area. This could have the result of improving experienced drivers' responses to hazards above that seen in restricted-view HP tests by allowing access to more information that may prime responses. Alternatively, perhaps the restricted field of view in a typical hazard perception test unduly focuses experienced drivers, and thus the provision of a wider field of view may lead them to respond more slowly to centrally appearing hazards simply because they may be less likely to be looking in the appropriate location when the hazard occurs. Novice drivers however may be unaffected by extending the field of view if they maintain the narrow, central search pattern indicative of their driving skill.

Recently Shahar, Alberti, Clarke and Crundall (2010) have argued that some biases might originate from the restricted field of view (approximating anywhere between 40 and 80 degrees of visual angle) provided by typical HP tests, failing to reflect some aspects of the complexity of HP skills in real driving, which involves detecting and processing occurrences that are external to this limited view.

Using a video-based HP test Shahar et al (2010) recorded button presses in a wide and narrow field of view condition finding that responses were faster in the wide field of view condition, even though the hazard appeared in the centre of the visual field. They presented a series of reasons why this would be the case including arguments that greater immersion with a wider field of view may evoke greater and more realistic sampling of the visual scene, or that increased arousal due to greater levels of relevant visual information may lower thresholds for detecting and reporting hazards.

Following on from the video-based study of Shahar et al. (2010), the current paper reports a study assessing the impact of the field of view upon hazard detection and avoidance in a simulated drive through a pre-determined route containing a series of hazardous events. If experienced drivers benefit more from an expanded field of view than novice drivers then their responses to hazards in the simulator should reflect safer driving behaviour. For instance, on approach to a hazard, the wide field of view may result in early braking times for experienced drivers, though the effect should be less pronounced for novices as they are less likely to use the additional visual information.

By examining HP in a simulator (e.g., Crundall, Andrews, van Loon & Chapman, 2010; Shahar, Poulter, Clarke & Crundall, 2010; Underwood, Crundall & Chapman, 2011) researchers bridge the gap between laboratory studies and real world driving. While simulators cannot beat video clips in the realism and complexity of their imagery, the interactivity provides an additional level of spatial presence, and a more realistic range of behavioural responses to the perception of hazards (e.g., Horswill & Mckenna, 2004; Sagberg & Bjørnskau, 2006). This will allow us to identify whether the effects noted by Shahar et al. (2010) translate into real differences in driving behaviour.

Specifically we predict that a wider field of view in the simulator will encourage safer driving behaviour in the presence of hazards, and that this safety improvement will be predominantly for experienced drivers. Furthermore we predict that this improvement in behaviour for experienced drivers will be concomitant with a wider spread of search in the wide field of view condition, as they take advantage of the additional visual information. Novices are less likely to display a wider search patter in the wide field of view condition.

2. Method

2.1 Participants

Forty participants took part in the experiment, including 20 experienced drivers of which five were women (Mean age = 28.6; SD = 9.91; Mean license seniority in years = 10.5; SD =9.99) and 20 novice drivers of which seven were women (Mean age = 22.4; SD = 4.96; Mean license seniority in years = 1.6; SD =0.82). Participants received an inconvenience allowance for their participation to the experiment. All of the participants reported normal or corrected to normal vision. A median split technique (Cohen, 2003) on licence seniority divided the sample in novice drivers and experienced drivers.

2.2 Design

A series of ANOVAs were conducted with two levels of field of view (narrow and wide) and two groups of drivers (novices and experienced) as between subjects factors for three dependent variables: crash rate, speed and brake pedal pressure. The approach distance from the hazards was a within-subjects factor when analysing the speed (km/h) and brake pedal pressure (0 to 100) of the drivers. These measures were compared over ten distances from the hazard location (100 metres, 90 metres, 80 metres, and so on with the last level providing data at a distance of 10 metres from the hazard) in a 2 x 2 x (10) design.A series of repeated *a priori* comparisons were used to compare levels of approach distance following Crundall et al. (2010).

The x and y coordinates of gaze on screen were recorded throughout the drives and fixations were calculated via a velocity-based algorithm with a minimum fixation cut-off of 100 ms. An observer marked the timestamps of the beginning and end of each precursor and hazard phase by viewing the video for each drive. As a measure of visual search, the standard deviations of the x coordinates of the fixations (in degrees of visual angle) were calculated to reflect the spread of the fixations (ALGORITHM IN APPENDIX B). Given that previous studies that have analysed the spread of search in relation to the appearance of video-based hazards have demonstrated that the presence of a hazard, or even a precursor to a hazard, results in an overt focusing of visual search (Chapman & Underwood, 1998), the horizontal spread was then analysed with a mixed 2 x 2 (x 3) (experience x field of view x (gaze window) ANOVA with three levels of gaze windows: the *pre-cursor* window occurring between the appearance of the precursor and hazard onset, the *hazard* window occurring between hazard onset and offset (i.e., either a crash or when the event was no longer hazardous), and *ordinary driving* (anything else).

2.3 Apparatus and stimuli

A Faros GB3 driving simulator (Faros Simulation System) was used for the experiment. This simulator presents a visual display of approximately 90° x 21° across three 19 inch LCD monitors (380 mm x 300 mm). It is possible to turn off the side screens leaving only the central screen presenting the virtual world. With an average individual seated 50 cm from the display, the central screen alone subtended approximately 40° in the horizontal plane. Side mirrors and rear view mirror information were visible in the display (with side mirrors presented in the left and right screens, while the rear view mirror was visible in the centre screen). Driving speed was presented via a dashboard-mounted speedometer (see Konstantopoulos et al., 2010, for further details). All car controls (steering wheel, handbrake, lights, indicators, and windscreen wiper switches, gear box and gear stick) were modelled on a right-hand drive Vauxhall Corsa (a GM sub-compact). Directions to the participant were provided through pre-recorded audio instructions triggered by the participant's location in the virtual world, and were supported by on-screen arrow symbols presented just above the dashboard. Eye movements were recorded using a SMI HED 50 Hz eye tracker. Frame-by-frame video analysis of eye movements required Noldus' Observer XT software. A 13-point calibration was performed before the recording. Figure 1 shows a close up of the simulator with the virtual road and traffic displayed on the three monitors; the eye tracker is visible on the head of the driver.

<Figure 1>

Figure 1. Simulator and SMI head-mounted eye tracker. The figure shows the view in the wide screen condition.

The route chosen for the experiment included various road and traffic conditions (e.g. 2-lane and 4-lane roads, left and right turns at crossroads and intersections) involving other vehicles and pedestrians. Nine hazards were presented along the route, which took approximately 10 minutes to navigate. Most of the hazards consisted of violations of traffic rules by other road users. Prior to each hazard, a precursor was identified on which basis careful drivers could have predicted the upcoming potential hazard. The precursor events and the hazard onsets were defined in previous research studies (Crundall et al., 2010; Crundall, Chapman, Trawley, Collins, van Loon, Andrews & Underwood, 2012). Precursors could either be the same object that will subsequently become hazardous (e.g. a pedestrian on the sidewalk is the precursor, yet when he steps into the road he comes the hazard), or a different object that occludes the hazard (e.g. when a pedestrian steps out from behind a parked vehicle, the vehicle is the precursor that occludes the hazard). While precursors could appear on the side screens, the hazard onsets were designed to appear on the central screen of the simulator. Table 1 in Appendix 1 provides a description of each of the nine hazard events with the precursor for each hazard.

<Table 1> move to the appendix

2.4 Procedure

The participants were told that they would have to drive on the simulator in a city environment that would include other road users. It was explained that the simulator operated similarly to a normal car including gear changes, steering, signalling, and so forth. In the narrow view condition, participants were told that they would have the front view and the rear view mirror (the information from behind the vehicle) available on the central screen. Participants in the wide view condition were given similar instructions but they were also told that peripheral information and information from behind the vehicle would be available through the side screens and the side mirrors. The participants faced the frontal screen at a variable distance ranging between 50 and 70 cm (they were allowed to adjust the seat for their comfortable driving position). At a distance of 50 cm the horizontal visual angle covered by the central screen was approximately 42 degrees, whereas the lateral screens enlarged that view to 91 degrees.

All of the participants were encouraged to drive regularly and to obey all traffic regulations. They were instructed to keep an eye out for hazardous events and were further told that if they spotted a hazard they should take the necessary action to avoid the danger (i.e. braking, swerving etc.). Following the instructions, participants drove a 3 minute practice route that had no traffic and was different from the test route, after which the experimenter calibrated the eye tracker and began the test. The experiment lasted about 30 minutes.

3. Results

The data of four participants (one from each condition) were excluded from the eye tracking analysis on the basis of poor calibration. Video analysis of all events confirmed that the majority of hazard onsets occurred on the central screen. One hazard however could appear on the left screen on some occasions depending on the position of the participant's vehicle. All data referring to this hazard (hazard 2, table 1) were therefore removed from further analysis. The following sections detail the analysis of the crash rates of drivers, the behavioural measures of speed and brake pedal pressure as recorded by the simulator, and the spread of visual search recorded by the eye tracker.

3.1 Crash rates

A 2x2 (experience x field of view) ANOVA performed on the total number of crashes (whether into a predefined hazard or for any other reason) yielded a significant main effect of field of view ($F_{(1,36)}$=4.73, p<.05), with fewer crashes in the wide view condition (M=1.85, SD=1.26) than in the narrow view condition (M=2.7, SD=1.26). The main effect of experience approached significance (p=.06) suggesting that experienced drivers had fewer crashes (M=1.9, SD=1.02) than novice drivers (M=2.65, SD=1.49). The interaction was not significant [*p*s > .10].

3.2 Speed and brake pedal pressure

In the analysis of the speed at which participants approached the hazard (between 100 and 10 metres), the main effect of distance was unsurprisingly significant ($F_{(9,324)}$=110.66, p<0.001) indicating a decrease in speed as the driver got closer to the hazard. Neither the main effect of experience nor the main effect of field of view were significant, but the distance x experience interaction was significant ($F_{(9,324)}=2.68$, $p=0.005$). Pairwise comparisons contrasting novice to experienced drivers at each of the distances suggested that the interaction was driven by a difference in novice and experienced driver speeds at a distance of 10 m from the hazard ($p<0.05$; see Figure 2). There were no significant differences between the two groups at any of the other greater distances. The field of view x experience interaction was also significant ($F_{(1,36)}= 4.26$, $p<0.05$), indicating slower speed in the wide-, as compared to the narrow-view condition, for the experienced drivers but not for the novice drivers (see Figure 3). Pairwise comparisons indicated that experienced drivers in the wide view maintained a lower speed than both the novices in the wide view ($p<0.05$) and the experienced drivers in the narrow view ($p=0.05$). The differences in speed between the wide and narrow view conditions for novice drivers and between novice and experienced drivers in the narrow view condition were not significant [*p*s > .10]. The field of view x distance and the experience x field of view x distance interactions were not significant [*p*s > .10].

< Figure 2 & 3>

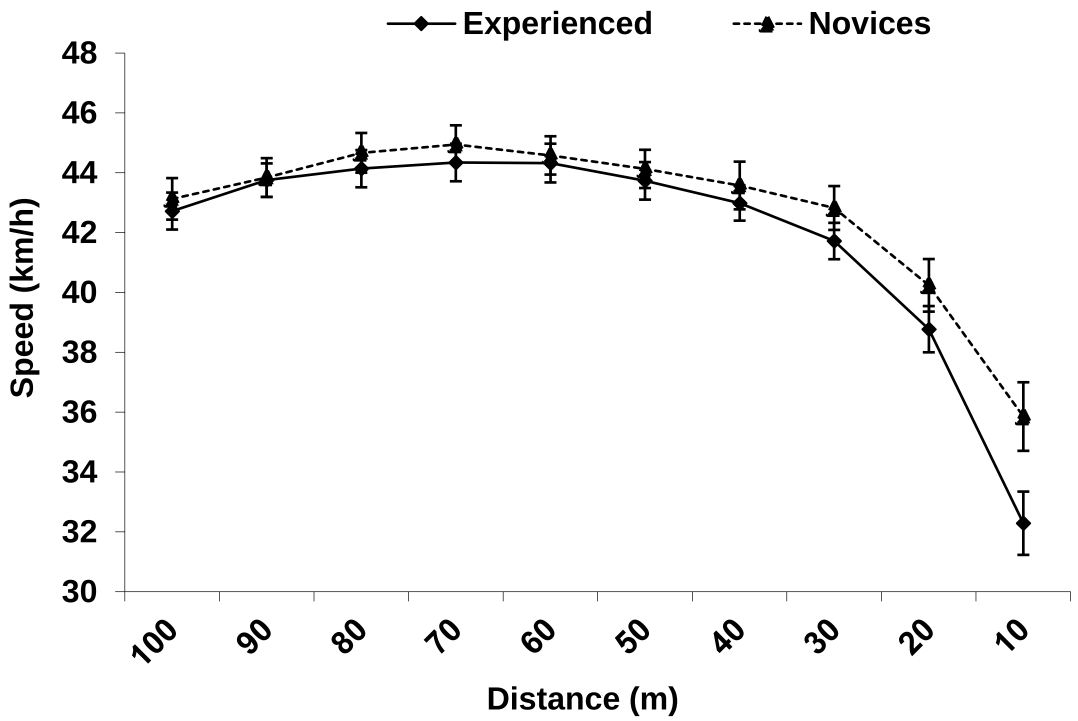

Figure 2. Mean speeds (Km/h) for experienced and novice drivers at set distances (100-10 m) from hazards. The error bars represent the standard error of the mean.

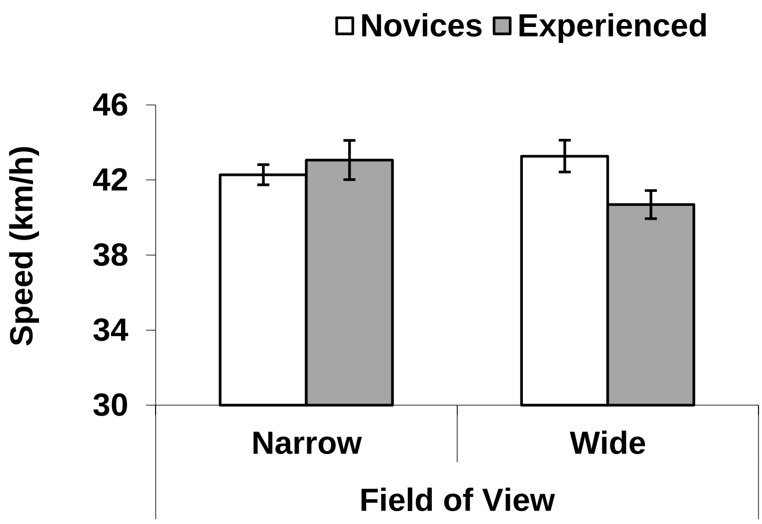

Figure 3. Mean speeds (Km/h) for experienced and novice drivers in the narrow and wide field of view conditions. The error bars represent the standard error of the mean.

These same patterns were also obtained when the speeds that the drivers maintained in non-hazardous sections were included in the analysis as a covariate, with the only exception that the main effect of distance was no longer significant [*p*s > .10].

Finally, the analysis of brake pedal pressure yielded another unsurprising significant main effect of distance ($F_{(9,324)}$= 141.07, p<0.001) confirming an increment in the pressure applied on the brake as the driver approached the hazard. The distance x experience interaction was also significant ($F_{(9,324)}$=2.61, p<0.01). Only at a distance of 10 m from the hazard did experienced drivers apply greater pressure on the brakes than novice drivers (p<0.05), but the differences between the two groups at all other, greater, distances were not significant [p > .10]. The main effects of screen and experience were not significant, and none of the remaining interactions reached significance. Figure 4 displays the brake pedal pressure of experienced and novice drivers at the various distances prior to the hazards.

< Figure 4>

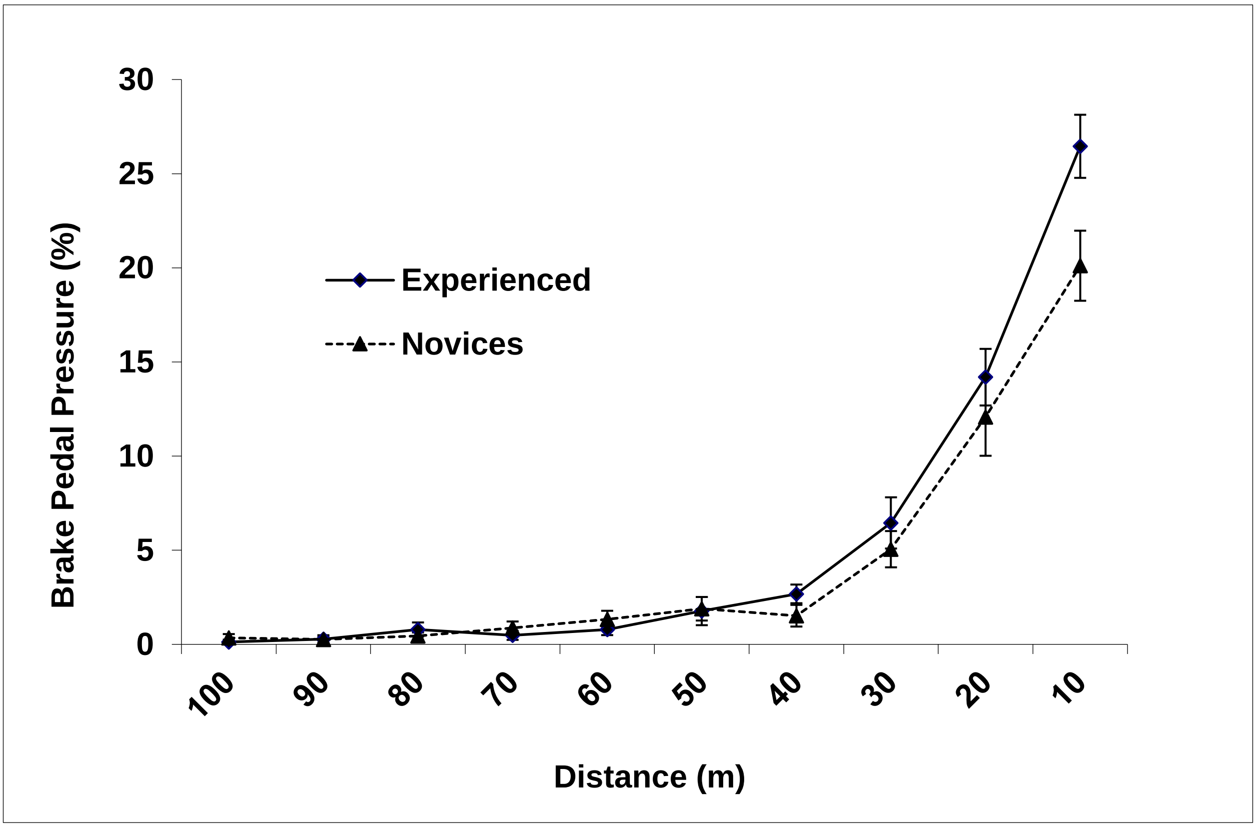

Figure 4. Brake pedal pressure for experienced and novice drivers at set distances (100-10 m) from hazards. The error bars represent the standard error of the mean.

3.3 Horizontal spread of fixations

The main effect of the gaze window was significant ($F_{(2,64)}$=11.40, p<.001), indicating a wider spread of search during ordinary (non-hazardous) driving than during both the precursor window and the hazard window (*p*< .005 and .001, respectively), but the difference between the precursor and the hazard windows was not significant [*p* > .10]. The effect of field of view was not significant, but the field of view x gaze window interaction was significant ($F_{(2,64)=}$4.57, *p*<.05). Pairwise comparisons indicated that only during ordinary driving was the horizontal spread wider in the wide view condition than in the narrow view condition (*p*<.01) and that in the wide view the horizontal spread was wider during ordinary driving than during both the precursor window and the hazard window (*p*s<.001). Although the omnibus experience x field of view x hazard window interaction was not significant, planned comparisons indicated that during ordinary driving in the wide view condition experienced drivers had a wider horizontal spread of fixations than novice drivers in the same condition ($F_{(1,32)}$=8.77, *p*<0.01), and than experienced drivers in the narrow view condition ($F_{(1,32)}$=13.49, p<0.001). Figure 5 displays the horizontal spread of fixations of experienced and novice drivers in the narrow and wide view conditions for the different driving situations.

< Figure 5>

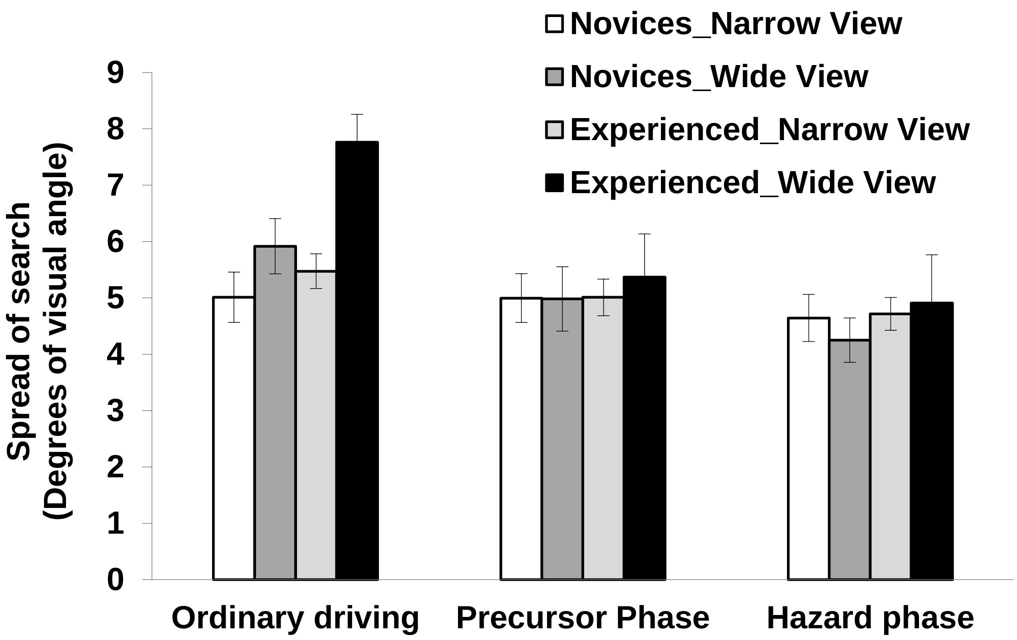

Figure 5. Horizontal spread of fixations (standard deviations of the x coordinates of the fixations in degrees of visual angle) of experienced and novice drivers in the narrow and wide view conditions for the different driving situations. The error bars represent the standard error of the mean.

4. Discussion

Participants had significantly fewer crashes in the wide view condition than in the narrow view condition. Although the interaction was not significant, the main effect of experience (p=.06) indicated that experienced drivers tended to crash less than novices, which may be partly explained by the experienced drivers reacting to hazards with greater braking and a greater decrease in speed when positioned 10 metres from a potential collision. Experienced drivers did make more use of the wide field of view than the novice drivers, with an increase in their spread of visual search during normal driving. This did not distract them from the precursor or the hazard however, as when such elements were present in the scene the experienced drivers focused their spread of search in the same manner that participants in all other conditions did. This additional visual information in the wide field of view condition also resulted in a lower speed for experienced drivers on the approach to a hazard, suggesting a more cautious approach (Borowsky, Oron-Gilad & Parmet, 2009; Wallis & Horswill, 2007).

These results extend the findings of Shahar et al., (2010) suggesting that not only may a restricted field of view lead to poorer hazard detection (as Shahar et al., found), it may also underestimate the level of hazard management (i.e. speed choice on approach to a potential hazard) that participants would apply if they were actually driving.

A number of points can be drawn from these results. First it should be noted that, at least for the experienced drivers, the presence of a hazard, or even a precursor to a hazard, results in a focusing of overt visual search. Previous studies that have analysed the spread of search in relation to the appearance of video-based hazards have demonstrated this focussing effect both overtly (Chapman & Underwood, 1998) and covertly (Crundall, Underwood & Chapman, 1999, 2002). A focussing effect is not apparent in the narrow field of view condition however, possibly due to a floor effect on the spread of search due to the restricted display.

Secondly, the focussing effect noted in the experienced drivers with the wide view suggests that they are responding to the presence of the precursor. Otherwise one might expect the focussing effect to only occur in the presence of the hazard (as observed in Alberti et al. 2012). This argues for the experienced drivers making early use of visual cues to inform them of upcoming potential hazards. From these data it is impossible to reject the possibility that novice drivers have not spotted these hazards also, though previous research using the same hazards in the same simulator, suggests that novices are slower to spot some precursors than more experienced drivers (cf. Crundall et al., 2012). Future studies should adopt high-resolution eye tracking technologies to check whether small saccades produced during fixation (i.e. microsaccades; see McCamy, Otero-Millan, Di Stasi, Macknik, & Martinez-Conde, 2014), also differ between expert and novice drivers. If this were the case we could hypothesis that ocular targeting might be related to information extraction differences in situations that require quick processing like driving.

Thirdly, the general wider spread of search of experienced drivers also reflects previous research (e.g. Crundall & Underwood, 1998; Chapman & Underwood, 1998). It has previously been suggested that this wider spread of search might enable experienced drivers to spot hazardous events sooner than novice drivers. We predicted that the novices would make less use of the wider field of view, due in part to their tendency to display narrow search patterns when driving or watching videos of driving. The current data fit with the suggestion that experienced drivers are better able to make use of a wider field of view in order to improve their responses to the appearance of hazards.

Finally, the behavioural data for speed and braking show an experience difference in the last 10 metres before the hazard (which is after the hazard has onset). While experienced drivers' speed during approach to a hazard is influenced by the field of view, their braking is not. During this approach experienced drivers do not display a wider spread of search but are instead focussing their search. This can be interpreted in two ways. First, the wider spread of search during normal driving may provide advance information regarding potential hazards that results in the driver slowing prior to the precursor window, with this speed reduction then being maintained throughout the precursor and hazard window. A second interpretation could be that the covert information received from the wider field of view influences speed management, perhaps by changing ones estimate of travelling speed. In regard to the second explanation, researchers have reported that speed is perceived to be faster in a wide- than in a narrow-view (e.g., Jamson, 2000; Pretto, Ogier, Bulthoff & Bresciani, 2009; Toet, Jansen & Delleman, 2007). It has also been suggested that in order to accurately estimate speed a horizontal field of view of at least 120° is necessary (Jamson, 2000; Kemeny & Panerai, 2003). As Time To Collision (TTC) estimation (and, consequently, braking responses) is dependent on speed estimation, it is not surprising that TTC estimates are more accurate with a wider field of view (Cavallo & Laurent, 1988). As novices have an impoverished functional field of view compared to more experienced drivers (Crundall et al., 1999, 2002) it is possible that they did not benefit from the wide field of view in this study as the extra-foveal information on the retina was not available for higher processing due to demand-induced limitations on processing resources (Lavie, 1995). Analogous problems have been identified in lane maintenance: while experienced drivers tend to process nearby lane markings peripherally in order to stay in position (Land & Horwood, 1995), novice drivers need to attend foveally to the lane markers (e.g. Mourant & Rockwell, 1972), presumably because their ability to use extra-foveal information is impaired.

The lack of a field-of-view effect on braking suggests that once the drivers have entered the hazard window, the field of view is less relevant. At this point visual search is extremely focused on the emerging hazard (e.g. a child walking into the road) and the braking decision is based on local information in the central portion of the field of view. Thus while overt and covert attention to the wider field of view may result in precautionary reductions in speed, the act of braking in response to the hazard is unaffected by the wider visual display. This initially might seem to contradict the findings of Shahar et al, (2010) who reported that response times were faster to centrally-located hazards in a wider field of view. However, the act of braking is further down the behavioural chain than merely spotting the potential hazard and pressing a button. A simple button response does not reflect the time at which the driver would brake, but merely signifies that she has identified an apparent hazard that she believes she may have to brake for in the near future. Greater braking in the last 10 metres does not necessarily imply harsher braking – it reflects an average across drivers and across a 10 metre distance. Thus drivers who do not brake at all or who brake too late contribute less to this mean. This suggests that experienced drivers are more likely to brake, and more likely to brake sooner (though one cannot also rule out the possibility of harsher braking as well). It is likely that this increased braking of experienced drivers therefore relates to earlier detection of the hazard, no doubt assisted in the wide field of view condition by the adoption of a slower speed. In sum, regardless of the mechanism behind which the wider field of view leads to a greater reduction in speed for experienced drivers, the results support Shahar, et al. (2010) inasmuch as the restriction of the field of view has a misleading impact on drivers abilities to spot and avoid hazards. While Shahar, et al. used simple push button responses to video clips of hazards, this research extends those findings to driver responses in a simulator. The ramifications are extremely important for future iterations of HP tests, especially where tests are used as a part of a driving licensing procedure as in the UK. If it remains a possibility that the narrow field of view is leading to an underestimation of HP skill and performance in safe drivers, it lowers the accuracy of distinguishing between good and bad drivers. This may result in some drivers who might respond very safely to hazards on the real road failing to obtain a license because they cannot respond to virtual hazards which do not provide the full range of visual cues. Furthermore, the introduction of the HP test into the UK licensing procedure has led to the creation of a training industry, with a wide range of commercially produced HP tests available on the UK market. If however these tests are training learner drivers to only use central cues when predicting a hazard (and their subsequent response to that hazard), then we run the risk of blinding new drivers to the full range of visual cues that will be available to them once they have passed the driving test and are out in the real world. On a similar note, by neglecting peripherally occurring hazards, such as vehicles approaching from the nearside and offside lanes, and other important areas of the visual scene that experienced drivers attend and make use of (e.g., mirrors), traditional HP tests also fail to reflect the inferiority of novice drivers as compared to experienced drivers in regard to how much (or how little) they attend the periphery. As such, HP tests that are used in the licensing procedure and commonly for research purposes also may overestimate the true skill of novice drivers.

One final point to note is that the results demonstrate a validity issue with driving simulators. Studies which use desktop simulators with a limited field of view may produce misleading result in regard to speed choice and visual search.

References

Alberti, C. F., Gamberini, L., Spagnolli, A., Varotto, D., & Semenzato, L. 2012. Using an Eye-

Tracker to Assess the Effectiveness of a Three-Dimensional Riding Simulator in Increasing Hazard Perception. Cyberpsychology, Behavior, and Social Networking, 15(5), 274-276

Borowsky, A., Oron-Gilad, T., Parmet, Y. 2009. Age and Skill differences in classifying hazardous traffic scenes. Transportation Research Part F: Traffic Psychology and Behaviour, 12, 277-287.

Cavallo, V., Laurent, M. 1988. Visual information and skill level in time-to-collision estimation. Perception, 17, 623-632.

Chapman, P. R., Underwood, G. 1998. Visual search of driving situations: danger and experience. Perception, 27, 951-964.

Cohen, J. 2003. Applied multiple regression/correlation analysis for the behavioral sciences (3rd ed.). Routledge: Lawrence Erlbaum Associates.

Crundall, D., Andrews, B., van Loon, E., Chapman, P. 2010. Commentary training improves responsiveness to hazards in a driving simulator. Accident Analysis and Prevention, 42, 2117–2124.

Crundall, D. E., Underwood, G. 1998. The effects of experience and processing demands on visual information acquisition in drivers. Ergonomics, 41, 448–458.

Crundall, D., Underwood, G., Chapman, P. 1999. Driving experience and the functional field of view. Perception, 28, 1075-1087.

Crundall, D., Underwood, G., Chapman, P. 2002. Attending to the peripheral world while driving. Applied Cognitive Psychology, 16, 459-475.

Crundall, D., Chapman, P., Trawley, S., Collins, L., van Loon, E., Andrews, B. Underwood, G. 2012. Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. Accident Analysis and Prevention, 45, 600-609.

Deery, H.A. 1999. Hazard and Risk Perception among Young Novice Drivers. Journal of Safety Research, 30, 225-236.

Di Stasi, L. L., Contreras, D., Cándido, A., Cañas, J. J., & Catena, A. 2011. Behavioral and eye-movement measures to track improvements in driving skills of vulnerable road users: First-time motorcycle riders. Transportation research part F: traffic psychology and behaviour, 14(1), 26-35.

Elander, J., West, R., French, D. 1993. Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. Psychological Bulletin, 113, 279-294.

Horswill, M.S., Mckenna, F.P. 2004. Drivers' hazard perception ability: situation awareness on the road. In: Banbury, S., Tremblay, S. (Eds.), A cognitive approach to situation awareness. Asgate, Aldershot, UK, 155-175.

Jamson, H. 2000. Driving simulation validity: issues of field of view and resolution. In Proceedings DSC, Paris, France, 57-64.

Kemeny, A., Panerai, F. 2003. Evaluating perception in driving simulation experiments. Trends in Cognitive Science, 7, 31-37.

Konstantopoulos, P., Crundall, D., Chapman, P., 2010. Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore visual search in day, night and rain driving. Accident Analysis and Prevention, 42, 827–834.

Land, M., Horwood, J. 1995. Which parts of the road guide steering? Nature, 377, 339–340.

Lavie, N., 1995. Perceptual load as a necessary condition for selective attention. Journal of Experimental Psychology: Human Perception and Performance 21, 451–468.

McCamy, M.B., Otero-Millan, J., Di Stasi, L.L., Macknik, S.L., & Martinez-Conde, S. 2014. Highly informative natural scene regions increase microsaccade production during visual scanning. Journal of Neuroscience, 34, 2956-2966.

McGowan, A.M., Banbury, S., 2004. Evaluating interruption-based techniques using embedded measures of driver anticipation. In: Banbury, S., Tremblay, S. (Eds.), A Cognitive Approach to Situation Awareness: Theory and Application. Ashgate, Aldershot, UK.

McKenna, F.P., Crick, J.L. 1991. Experience and expertise in hazard perception. In Grayson, G.B. & Lester, J.F. (eds.), Behavioural research in road safety. PA2038/91 Transport and Road Safety Laboratory, Crowthorne.

McKenna, F.P., Crick, J.L. 1994. Hazard perception in drivers: a methodology for testing and training. Contractor report No. CR 313. Transport Research Laboratory, Crowthorne, UK.

McKenna, F.P., Horswill, M.S., Alexander, J., 2006. Does anticipation training affect drivers' risk taking? Journal of Experimental Psychology: Applied, 12, 1–10.

Mourant, R.R., Rockwell, T.H. 1972. Strategies of visual search by novice and experienced drivers. Human Factors, 14, 325-335.

Pradhan, A.K, Hammel, K.R., DeRamus, R., Pollatsek, A., Noyce, D.A., Fisher, D.L. 2005. The use of eye movements to evaluate the effects of driver age on risk perception in an advanced driving simulator. Human Factors, 47, 840-852.

Pretto, P., Ogier, M., Bülthoff, H. H., Bresciani, J.-P. 2009. Influence of the size of the field of view on motion perception. Computers and Graphics 33, 139-146.

Sagberg, F., Bjørnskau, T., 2006. Hazard perception and driving experience among novice drivers. Accident Analysis and Prevention, 382, 407–414.

Shahar, A., Alberti, C., Clarke, D., Crundall, D. 2010. Hazard Perception as a function of target location and the field of view. Accident Analysis and Prevention, 42, 1577–1584.

Shahar, A., Poulter, D., Clarke, D., Crundall, D. 2010. Motorcyclists' and car drivers' responses to hazards. Transportation Research Part F: Traffic Psychology and Behaviour, 13, 243-254.

Toet A, Jansen S. E, Delleman N. J. 2007. Effects of field-of-view restrictions on speed and accuracy of manoeuvring. Perceptual Motor Skills, 105, 1245-56.

Underwood, G., Chapman, P., Bowden, K. Crundall, D. 2002. Visual search while driving: skill and awareness during inspection of the scene. Transportation Research Part F: Traffic Psychology and Behaviour, 5, 87-97.

Underwood, G., Crundall, D., Chapman, P. 2002. Selective searching while driving: the role of experience in hazard detection and general surveillance. Ergonomics, 45, 1-12.

Underwood, G., Crundall, D. Chapman, P. 2011. Driving simulator validation with hazard perception. Transportation Research Part F: Traffic Psychology and Behaviour, 14, 435-446

Watts, G. R., & Quimby, A. R. (1979). Design and validation of a driving simulator (Number LR 907). Crowthorne, England: Transport and Road Research Laboratory.

Wallis, S.A., Horswill, M.S. 2007. Using fuzzy signal detection theory to determine why experienced and trained drivers respond faster than novice drivers in a hazard perception test. Accident Analysis and Prevention, 39, 1177-1185.

Wirth, W., Hartmann, T., B, Böcking, S, Vorderer, P., Klimmt, C., Schramm, H., Saari,T., Laarni, J., Ravaja, N., Ribeiro Gouveia, F., Biocca, F., Sacau, A., Jäncke, L., Baumgartner, T., & Jäncke, P. (2007). A process model of the formation of spatial presence experiences. Media Psychology, 9, 3, 493-525.

Table and figure captions

Figure 1. Simulator and eye tracker.

Table 1. Descriptions of precursors and hazards.

Figure 2. Mean speeds (Km/h) for experienced and novice drivers at set distances (100-10 m) from hazards. The error bars represent the standard error of the mean.

Figure 3. Mean speeds (Km/h) for experienced and novice drivers in the narrow and wide field of view conditions. The error bars represent the standard error of the mean.

Figure 4. Brake pedal pressure for experienced and novice drivers at set distances (100-10 m) from hazards. The error bars represent the standard error of the mean.

Figure 5. Horizontal spread of fixations (standard deviations of the x coordinates of the fixations in degrees of visual angle) of experienced and novice drivers in the narrow and wide view conditions for the different driving situations. The error bars represent the standard error of the mean.

APPENDIX A

Table A.1. Descriptions of hazards and precursors for each hazard.

	Precursor phase	Hazard phase
1	Among a line of parked cars on the drivers' near side a child's head and shoulders are visible.	As the participant approaches the child steps into the road becoming the hazard.
2	The driver approaches a blind bend to the left.	Travelling around the bend, a broken down truck (with hazard lights on) suddenly becomes visible.
3	A parked ice-cream van is visible ahead on the drivers' near side.	From behind the ice-cream van a child suddenly steps into the road.
4	The driver approaches a crossroads with priority. Other vehicles are seen to cross on approach indicating that traffic can come from either side.	A car from the right fails to give way, crossing immediately in front of the driver.

5	An oncoming motorcycle is visible ahead in the contraflow lane. Its position and speed make it clear that it intends to turn across the driver’s lane into a side road.	The motorcycle then makes the turn without giving way to the driver.
6	A bus ahead has stopped on the near-side of the road. A pedestrian is also visible in the central reservation.	The pedestrian crosses the road to reach the bus, directly in the path of the driver.
7	A car approaching from a side road is visible ahead. It does not appear to slow down.	The car crosses the give way line onto the main carriageway entering the driver’s path.
8	A van can be seen ahead in an offside rest area. It has its hazard lights on.	A pedestrian hidden from view by the van enters the road carrying a large box.
9	Two pedestrians are visible, one on either side of the road. The off side pedestrian waves to the near side pedestrian	The near side pedestrian steps into the road in front of the driver.