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1 Chapter 1

1.1 General introduction

1.1.1 Objectives

The objective of this thesis is building ideas about how drivers perceive upcoming hazards. Simulators are useful at this purpose because they aim at reproducing real road conditions allowing an interaction with the vehicle on the road and within the environment. Moreover, the simulator allow us to put the participant in a virtual and controlled world where we can study how the hazard situations are faced.

The registration of eye movements together with the recording of response times, speed maintenance and braking reactions permits to study the developing analysis of the hazard from the perceptual to the reaction phases.

In this research field, it is particularly important to know if the research findings can be generalized to the real world. But it is not easy to repeat these researches in real traffic conditions. The only way we have to gain evidences about drivers' behaviours is observational studies and experiments. I will present three experimental studies in my thesis that is made-up of 5 parts.

Chapter 1 presents an introduction of the most important scientific results obtained in traffic safety research, dealing with the explanation of the involvement of young drivers and motorcycle riders in such a great number of accidents on the road. Moreover I present a review of how hazard perception skill has been studied through eye movements recordings, button press reaction times and in simulation conditions trying to throw light on the experiential differences found in a great number of studies. A part of chapter one is dedicated to discussing how setting conditions influence the performance of participants in driving research, reporting the results obtained when a wider field of view was used for displaying the visual scene and when the participants were immersed in a more realistic driving scenario and could control the vehicle through the use of simulators. The last section reports results obtained by training programs for the amelioration of hazard perception.

Chapter 2-4 form the practical part of the thesis, where I present the results from the three experiments. Chapter 2 presents a research case which has as its purpose the analysis of the different levels of hazard perception, from the initial phases of detection to the last response phases. Three groups with different experience in car driving and motorcycle riding are tested in a hazard perception task. During the hazard perception task eye movements (gaze latencies) and pedal press responses are recorded to hazards presented in video-clips taken from the driver perspective.

This experiment provide an opportunity to studying how drivers and riders scan the visual scene and react to hazards when a wide visual field presenting realistic dimensions is available.

Chapter 3 presents a research situation in which fixation latencies are used as a measure of hazard detection and the effect of practise is measured after different sessions in which several hazard situations are presented. Participants are inexperienced young riders that undergo several sessions on a fixed-base riding simulator. This experiment is using a simulator therefore it is an interaction situation with the vehicle's behaviour and the road condition changing in response to rider's commands, however the simulator is not providing the driver with a wider visual field.

Chapter 4 concerns the corroboration of ideas accrued during previous experiments about the interaction between field of view size and experience in hazard perception. This experiment uses a car simulator and records speed and braking pedal pressure. An eye tracking device provides information about the spread of fixations along the horizontal coordinate.

Chapter 5 is the last part of the thesis, where a review of the results and a discussion about the main findings are provided. Moreover in the last chapter some conclusions and recommendations for improving the realisms of results in accident research are provided.

1.1.2 Accidents and Young drivers

Young drivers are overrepresented in road accidents (McGwin & Brown, 1999; Ryan, Legge & Rosman, 1998) and the different countries adopted different measures to face the situation: postponing licensing year, developing graduated licensing programs (gradually allowing new drivers to gain experience in low-risk situations with a minimum of three stages in the licensing process: learner's permit, restricted licensure and full licensure) and putting licensing drivers through the hazard perception test. The idea is making the novice drivers gain more experience before allowing them to drive in more risky scenarios (Ferguson, 2003).

Both youth and inexperience could determine the higher involvement of young drivers in crash accidents. Studies have attempted to quantify the relative importance of these factors (LaBerge-Nadeau, Maag & Bourbeau, 1992; Waller, Elliott, Shope, Raghunathan & Little, 2001).

McKnight and McKnight (2003) report how separating age and experience the influence of experience greatly exceeds that of age.

Consistently, it has been demonstrated that driving experience has an effect on crash risk, even when the effect of age is controlled (Maycock, Lockwood & Lester, 1991) and that in the first months after licensing there is a strong risk reduction likely due to some skill acquisition (Gregersen, Berg, Engström, Nolen, Nyberg, Rimmö, 2000; Mayhew, Simpson, Pak, 2003).

McCartt, Shabarova and Leaf (2003) reported the result of a survey on 911 teenagers over the first year of licensure and first 3500 miles driven on self-reported crash involvement: they reported that the risk of a crash was higher during the first 500 miles, and during the first month than during any of the remaining 11 months. Sagberg (1998) found a sharp decline in crash risk per kilometre driven during the first few months of licensure.

Researches have examined the factors contributing to the higher probability of teenage involvement in crashes. Factors identified as related with teenage crash involvement were: teenage passengers (Preusser, Ferguson & Williams, 1998) and time of day (Preusser, Williams, Zador & Blomberg, 1984). Moreover, Boyce and Geller (2002) found that young drivers maintained higher speeds and closer following distance than middle age and older drivers.

Gregersen and Bjurulf (1996) developed a model for explaining young drivers' accident involvement and took into consideration the learning process (teaching, training and experience), individual characteristics (lifestyle, age, gender and personality) and the social influences (norms, role expected) in their analysis. The analysis goes through automation of processes, mental workload, risk awareness, motivation and intentions as processes related with accident involvement.

Although their analysis takes into consideration a wide range of factors which could determine crash involvement, it looks like a major cause of crashes for newly licensed drivers is the failure to scan effectively for potential risks (McKnight & McKnight, 2003; Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer & Castellan, 1979).

A great number of studies have demonstrated that accidents are mostly due to human error (Lewin, 1982; West, French, Kemp, & Elander, 1993) and it is reported that the probable cause of the majority of accidents are errors in perception and decision making (Groeger, 2000; Groeger & Chapman, 1996).

McKnight and McKnight (2003) completed a field analysis of 2000 police crash reports involving young drivers and found that the largest fraction were due to failures of attention and visual search (ahead, to the side and to the rear) and not to high speeds and risky behaviour. These results are similar to that reported by Treat et al. in 1979. The analysis by Mcknight and McKnight (2003) showed that 42.7 % of the crashes were attributable to failures to search ahead, to the side, and to the rear, 23.0% to failure to pay attention, 20.8% to lack in adjustment of the vehicle's speed; those are all examples of inadequate behaviours that could be attributable to inexperience. It is to be noted that only 0.7% of the crashes were included in the category high speeds.

1.1.3 Accidents and Riders

The rate of death or injury for motorcycle riders is greater than that for other vehicle users: the US report about traffic safety inform how in 2004 motorcycle riders were 34 times as likely as passenger car occupants to suffer a fatal injury (National Highway Traffic Safety Administration, 2006), and similar estimated have been reported in Europe (European

Transport Safety Council, 2007), the UK (Chesham, Rutter & Quine, 1993), and in Australia (Australian Transport Safety Bureau, 2008).

Horswill and Helman (2001) report how in the UK in the three-year period 1997-1999 motorcycles were 9.3 times more likely than cars to be involved in an injury or fatal accident, controlling for time spent travelling.

Chesham, Rutter and Quine (1991) report how young male motorcyclists are at a higher risk of being involved in an accident than other motorcyclists, and even though the same is also valid for young male drivers compared with other car drivers (Maycock, Lockwood & Lester, 1991), the motorcycle population is made up of more young males with respect to car drivers population.

Contradicting these results, Savolainen and Mannering (2007) in their analysis of the crash database of the state of Indiana found that older motorcyclists were more likely to be involved in severe-injury crashes.

Similarly to what we did in the section regarding young drivers we want to analyse which the causes of such a great number of accidents involving motorcycle riders might be.

Questioning whether there is a pattern of accident-related behaviour that motorcyclists put in practise or whether the higher rate of accidents on the motorcycle is related with characteristics of the vehicle is useful: Clarke, D. D., Ward, P., Bartle, C. and Truman, W. (2004) from an analysis of police reports identified that the great majority of accidents due to motorcyclists' behaviour were related with overtaking (16.5%) or filtering manoeuvres or with loss of control on a bend, corner or curve.

Horswill & Helman (2003) found differences between motorcycle riders and a matched groups of car drivers in speed choices, overtaking and pulling out into small gaps propensities (see the Section Motorcycle riding and hazard perception, par. 1.1.6). But they concluded, using the rule of thumb equation developed by Joksch (1993) that speed could account only for a 4 % difference in fatality probability between car drivers and motorcycle riders. However there is evidence that speed has a U-shaped relationship with accidents, with either extremes being linked with increased accident liability (e.g. Finch, Kompfner, Lockwood & Maycock, 1994).

From these studies it appears how the higher crash liability of motorcyclists is related with the behaviours that riders put in practise and that depend on the characteristics of the vehicle, like overtaking more often (thanks to larger acceleration) and pulling out into smaller gaps (thanks to smaller dimensions).

Coherently Horswill & Helman (2003) showed that a group of motorcycle riders that were asked to respond as if driving a car did not differed in speed choices, overtaking and pulling out into small gaps propensities from a matched group of car drivers. Moreover questionnaires submitted to car drivers and motorcyclists in this study showed that they not differ in attitudes to driving/riding, sensation-seeking and social motives.

However, previous epidemiological studies have shown that prior driving experience confers a protective effect on the risk of a motorcycle accident (Wong, Lee, Phoon, Yiu, Fung, McLean, 1990; Lardelli-Claret, Jimènez-Moleon, Luna-del-Castillo, Garcìa-Martin, Bueno-Cavanillas, Galvez-Vargas, 2005): whether this is due to experience with hazardous situations (Horswill & Hellman, 2003; Hosking, Liu & Bayly, 2010) or to awareness of what car drivers' attitudes toward motorcyclists are (Crundall, Clarke, Ward, & Bartle, 2008), this is an interesting effect.

1.1.4 Differences between experienced and novice drivers in visual scanning

A number of studies have been conducted to investigate what differentiate the performance of experienced drivers from that of novice drivers. Many interesting researches have been conducted using eye tracking technologies to record eye movements patterns. An early, pioneering study measuring eye movements of drivers indicates that novices do not scan the road as widely as more experienced drivers do and move their eyes less frequently (Mourant & Rockwell, 1972), this determining a lack in peripheral risk-relevant elements' inspection. Other studies have confirmed that novices had reduced variance in their fixations locations compared to experienced drivers during video-clips scanning (Underwood, Chapman, Bowden & Crundall, 2002) and experienced drivers varied width of variance of fixations locations along the horizontal axis according to the complexity of the roadway having a wider scanning in dual-carriageway roads, while novices had inflexible scanning patterns (Crundall & Underwood, 1998). Coherently other studies have demonstrated that experienced drivers have more flexible visual search strategies depending on the type of road and traffic conditions (Chapman & Underwood, 1998; Falkmer & Gregersen, 2005).

The results obtained with a double-task paradigm are consistent with reported findings: when a peripheral target had to be detected while viewing video-clips taken from the drivers' perspective, learners showed a degradation of attention deployment to extra-foveal regions over a longer period of time than experienced drivers (Crundall, Underwood & Chapman, 2002).

These studies demonstrate that the width of eye scanning and of attentional deployment is discriminating the performance of novice and experienced drivers.

Moreover, the fixation duration measure is discriminating between experienced and novice drivers: experienced drivers tend to have shorter fixation durations than novices (Underwood, Crundall & Chapman, 1997; Crundall, Chapman, Phelps, Underwood, 2003). Fixation durations are related with the processing power of the fixations: processing an item takes time and effort (Labbett and Langham, 2006) and while some items may require very little effort, some unexpected, novel or complex objects may take considerably more effort. The difference in fixation durations between experienced and novice drivers could depend on the fact that the processing of road information is easier for experienced drivers, while novice and learner drivers need to fixate for longer, especially when they encounter hazardous situations (Chapman & Underwood, 1998). Fixation durations are particularly important during driving because time is limited and the driver has to extract the maximum amount of information during this time: there is therefore a trade-off between the extraction of information within a fixation and the need to move the eyes to another location, this competition between the need to fixate and the desire to move the eyes was first highlighted in the model of saccade generation by Findlay and Walker (1999). The results obtained about spread of fixations and fixations durations are then related: an efficient scanning would be the one that considers all the important positions in the scene in a convenient interval of time and it was demonstrated this is possible only for experienced drivers, that show a raise in the sampling rate of the search strategy (Crundall & Underwood, 1998).

Indeed, the majority of fixations during driving are accrued by the focus of expansion (FoE) or the direction of heading (Underwood, Chapman, Brocklehurst, Underwood &

Crundall, 2003) as this is the location that provides most of the information during driving and is a valuable location to monitor for collision avoidance. Fixations away from heading direction can be dangerous and impair driving performance (Summala, Nieminen, & Punto, 1996). This is the reason why drivers tend to monitor this position continuously, although in some situations it is worth checking other positions. While experienced achieve in distributing their resources to different locations, novice drivers are less capable. Even when the scanning should be directed to various locations, novice drivers have longer and less spread fixations, mostly directed to the heading direction.

The activity generated by scanning the road information while controlling the direction of heading is influenced by speed: higher speed cut down the number of fixations that the driver can make on the road and the durations of them.

Scanning but not processing some locations on the road could determine the so-called Look But Fail To See errors, and this phenomenon could be related with the fact that the fixations made by the driver are too short.

What the reasons are for the different scanning pattern of experienced and novice drivers is still debated. It could be ascribed to the different levels reached in the construction of a mental model of the road situations (Underwood, Crundall, & Chapman, 2002; Pradhan, Hammel, DeRamus, Pollatsek, Noyce & Fisher, 2005) or to the diverse employment of mental resources when facing road conditions (Crundall, Underwood, Chapman, 1999, 2002).

Underwood, Crundall, & Chapman (2002) claim that the poor visual scanning of novice could be due to an inappropriate mental model, or schema, for that particular driving situation. Indeed there is evidence that in specific situations experienced drivers show definite scanning patterns, probably reflecting the development of specialised sub-schemata about how to face the situation (Liu, 1998; Shinoda, Hayhoe, & Shrivastava, 2001; Salvucci & Liu, 2002).

On the other side, there is some evidence of limited peripheral processing in novice drivers: novice drivers focus their mental resources and fail to consider different road information at the same time (Crundall, Underwood, Chapman, 1999, 2002). This limit in peripheral processing is probably the consequence of the mental requirements that the driving task poses on novice drivers' resources.

As an example, Land and Horwood (1995) demonstrated that novices tend to fixate lane markers quite often (e.g. Mourant and Rockwell, 1972; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003), while experienced drivers take in information from lane markers through peripheral vision. This example is consistent with the argument provided by Underwood (2007) to explain novice drivers' worse performance. He attributes the limit in attentional resources of novices to a lack in automated car control: on-road driving requires attention to be devolved to steering and lane maintenance and drivers prioritise navigational tasks over other task goals (Cnossen, Meijman & Rothengatter, 2004) therefore when driving lots of fixations are devolved to the control of the vehicle (Shinar, McDowell, Rockwell, 1977; Laya, 1991; Land & Lee, 1994). Following this line what differentiates experienced from novice drivers is the efficient balance between navigational fixations and visual search fixations.

The same two types of explanation were also used by Pollatsek, Fisher & Pradhan (2006) to account for the differences between experienced and novice drivers: they reported how the failure of novice drivers to search effectively might be due to an informational problem (young and inexperienced drivers do not recognize the situations in which it is useful to look at particular areas to help avoiding risks) or to a structural problem (younger and inexperienced drivers are less able to attend to areas of the roadway other than straight ahead).

Pradhan, Hammel, DeRamus, Pollatsek, Noyce and Fisher (2005) in a simulator study conducted an analysis on the fixated elements in risky situations and demonstrated that novice drivers fail to look at the regions where hidden risks may emerge or fail to look at the critical elements of a scenario (critical elements are those that could create a risk): only a small number of novices looked at the critical elements while a greater proportion of experienced did. In their opinion the exposure to hazardous situation develops the schemata to face the same situation again. Although the construction of schemata for rare events like hazards can be difficult (Chapman & Underwood, 2000). Results similar to that of Pradhan et al. have been reported by Garay-Vega and Fisher (2005) that, using eye movements analysis, found that young drivers had more difficulties predicting a potential hazard occurrence when viewing cues of the hazard.

These studies highlighted how experienced and novice drivers differ in scene inspection and what could be the causes of these differences.

In combination, differences between experienced and novice drivers have been found also on the hazard perception test: it was found that novice drivers are slower than experienced drivers in detecting hazards when the detection measure is button pressing latency (Mckenna & Crick, 1994).

Deery (1999) in a review about hazard perception and novice driver's performance claims that "compared to experienced drivers, novice drivers detect hazards less quickly and efficiently and perceive them less holistically".

1.1.5 Hazard perception skill and the hazard perception test

The different definitions provided for hazard perception (HP) tend to simplify the characterizations of a construct which is instead complex.

It has been defined as a driver's "ability to read the road and anticipate forthcoming events" (McKenna, Horswill & Alenxander, 2006) or as "the ability to quickly perceive and respond to a potentially dangerous driving event" (Crundall, Chapman, Phelps & Underwood, 2003).

Traffic researchers have individuated two moments related with hazard perception: an evaluation moment, the "degree of perceived hazard associated with the situation" (Sagberg & Bjørnskau, 2006) or the quantification of "the dangerous potential of hazards" (Deery, 1999), and a response moment (Deery, 1999; Sagberg & Bjørnskau, 2006). Applying the theory of situation awareness (Endsley, 1995) to hazard perception we can recognize three stages through which the awareness of the occurring situation increases: level 1 when the elements of the environment contributing to the situation are detected (perception), level 2 when their meaning is extracted and understood (comprehension) and, finally, level 3 when the observer/decision-maker projects the future status (projection). In the perspective of the situation awareness (SA) theory, after the perception phase (level 1), the decision-maker creates an holistic picture of the environment comprehending the significant of objects and events and comparing the situation with the action-goals to project future states (level 2 and 3). A novice might be able to achieve the first stage (level 1) as an experienced decision-maker but might not be able to integrate various data element with pertinent goals. The reaction moment that follows these stages would coincide with the decision process. Therefore, coherently with the theory, before making a decision drivers must focus their effort on assessing the state of the environment.

Quite a lot of interest have been posed on HP after it was demonstrated to be related with accident involvement (Quimby, Maycock, Carter, Dixon & Wall, 1986; Horswill & McKenna, 2004) and to distinguish between experienced and novice drivers (Quimby et al. 1986; McKenna & Crick, 1991,1994; Groeger & Chapman, 1996; Wallis & Horswill, 2007). A methodology to measure HP was developed that uses the button presses of participants to measure their ability to detect and recognize hazards in video-clips of road traffic scenarios (Horswill & Mckenna, 2004 for a review).

RT is a simple but effective measure of HP but it has been argued that hazard perception is a complex skill and its dynamics might not be reflected by a button press which is the result of hazard processing (Jackson, Chapman & Crundall, 2009). Whether or not the button press response could be associated in time with the start of a reaction to the hazard is dependent on the construction of the hazard scenarios, that could require more a reaction effort than a predictive ability (Sagberg & Bjørnskau, 2006).

However, before Hazard Perception (HP) test being introduced in 2002 in English speaking countries as part of the driving licence examination, several studies have demonstrated the efficacy of HP test to discriminate between experienced and novice drivers or non drivers (McKenna & Crick, 1991, 1994; Wallis and Horswill, 2007) and drivers with high crash involvement resulted have a worse hazard perception than other drivers (Quimby et al., 1986; Horswill & McKenna, 2004).

The rationale of the HP test is checking the ability of road users to identify potentially dangerous situations as they arise from its earliest warning signs (McKenna & Crick, 1994) as the examinee is required to give a response as quickly as possible when a dangerous situation is arising (McKenna & Crick, 1991; Quimby et al., 1986). Based on the response delay, a score is given to the examinee.

Although the hazard perception test resulted to be promising in a number of lab studies, there is no evidence that it reduces crash rates among young drivers on the roads (Ferguson, 2003). Moreover some studies employing HP test failed to differentiate between experienced and novice drivers (Crundall, Underwood and Chapman, 2002;

Sagberg & Bjǿrnskau, 2006). Consequently, face validity (button presses may be considered different from real driving), low internal consistency (not all clips are suitable to demonstrate experiential differences) and criterion differences are threats for the HP test's consistency.

The reason why experienced and novice drivers differ in HP response time is still debated. While it is commonly accepted that there are some experience-related differences in visual search ability and overt attention deployment (discussed in the section Differences between experienced and novice drivers in visual scanning, par. 1.1.4) , still it is to be individuated the reason for such differences, and whether such differences can account for HP performance.

On the other hand, Wallis and Horswill (2007) suggested that what determines the different performance of experienced and novice drivers in the HP test is a difference in response criterion: using fuzzy signal detection theory, they found that experienced and novice drivers were equally good in discriminating the levels of hazardousness of the traffic scenes, but novices responded to hazards less often and slower than experienced drivers. This could be due to the fact that young drivers are less willing to label traffic scenarios as hazardous, or even if novice drivers rate hazardous events in the same way as experienced drivers, they do not experience the same urgency to respond to them (Horswill & McKenna, 2004). To date no relationship between driver's rating of the level of risk and HP reaction times has been found (Horswill & McKenna, 2004).

Farrand and McKenna (2001) consider how instructions on how to perform the HP task can influence responding rate, suggesting that response biases can depend on instruction.

It is interesting at this point to make a distinction between hazard perception skill and risk-taking behaviour, between driving skill and driving style (Elander, West & French, 1993; McKenna, Horswill & Alexander, 2006): if skill and risk-taking behaviour are independent, then skill improvement should have no impact on risk-taking behaviour, on the other side if there is a correlation between skill and risk taking then it is to be analysed whether it is a positive correlation with skill improvement increasing risk taking or a negative correlation with skill improvement decreasing risk taking. An answer to this question is provided by McKenna, Horswill and Alexander (2006) that demonstrated that a skill-based training program decreased risk-taking behaviour. This result supports the importance of developing hazard perception skills to reduce accident probability.

On the other side there is contradictory evidence that perceived self-efficacy is positively correlated to risk-taking behaviour (Krueger & Dickson, 1994; Horswill, Waylen & Tofield, 2004).

1.1.6 Motorcycle riding and hazard perception

Motorcyclists is a subgroup of drivers particularly involved in accidents (Horswill and Helman, 2001), with young motorcyclists being subjected to a higher risk of involvement (Chesham, Rutter and Quine, 1991). Moreover, when involved in a crash, motorcycle riders are more subjected to serious injuries with respect to car drivers, due to the characteristics of the vehicle.

We introduced previously the importance of HP as a skill that differentiate experienced form novice drivers and that was found to be related with crash involvement (see Hazard perception skill and the hazard perception test, par. 1.1.5). Given the high crash probability of motorcyclists it makes sense studying HP in this population checking a) whether the higher crash involvement of riders is related in any way with HP ability b) whether the higher crash involvement of novice rider with respect to experienced riders is related with HP ability.

The differences between car driving and motorcycle riding are various.

Liu, Hosking and Lennè (2009) make a distinction between hazards that involve other road users, like pedestrians or other vehicles (road-user-based hazards) and hazards that involve road surface characteristics, like a ruined road surface (road-surface-based hazards). While the first can pose safety problems to both drivers and riders, the second are more dangerous for riders.

Therefore, a wider range of hazards can affect motorcycle riders as they have to take into consideration also road characteristics apart from traffic situation. For this reason hazard perception tests that are valid for drivers might not be as valid for riders.

Moreover, apart from the higher number of hazards that can affect riding, the structure of the bike with respect to the car (the axis of the head and eye-height are different) is different.

And this difference can influence the visual scanning patterns of motorcyclists with respect to car drivers: motorcycle riders when driving a car looked further ahead than car drivers without motorcycle riding experience (Tofield & Wann, 2001) and riders looked more often at the road-surface ahead to detect any surface irregularities than car drivers whose fixations were more frequently directed at or above the horizon (Nagayama, Morita, Miura, Watanabem, Murakami, 1980).

It is to be tested whether these differences between riders and drivers influence HP skill.

Contrarily from what might be expected looking at the crash involvement statistics, Underwood and Chapman (1998) found that motorcycle riders have shorter reaction times to hazards if compared with car drivers, and are faster to classify an object as an hazard after fewer fixations.

To test the differences in HP between motorcycle riders and car drivers Horswill and Hellman (2003) run an experiment where they asked a group of motorcyclists to imagine and react at hazards in a HP test as if they were driving a car and another group of motorcyclists to imagine riding a bike. Horswill and Hellman (2003) demonstrated that there is a difference in HP abilities when imagining to drive a car or riding a bike: motorcyclists obtained better results in the HP test than car drivers (supporting the findings of Underwood and Chapman, 1998) but only when they were imagining to drive a car, and the advantage was absent when they were asked to imagine riding a motorcycle. There were not certainties that the better performance of experienced riders (with respect to car drivers and motorcyclists imagining to ride a bike) in a classical HP test would extend to more realistic situations such as riding on a simulator or on the road.

Therefore the same two groups of motorcyclists (those imagining to drive a car and those imagining to ride a bike) were asked to complete a series of more realistic laboratory tasks checking risk-taking behaviour: when motorcyclists were asked to complete the tasks as if driving a car they did not differ from the non-motorcycle car drivers on the risk-taking behaviour. While when they were asked to imagine riding a bike they chose faster speeds, overtook more and pulled into smaller gaps in traffic. These results suggest (coherently with what reported in Accidents and Riders, par.1.1.3) that what distinguish a motorcycle rider from a car driver is a more risky behaviour and an objectively more dangerous condition compensated by enhanced skills.

Hosking, Liu & Bayly (2010) have measured visual search patterns and hazard perception responses of a) experienced motorcycle riders who were experienced car drivers, b) inexperienced motorcycle riders but experienced car drivers and c) inexperienced riders/inexperienced drivers. Participants had to click a response button when an hazard was identified (HP test) while sitting in a scenario that emulated a realistic riding posture: results showed that response times decreased monotonically as experience levels progressed from inexperience on both vehicle to experience on both vehicle.

Instead no effect of experience was found on standard deviation of gaze fixations angles in contrast with the results of Chapman and Underwood (1998) and of Mourant and Rockwell (1972).

When the analysis of deviation of gaze location was repeated using another measure such as the absolute deviation of gaze rotation from the centre of the visual field the results showed that the expert drivers (whether or not they are also expert motorcyclists) reduced the variance of search in the hazard situation with respect to the non-hazard condition, while the novice did not. This result supports the findings of Chapman and Underwood (1998) that experienced drivers have a more flexible search strategy than novice drivers and reduce their spread of search in the horizontal plane in the presence of hazards.

1.1.7 Simulators

The use of driving/riding simulators is expanding rapidly as a consequence of technologies amelioration and because simulators allow to test drivers/riders responses in conditions that would not be safe to study on road for safety reasons.

Driving/riding simulators aim at recreating the real world into a laboratory setting. A main concern is however how much simulation results can be applicable to the real situation. Kemeny and Panerai (2003) claim that simulation fidelity is necessary if results are to be generalised to road situations.

In order to reproduce the driving/riding behaviour a simulator must be provided with a input module (in the simple form including a steering wheel/handlebar and simple pedals, while in the sophisticated version including the entire vehicle structure) and a visual and sound module (providing visual and sound information about the virtual environment); some simulators might include a vehicle's movement feedback, therefore providing to the driver/rider with vestibular stimulation. The discussion we are developing for driving simulators is valid also for riding simulators with adaptations.

Three types of driving simulators can be identified basing the classification on the possibility of the simulator to recreate a realistic driving performance:

- the low-level driving simulators use a regular PC for graphic and controls but may contain extra devices such as a steering wheel, throttle, brake and so forth;
- the mid-level driving simulators are distinguished from the low level driving simulator as they are more advanced, even though they often do not have an advanced motion-based system or visualization;
- the high-level driving simulators are more advanced in graphics and controls and typically provide a 360° field of view and an advanced motion-based system allowing 6 degrees of freedom and providing a good sense of motion during driving.

Visual information plays the most important role in the simulation of self-motion, however the sensory information provided by vestibular and proprioceptive cues also contribute and might be useful to the simulation of self-motion. That explains why high level driving simulators are considered the best option for driving research.

While most of the simulators simply provide the experimenter with behavioural data on the driver's interaction with the vehicle and the environment (speed, lateral position, accelerator pedal pressure, braking pedal pressure, steering wheel angle); some simulators allow also the acquisition of psycophysiological measures (such as heart rate) and the integration with eye trackers. Then the definition of the technologies to use and of the variables considered in the analysis is dependent on the specific task and on the questions at hand: for example, standard deviation of gaze was used for measuring the demands posed by visual and auditory in-vehicle tasks (Victor, Harbluk & Engstrom, 2005).

In sum, the use of a simulator allow to analyse driving performance and eye movements through controlled driving scenarios and with low costs.

However, there are some disadvantages into using a driving simulator: first of all the driver is introduced to a new vehicle and to a virtual reality environment and might take time to adjust to the new situation. Clarion, Leclerc, Petit, Holler, Collet and Mollard (2006) measured skin resistance to assess driver's arousal state on a dynamic-based simulator and results showed that arousal level stabilized after a few minutes, therefore after a familiarization period drivers should be sufficiently used to driving in a simulator. But apart from arousal state, the performance itself could be influenced by the use of a new vehicle and environment. Adjusting to the vehicle and the environment might require a longer time. Therefore when first entering a simulator the driving behaviour might not be representative of actual driving.

This could be a general problem of a simulator not characterizing just the first sessions: it is difficult to know how realistic the driver's experience is compared to real world as visual, sound and motion feedbacks are difficult to recreate realistically.

Finally, another disadvantage that is to be taken into consideration when planning a simulator study is the possibility of simulator sickness.

Driving simulators can be used for different purposes: studying in-car technologies, road design, roads regulations, traffic equipment, safety features in vehicles, drivers' reaction in different conditions (drowsiness, alcohol and drugs use) are some examples. One of the problems with testing hazard perception ability with the hazard perception test is that hazard perception latencies measure only the hazard perception and not the negotiation skill of the driver/rider in the dangerous situation. The ability to adequately face the dangerous situation with appropriate manoeuvres is also related with crash probability.

Moreover analysing the behaviour of the driver/rider can serve the role of evaluating what behaviours are more related with accident involvement.

Previous studies have demonstrated how different driving behaviours such as speed choice (Wasielewski, 1984; Wilson & Greensmith, 1983), car following distance (Evans & Wasielewski, 1983), overtaking propensity (Wilson & Greensmith, 1983) can discriminate between accident-involved and accident-free drivers.

1.1.8 Riding simulators

Horswill & Helman (2003) report differences between motorcycle riders and car drivers (the former are more likely to be involved in an accident than the latter) in speed choices, overtaking and pulling out into small gaps propensities (see the section Motorcycle riding and hazard perception, par. 1.1.6)

Therefore the use of a riding simulator is necessary when apart from riders hazard perception reaction times also the success in facing the dangerous situation or the overall riding behaviour are to be studied.

Liu, Hosking & Lennè (2009) have studied the HP of motorcyclists using an interactive riding simulator (Honda Riding Simulator). They recruited motorcyclists at different experience levels: experienced motorcycle riders with a full driver licence, inexperienced motorcycle riders (learner permit) with a full driver licence, novice motorcycle riders (no learner permit) with a full driver licence, and novice motorcycle riders (no learner permit) with a probationary driver licence. The participants were tested on three scenarios ("Touring", "Avenue", "Path") and the number of crashes, the performance evaluation and the speed decrements at hazards were analysed.

Results showed that, in the Touring scenario, novice riders with probationary driving licence crashed the most frequently with respect to the other groups (including novice riders with full driving licence). The authors provided two alternative explanation for this result: one is that experience as a car driver can be beneficial for motorcycle riders (Wong at al.,1990; Lardelli-Claret et al., 2005), the other is that there is an effect of age that act as a confounding variable as it was demonstrated that young people tend to underestimate the dangerousness of hazards (Groeger & Chapman, 1996), and all the participants recruited as novice riders with probationary driving licence were young (19-23 years) while the other groups were more balanced in terms of age.

Also the results of Hosking, Liu and Bayly (2010), which are similar, could have the same explanation.

The authors interpreted the absence of a difference between the other three experience groups in crash rate as depending on the issue that the proportion of crashes in the simulator is not a reliable indicator of riding experience. An explanation given by the authors is that many of the crashes were due to causes not related with riding skill because of the nature and timing of the hazard. However, Vidotto, Bastianelli, Spoto, Torre & Sergeys (2008) demonstrated that the number of crashes decreases with practise on the simulator, although it is required to complete a relatively long practise (12 routes) to find an improvement.

The second result, obtained by Liu, Hosking & Lennè (2009) just for the Avenue scenario, was that experienced and inexperienced riders had a better performance evaluation (the simulator provides an evaluation of each participant's performance for each event, that is based on the relative distance to the hazard) than novice riders.

The third analysis was run on speed and the results show how, in the Avenue scenario, experienced riders decreased their speed earlier than novice riders after hazard onset, even if there were not differences between experienced and inexperienced riders. This result is in agreement with HP test results that show quicker response times for experienced riders (Hosking, Liu & Bayly, 2010)

1.1.9 The importance of a wider field of view

HP tests basically assess the ability to identify potentially dangerous situations within driving scenarios. Usually experimental set-up used for testing HP contain only the frontal view, which approximately covers 60-80 degrees of visual angle (an exception is in Hosking, Liu & Bayly, 2010), and ignore completely the information that comes from the sides and from behind the vehicle. The limitations in the scenario spatial dimensions reduce the types of hazard that is possible to display, moreover the lack of the information which is usually present in normal driving makes the road and hazard presentation less realistic determining results hard to generalize.

On-road driving situations often requires information from the lateral screens and from the side and rear view mirrors to be evaluated by the driver and previous results have shown that the amount of experience of the driver influences the scanning of the rear and side mirrors (Underwood, Crundall & Chapman, 2002). But with a reduced size of the view these differences are not emphasized in the HP test.

With respect to the classical HP test the presence of more information conveyed from a wider field of view including the rear and side mirrors could have two different outcomes: one could be the overloading of viewer's attention and scanning (as these different sources of information compete for attention and scanning priority) with an increase in mental load (Crundall, Underwood & Chapman, 1999, 2002; Recarte & Nunes, 2000, 2003). On the other side having more elements to take into consideration could a) increase pressure and require a more efficient analysis of the scene preventing from overstaying on uninformative areas or b) determine a greater number of shorter fixations with a low processing power increasing the possibility of Look But Failed To See errors (Brown, 2002; Crundall, Clarke, Ward, Bartle, 2008). In the fist case, overloading attention and scanning could determine an increase in RTs and a worse HP performance for novice drivers (this suggest that the single-screen tests over-estimates HP skills of novice drivers and maybe under-estimates HP skills of experienced drivers). In the other case, rendering the scanning more realistic could improve HP results (this suggests that the single screen set-up might underestimates HP skills of both experienced and novice drivers) or again accentuate the gap between experienced and novice drivers' performances.

Other reasons why a wider field of view could provide a more immersive experience and influence behaviour can be suggested: a more realistic display of information could higher the level of arousal and alertness determining more prompt responses by lowering criterion thresholds; a wider field of view might have more environmental cues related with the hazardous situation allowing a better estimation of distances, speed and time-to-collision (Cavallo & Laurent, 1988) and providing participants with a better situation awareness (Endsley, 1995).

An experiment conducted by Allen, Cook and Park (2005) investigates the role of visual field size on novice drivers' performance using three types of simulator platforms: a single-screen (Narrow Field of View Desktop, 45° field of view, 50% image size), a three-screens (Wide Field of View Desktop, 135° field of view, 50% image size) and a large screen display (Wide Field of View + vehicle cab, 135° field of view, 100% image size); they demonstrated that novice drivers had different behaviours in the single-screen simulator with respect to the other two: they maintained faster speeds, broke more harshly, reduced time-to-collision and had more accidents in the single screen condition. The authors attributed the behavioural differences to the more realistic information provided in the wider field of view conditions.

Allen, Park, Cook and Fiorentino (2007) conducted an experiment on training efficacy and found that the training obtained better results with higher simulation fidelity, ie. wider field of view display.

Shahar, Alberti, Clarke & Crundall (submitted) found a difference in HP response times depending on field of view size: response times were faster when the peripheral information was present (three screens condition) with respect to the situation with only the frontal view. This result suggests that the single screen HP test therefore do not provide a realistic evaluation of HP skill that could be applicable to in-car driving.

1.1.10 Distance, Speed and TTC

In real-driving or simulated-driving, drivers have to control speed and adjust it to the road conditions, for example they need to brake (reduce speed) when they realise that a vehicle is going to intersect their trajectory and crash. Speed reduction depends on the estimated time-to-collision (TTC).

A lot of attention have been devoted to the study of the TTC (over 100 studies were counted in 1999; Gray & Regan, 1999c); the reason of this interest is that the definition of how the TTC is calculated had been in the centre of a debate between two theoretical positions in perception: the traditional indirect approach and the theory of direct perception (Gibson, 1966, 1979). The first argues that computational processing stages are required on the retina message to extract the information to be used for action, in contrast the second claims that perception is a direct reception of information from the environment without computational processing stages.

The following equation (known as the τ equation) defines time-to-collision with an approaching vehicle for the direct perceptual approach:

$$TTC \approx \theta / (d\theta / dt)$$

θ is the oncoming vehicle's instantaneous angular subtense and $d\theta / dt$ is its instantaneous rate of increase (Hoyle, 1957; Lee, 1976).

An alternative equation for the calculation of TTC, which is based on the so-called perceived-distance strategy and referring to the indirect approach of perception, is

TTC ≈ perceived absolute object distance / perceived absolute approach speed

If the perceived-distance strategy is valid, the provision of distance information should improve the TTC judgements. The debate between the two approaches has not come to an end yet, and experiments did not produce incontrovertible evidence in support of any of the two. Some results about the effect of distance cues showed that the performance was not improved by the use of a textured ground plane adopted to enhance distance information (Schiff & Detwiler, 1979). Cavallo and Laurent (1988) argued that the lack of an effect in the Schiff and Detwiler's study was due to a reduced stimulation of the peripheral visual field with respect to real-world conditions, being the peripheral visual field a potential source of distance information. In their experiment they varied the size of the visual field and showed how the accuracy in TTC estimates were significantly more accurate with a wider field.

Although this result does not provide incontrovertible evidence of the validity of the perceived-distance strategy, as the better performance in the wide field condition might be the result of additional retinal-image-expansion information due to the separation of texture elements in the surround (global optic flow, Bardy, Baumberger, Fluckinger & Laurent, 1992; Tresilian, 1991), it allows important conclusions about the accuracy of TTC estimates in different field size conditions.

A series of experiments were run using elements' size manipulation with the purpose of examining if perceived distance influences observer's judgements of time to collision (DeLucia, 1991; Steward, Cudworth & Lishman, 1993; DeLucia & Warren, 1994): the results obtained supported the perceived-distance strategy. In fact observers TTC estimates were influenced by distance cues: a large square with a far starting distance arrived sooner than a small square with a near starting distance (DeLucia, 1991), responses to larger objects started before than responses to small objects (DeLucia and Warren, 1994; Horswill, Helman, Ardiles, & Wann, 2005) and observers initiated braking sooner for larger objects (Steward, Cudworth & Lishman, 1993). This was addressed as the "size-arrival effect" (DeLucia and Warren, 1994).

An interpretation of the conclusions yielded by these studies would be that the misperception of dimensions (i.e. confusing a child with an adult) could lead to an error in the judgement of distance and consequently could determine an error of the TTC estimation.

In a simulated driving task, Caird and Hancock (1994) found that drivers' estimates of arrival times at a junction varied with the size of the vehicle, with smaller estimation of arrival time for smaller vehicles. Therefore, collision avoidance for small objects can occur later than for large objects (DeLucia, 1992). The size-arrival effect was not replicated by Herstein and Walker (1993) that found no effect of vehicle size on estimated time to collision. They suggested that the discrepancy between their results and other data supporting the size-arrival effect was that their vehicles were perceived from a long distance, whereas other studies tended to use relatively near approaching vehicles.

More recently, Horswill, Helman, Ardiles, and Wann (2005) replicated the size-arrival effect using video stimuli of various vehicles approaching a junction at 30 and 40 mph. They found that smaller vehicles, such as motorcycles, were perceived to arrive later than larger objects moving at the same speed. As it could have been argued that the smaller vehicle used in this study were too small for an estimation of the expansion rate (that would therefore allow the use of the tau-equation for the calculation of TTC), the author repeated the experiment controlling that the vehicles in the experiment had an expansion rate above the threshold for calculating tau: the minimum expansion of an image required for detection is approximately 0.17 degrees of visual angle (Hoffman & Mortimer, 1994). Even controlling the expansion rate of stimuli the results were the same.

These results suggest that object size is an important cue for time-to-collision estimation and consequently influences responses to hazards.

Gray and Regan (1999b) have found that when measuring the accuracy of TTC judgements for approaching textured objects, the TTC information provided by the texture elements is weighted less heavily than the TTC information provided by the object size, when the size of the texture elements on the surface of the object is below a critical size (approximately 2-4 arcmins). This result supports the idea that observers base their TTC estimation on different sources in different situations (Gray & Regan, 1998, 1999b). Therefore, when a source is not reliable to provide information on TTC it is given less weight, and this has the effect of favouring the more unequivocal and reliable information (Gray & Regan, 1999c; Tresilian, 1994; Wann, 1998).

It is evident that drivers extract unequivocal and reliable information about the TTC under most conditions, but results on the accuracy of TTC estimates has yielded mixed results (Gray & Regan, 2005): some studies have concluded that observers make large (20-40 %) underestimates of TTC, increasing for larger values of TTC (Schiff & Detwiler, 1979; Cavallo and Laurent, 1988; Groeger, 2000), but the same estimation errors were not observed in other studies (Gray and Regan, 2003).

There is evidence that staring straight ahead during simulated driving on a straight open road adaptation can occur: the expanding retinal flow pattern can cause adaptation of the perceived speed of self-motion determining an underestimation of driving speed (Denton, 1976). The consequence is the illusion that the TTC with other vehicles is longer than it really is (Gray & Regan, 2000).

It was demonstrated that optic flow is important in determining driving speed (Pretto & Chatziastros, 2006): with an increased optic flow velocity, drivers slowed down, while with a slower optic flow they increased their speed. Kemeny and Panerai (2003), considering what parameters influenced perceived speed, discussed the influence of field of view size: when a large field of view is available longitudinal speed can be estimated correctly from visual information (Jamson, 2000). Also general contrast, related with fog conditions, influences perceived speed (Snowden, Stimpson & Ruddle, 1998; Pretto & Chatziastros, 2006), and related to this, also image resolution influence perceived speed (Kemeny and Panerai, 2003).

1.1.11 Brake

A driver usually decides when to start braking depending on his assessment of the urgency of the situation. The degree of urgency depends on various factors: the rate of closing and separation from the obstacle, the speed and deceleration of the other vehicle, and the braking power of the vehicle (Lee, 1976). TTC information appears to be important for the initiation and control of braking (Lee, 1976; Yilmaz & Warren, 1995; van Winsum & Heino, 1996): it seems possible that a driver might tend to start braking when the TTC reaches a certain margin value (Spurr, 1969).

Visual angle expansion is an optical property that could be related with the control of braking (Lee 1976, 1980). Lee (1976) showed that the time derivative of τ (which is specified by the inverse of the relative rate of expansion), called tau-dot, could be used to control deceleration during braking, as it specifies the rate of change in time-to-contact and therefore provides information about whether the level of deceleration is sufficient to stop in front of an object.

Yilmaz & Warren (1995) tested the tau-dot hypothesis (Lee, 1976) and concluded that the current value of tau-dot is used to determine both the direction and approximate magnitude of the next brake adjustment.

Apart from braking control, it is interesting dealing with braking tendency. In fact it is suggested that braking responses in simulated environments depend on experience levels, with experienced drivers braking more often than novice drivers (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002).

1.1.12 The effects of training

Considering the high involvement of young drivers in accidents it is reasonable to ask whether any kind of education or training that involve newly licensed drivers could reduce crash accidents in young population.

Standard drivers education in US (30 classroom hours, 6 on road driving hours, 6 as an observer) have failed to decrease newly licensed drivers' fatalities (Mayhew & Simpson, 2002).

Currently, newly licensed drivers get the necessary skills through simple experience and it can be a slow and inefficient process requiring years rather than hours, it could also happen the intervention of death or injury on the road before the ending of the training process.
The development of training programs that can be conducted in a relatively short period of time and in simple and safe setting conditions rather than on the road have been proposed.
As Hazard perception is such an important driving skill which was demonstrated being related with accident involvement (Horswill & McKenna, 2004), most of proposed training programs aim at developing different skills related with hazard perception and make novice drivers build a mental model of how the elements interact in traffic. This was done pushing novice drivers to make predictions about future events in the system (McKenna & Crick, 1997; McKenna, Horswill & Alexander, 2006) or making them aware of not visible hazard that could happen (Pollatsek, Fisher & Pradhan, 2006).
As differences in anticipation abilities between experienced and novice drivers have been found (McKenna & Crick, 1991), McKenna & Crick (1997) proposed a training programme that could be conducted in a class room setting and aimed at improving hazard perception ability of young drivers. The programme concentrated on forcing the novices to anticipate future situations presenting road scenarios and requiring to make predictions about what would happen next. The effects of the training were assessed employing two parallel HP tests before and after the training: the response latencies of the novice group receiving training have improved by about 0.5 seconds and matched the performance of experienced drivers (using data from an earlier study by McKenna and Crick 1991 for comparison). Whether the effect of training is transient or enduring need to be tested.
McKenna, Horswill & Alexander (2006) used an hazard anticipation training programme and checked afterwards the effects on risk-taking behaviour. The anticipation training consisted in the generation of verbal commentaries (commentary drive technique). And the risk-taking behaviour after the training was checked using a range of established laboratory tests: measures of speed choice (Horswill & McKenna, 1999a), following distance and gap acceptance (Horswill & McKenna, 1999b), speeding and driving violations questionnaire inventories (French, West, Elander & Wilding, 1993; Parker, Reason, Manstead & Stradling, 1995). Results showed that the training effectively decreased risk-taking behaviour, measured with the above mentioned measures.

A video-based training was tested by Isler, Starkey & Williamson (2009). The training was developed to improve HP of young drivers and consisted in requiring a verbal commentary about hazard situations (including potential and immediate hazards) occurring during video-clips viewing. The training was tested measuring participants performance on a hazard perception dual task involving participants in a hazard perception task while tracking and controlling the position of a moving dot within a rectangle on the screen, a task that simulated the steering. After the training the mean percentage of hazards identified by young drivers improved to the level of experienced drivers and was higher than the control group. This training technique seems to encourage drivers to actively search for hazards and improve awareness of the risks involved.

Different types of advanced training have been created, focusing on developing young drivers' ability to check the environment for cues of potentially hazardous situations: as it has been demonstrated that novice drivers do not look at critical elements and are not aware of hidden risks (Pradhan, Hammel, DeRamus, Pollatsek, Noyce & Fisher, 2005), some PC-based training programs (RAPT, Risk Awareness and Perception Training) have been developed at the University of Massachusetts to improve novices' attention to critical regions during the driving (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002). The Massachusetts' group developed several generations of training programs. The training used plan views of specific traffic scenarios that were shown to trainees, coached to appreciate where they should be looking in order to reduce risks. After the training, participants were tested on a driving simulator where scenarios had different levels of similarity to those presented in the training. Participants were scored on whether they fixated the area that could reduce the potential risk within an appropriate time window.

If the problem is mainly related with little spare attentional capacities (see Differences between experienced and novice drivers in visual scanning, par. 1.1.4), the informational training should be ineffective. On the other hand if the problem is related with the lacking of information about where to look then the program could be effective (Pollatsek, Fisher & Pradhan, 2006). The training was successful: trained drivers fixated the appropriate regions on the simulator scenarios significantly more often than untrained drivers. Therefore is looks like novice drivers have an informational problem related with the absence of a mental model of what could be the dangerous situations and what cues might hint them.

The effectiveness of the training have been tested on a driving simulator (Pollatsek, Narayanaan, Pradhan & Fisher, 2006) and have been replicated on the road (Pradhan, Fisher, Pollatsek, Knodler & Langone, 2006). The on road testing of the training was done in the Amherst area (Massachusetts, US) and most of the scenarios were natural, one or two were staged. Results showed the efficacy of the training in rising the number of critical elements spotted on the road.

Another PC-based training program, that was aimed at improving novice drivers' awareness of risks, was developed and tested by Chapman, Underwood and Roberts (2002). The training procedure used videos taken from the driver's perspective with superimposed markers indicating what experienced drivers had looked at and places where potential hazards were located. The training was tested on the road using eye movements and results showed the training increased the percentage of horizontal eye movements.

The Accident Research Centre at Monash University (Melbourne, Australia) developed a PC-based risk-awareness training program (DriveSmart; Regan, Triggs & Godly, 2000) to train four skills: risk perception (the ability to detect, perceive and assess the degree of risk associated with actual and emerging traffic hazards), attentional control (the ability to prioritise attention), time-sharing (the ability to share limited attention between multiple competing driving tasks) and calibration (the ability to moderate task demands according to one's own performance capabilities, Triggs, 1994).

This training, that used video-taped real-world driving scenes, was evaluated on a driving simulator and the driver's awareness of risk was measured using vehicle behaviour, specifically brake onset time. The training resulted to be effective in ameliorating the risk perception and the attentional control skills that, once acquired, persisted for at least 4 weeks. The advantage of the training was valid for traffic situations similar to those encountered during the training but also extended to new ones.

The Driver Assessment and Training System (DATS) was developed and tested by Simulation Technologies, Inc. (Allen, Rosenthal, Park, Cook, Fiorentino & Viire, 2003) and used simulated scenarios with simple controls.

All previously presented PC-based training programs were tested on driving simulator or on the road and all led to a significant improvement in driver's performance.

The effectiveness of drivers' training is however controversial: some studies have reported no significant difference in crash risk after the training (Lund & Williams, 1985; Struckman- Johnson, Lund, Williams & Osborne, 1989), while other studies have demonstrated that the provision of a package of safety measures can be effective in reducing accident rates (Gray, 1990; Gregersen, Brehmer & Moren, 1996).

In sum, the question is what should be trained: while training about specific skills such as skid control have failed to find measurable improvements in accident probability (Katila, Keskinen, Hatakka & Laapotti, 2004; Katila, Keskinen & Hatakka, 1996), training in higher order skills such as hazard perception resulted being effective in reducing crash risk (McKenna & Crick, 1994).

In determining the effectiveness of a training it is important the selection of the efficacy measures: while accident rate could appear an informative measure, it might not be a reliable indicator of training effectiveness (af Wåhlberg, 2003). In fact, an accident can be the result of several aspects of driving ability that could be related with factors not considered during the training, moreover accidents are rare events considered everyday driving behaviour. For this reasons it could be useful to consider other measure to evaluate the effectiveness of the training, an example is measuring risk-taking behaviours like the propensity to maintain higher speed and to overtake (Dorn & Barker, 2005; Horswill & Helman, 2003; Liu, Hosking & Lennè, 2009).

Crundall, Underwood, Roberts (2002) have argued that eye movements training in new drivers may be counter-productive if such programs are asking novice drivers to perform visual scans that exceed their attentional resources.

Ivancic & Hesketh (2000) tested the efficacy of an active training (where participants made their own errors) on a driving simulator task, and of a guided error training (where participants learned from examples of errors) comparing them with an errorless training (where participants drove through a training run not designated to elicit errors). The comparison showed that the active error training group made significantly fewer errors in the testing phase than the errorless learning group, while there were no differences in the testing phase between the guided error training and the errorless learning group.

While the above reported results have been obtained using driving simulators, the same comments apply to riding simulators. Riders' training programs have generally neglected hazard perception skill as an important factor in preventing crash accidents and that therefore needed to be trained. Nevertheless, it is likely that a hazard perception training would be of benefit also for motorcycle riders.

Traditionally, during training, riders learn vehicle control (Chesham, Rutter & Quine, 1993). An evaluation of the effectiveness of US training program highlighted how the on-road accidents rate of trained riders did not differed from that of non-trained riders (Mortimer, 1988). Different results were obtained by McDavid, Lohrmann & Lohrmann (1989) that found that trained riders in a Canadian program had fewer and less severe accidents.

2 Chapter 2

2.1 Hazard perception as a function of driving experience: An eye-tracking study with a wide field of view.

2.1.1 Introduction

A number of studies suggest that the great majority of accidents on the road are due to human error (e.g., Lewin, 1982; Treat et al.,1977; West, French, Kemp, & Elander, 1993), with a great deal of the accidents occurring due to "perceptual" errors (Treat et al.,1977). So called "perceptual" errors consist with lack to perceive and recognize potential hazards (McKnight and McKnight, 2003). It is therefore not surprising that visual search patterns have been identified as one of the most important determinants of drivers' ability to detect hazards (Shinar, 2008). Amongst the differences between experienced and novice drivers in visual search and scanning patterns, there are findings that novices fail to take into consideration critical elements on the road (Pradhan, Hammel, DeRamus, Pollatsek, Noyce & Fisher, 2005), that they scan the rear and side mirrors in an inappropriate way (Underwood, Crundall & Chapman, 2002), and that they scan the road less widely than experienced drivers on the horizontal plane (Mourant & Rockwell, 1972; Underwood, Chapman, Bowden & Crundall, 2002; Crundall & Underwood, 1998) and on the vertical plane (Mourant & Rockwell, 1972).

Apart from visual scanning, differences have been found between experienced and novice drivers/riders also in the behavioural response patterns in HP (McKenna & Crick, 1991, 1994; Hosking, Liu & Bayly, 2010), in speed decrement (Liu, Hosking & Lennè 2009), and in braking responses (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002). Previous studies also have demonstrated how driving behaviour can discriminate between accident-involved and accident-free drivers (Wasielewski, 1984; Wilson & Greensmith, 1983; Evans & Wasielewski, 1983).

Experiment 1 aimed at isolating experiential effects on HP. Considering HP as a multi-level construct that involve perceptual and appraisal processes, in order to differentiate between appraisal and perception, in addition to behavioural measures Experiment 1 also recorded eye-movements. Thus, three groups of drivers including novice-, experienced- and dual-drivers engaged in a HP test in which video-clips of realistic scenarios that involve most of the information that would be available on the road including side views and information from behind the vehicle, are presented on a wide field of view approximating 180 degrees. Based on the literature on HP, it was predicted that experienced drivers will perform better than novices, and that dual drivers will perform even better than experienced drivers.

2.1.2 Methods

Participants

Eighty participants volunteered to take part in this study.

Thirty novice car drivers (0-2 years of driving experience since passing test), 25 experienced car drivers (over 7 years of driving experience) and 25 dual drivers (over 7 years of active motorcycle experience) took part in the study. Of those participants, five novice car drivers, two experienced car drivers and two motorcyclists were excluded from the analysis. Eight participants were excluded on the basis of poor calibration and/ or a large number of missing trials. In order to make the male/ female ratio of the three groups more similar, prior to any data analysis only female participants were excluded from the novice group; those excluded were the ones with the poorest calibration. One experienced car driver was excluded because she had some years of experience riding a scooter.

Table 1. Demographics for the three groups.

	age	Male/female ratio	Car driving experience (years)	Annual Mileage in car	Motorcycle Riding Experience	Annual mileage On

					(years)	motorcycle
Novice	20.6 (2.2)	11/14	1.6 (0.6)	3016 (3356)	0.0 (0.2)	5 (24)
Experienced	33.7 (8.5)	16/7	14.9 (8.0)	9000 (6445)	0.0 (0.2)	173 (834)
Motorcyclists	45.6 (9.0)	17/6	26.1 (10.4)	11613 (8282)	21.1 (10.9)	6196 (4162)

There was a significant age difference between the three groups, $F(2,68) = 73.19$, $p < .001$. A Tukey Post Hoc test revealed that the experienced drivers were older than the novice drivers, and the motorcyclists were older than the experienced drivers. Car driving experience differed significantly between all three groups, $F(2,68) = 64.68$, $p < .001$, with the novice drivers having the least years of experience and the motorcyclists the most. The annual car mileage was significantly lower for the novice drivers than for the motorcyclists and the experienced drivers, $F(2,67) = 11.44$, $p < .001$. Participants in the motorcyclist group had more experience riding a bike, $F(2,68) = 89.65$, $p < .001$, and their annual mileage on the bike was higher than that for the other two groups, $F(2,68) = 49.82$, $p < .001$.

Participants took part voluntarily at this study and received an inconvenience allowance of £10. Participants had normal or corrected to normal visual acuity.

The experiment was undertaken with the written consent of each participant.

Apparatus and stimuli

We used a sub-part of the video-clips used by Shahar, Alberti, Clarke & Crundall (submitted). The filming and editing procedures are decribed in the just mentioned paper

Clips selection

From the footage about 20 HP video-clips each containing one hazardous event and lasting up to 60 seconds were edited so that the rear mirror appeared in the upper part of the central screen, and the side mirrors appeared at the bottom-right of the left screen and bottom-left of the right screen.

12 HP video-clips were selected for presentation in the experiment. Table 1 summarizes the situations presented in these video clips. Most of the clips were staged involving stooge vehicles or pedestrian, while some hazardous situations arouse unexpected during the filming. Apart from the HP clips a set of 54 clips was presented as part of the experimental video-clips sequence: these clips did not contain any hazardous situations therefore their presentation made the hazardous events more rare in the experimental session.

Experimental set-up

Three screens displayed the video-clips around the participant.

The participants faced the frontal screen while the other two were positioned on the sides, rotated with respect to the frontal plane of a 64 degrees angle. The central screen was located at a distance of 115 cm away from the participant eyes, the horizontal visual angle of the central screen was approximately 42 degrees. The lateral screens enlarged the visual field up to 112 degrees. The actual view from the 3 forward cameras on the film car was closer to 180 degrees but the experimental set-up required to condense this angle into a narrower one; though this provoked some distortion of the visual scene three driving experts were consulted and reported to be happy with the display.

The screens were Toshiba 40XF355D televisions (40 inches); a screen resolution of 1280x720 was used. The playback system consisted of a PC endowed with 3 DVI digital outputs converted to HDMI via an adaptor for connections with the monitors. The frame rate of the videos was 25Hz.

A push button and a foot pedal were provided to participants for response recording.

Smart Eye Pro remote eye tracking technology (Smart Eye®) was used for eye movements recordings during the experimental session. Four cameras were positioned around the participant on the table below the monitors. Each camera allowed measurements of head pose and gaze in 3D, allowing free head movements. The four cameras were mounted with 12mm lenses, and provided with two IR-flash illuminators connected on the inner side of the outermost cameras at a distance of 10 cm. The distance between the two innermost cameras was 44 cm, while the external cameras were 33 cm far apart from the internal ones.

After cameras calibration the 3D position and orientation of the head was estimated by tracking a number of facial features in the image of the subject and then matching these feature points to a 3D head model adapted to the subject. The iris and pupils were localised to determine the subject's gaze direction, using a calibrated geometrical model of the eye. The system sampling rate was 60 Hz.

Smart Eye Pro 5.4 software (Smart Eye®) controlled face features profiling, eye calibration and the recording of the geometrical coordinates of gaze position on the screens.

A replay visualization of gaze positions on video-clips was exported in avi format using TripleVideoComposer software (SmartEye®). The gaze replay video-clips were then converted into Mpeg2 format for analysis of gaze positions with The Observer XT 8.0 software (Noldus Information Technology®). Fig 1 displays the multi-screen and eye tracking cameras set-up.

Figure 1. Multi-screen and eye tracking cameras set-up.

Procedure

Each participant received the information sheet and subscribed the consent form. During the experimental session participants viewed 70 clips: 12 HP clips and 58 clips from two categories: t-junctions clips and changing lanes clips. A recorded voice introduced which the task was before each clip, except for HP clips that received the same instructions of the t-junction clips. The instructions introduced participants that they would see a series of short video clips taken from the perspective of a driver in a moving vehicle, and that the central screen would display the front view, while the right and left screens would display the side views, in addition rear and side mirror images would allow to see information from behind the vehicle. The participant were exhorted to watch the video as if they were the driver controlling the car and a voice would have told them what the driver-participant intended to do during the clip. The task was taking a decision in each clip about the starting of a manoeuvre and pressing a button when it was safe to do so: two kinds of manoeuvre were required depending on the clip, in some clips participants would drive along one or more roads until reaching a T-junction and the participant was requested to press the button as quickly as possible when he felt it was safe to pull out to the right; in some other clips the participant was required to press a button as soon as possible when he could change lane to the right without risk of a collision. Participants were warned that some clips might terminate before having the chance to make a response but that most would have given them enough time for a quick but safe response. Moreover, participants were instructed to keep an eye out for any hazardous situation in all of the clips and to press the foot pedal as soon as possible whenever they spotted an hazard. Hazards were described as situations where a dangerous event occurs that would normally determine a brake or a swerve to avoid a potential collision. As an example participants were presented with the following scenario: you are watching a clip where you have been told to press the button to turn right at a t-junction, but before you reach the t-junction another car suddenly violates your right of way. This could be considered an hazard and you should press the foot pedal as quickly as possible to show that you have spotted it. The video clip may then continue and you eventually reach the t-junction and then press the button to pull out when you feel safe.

The video-clips presentation lasted about 30 minutes. The system displayed a feedback after each press making it clear that a foot pedal or button presses had occurred. While the clip continued after pedal presses, the button presses ended the clip. Video-clip were presented in a random order; a blank screen was present for 3 sec between subsequent video-clips.
In this report we will report the results concerning the hazard perception clips.

Design

A 3(x3) experimental design was used comparing a group of experienced drivers, a group of novice drivers and a group of dual drivers (car and motorcycle drivers). Separate analyses used either the initial location of the object that would later become a hazard (hazard appearance) or the location of the object at the beginning of the hazardous situation (hazard onset) as the within-subjects factor.
For the analysis of the initial hazard location (hereafter, hazard appearance) the 12 clips were categorized in 3 groups: four clips (1, 2, 6, 7) had the object appearing within the central 50% of the central screen (central condition), in three other clips (3, 8, 10) the to-be-hazard first appeared on either the left 25% or on the right 25% area of the central screen (peripheral condition) and in two other clips (11, 12) the object was first visible through either one of the lateral screens in the side mirrors, in addition to the central screen through the rear view mirror (the lateral condition).

For the analysis of hazard location at onset the 12 clips were also categorized in 3 groups, though differently for the central and peripheral conditions: using the same criteria to define each condition (central 50% for the central condition etc.) the central condition consisted of 7 clips (1-5, 7, 9), the peripheral condition consisted of three clips (6, 8, 10), whereas the lateral condition remained the same (11, 12).

Clips 4 and 9, which were included in the onset analysis (in the central condition) were not included in the appearance as in these clips appearance of the hazardous events was coincident with the hazard onset . The data of clip number 5 were excluded from the analysis as none of the participants, except one, went through the hazardous situation, because of clip aborting by button pressing. The dependent variables were HP reaction times (RT) and Gaze latencies to the hazards onsets (in seconds). Gaze latencies to hazards appearances were also analysed. The onsets for RTs analysis were defined a priori by two driving experts and differed between hazards. Missing responses in RT data were assigned a maximum RT that was based on either an a-priori offset depending on time-to-collision, or, if later responses were present, based on the time of the latest response. For each hazard, missing gazes on these hazards were assigned maximum latencies that were based on the time of the latest gaze latencies for those hazards. For video clips which were aborted before hazard offsets (i.e., instances in which participants pressed the button to commit themselves to a manoeuvre – change lanes or pullout of a junction - rather than the foot-pedal in response to a hazard) the mean of gaze latency values was assigned.

Table 2. Descriptions and hazard onsets of the hazards presented in the video clips.

	Hazard	Description	Hazard onset
1	Bicycle enters the road	The film car is travelling on a 30 mph suburban road. Ahead, a bicycle appears on the pavement from the left hand side and enters the road in front of the film car.	When the front wheel of the bicycle reaches the edge of the pavement.
2	Car invading the lane	The film car is travelling on a 30 mph suburban road, approaching a t-junction. A car approaches from the left hand side and turns right into the road cutting the corner in front of the film car.	When the car begins to turn.
3	Pulling out lorry	The film car is travelling on the central lane of a 30 mph three lane urban carriageway. A lorry, ahead in the left lane suddenly signals and immediately turns right, entering the lane in front of the film car.	When the lorry's signal onsets.

4	Pedestrian enters the road (1)	The film car is travelling on a 30 mph one-way urban road. A pedestrian, hidden from view by a parked car enters the road from the left hand side and crosses in front of the car.	When the pedestrian steps out from behind the car.
5	Car reversing into lane	The film car is travelling on a 30 mph one-way suburban road. A parked car suddenly reverses out of a parking driveway from the left hand side, invading the lane.	When the car starts reversing.
6	Car pulls out	The film car is travelling on a 30 mph one-way suburban road, approaching a right turn. A car is driving in front of the film car. It stops on the left hand side and suddenly pulls out again and turns right in front of the film car.	When the braking lights of the vehicle ahead offsets.
7	Opening door	The film car is travelling on a 30 mph suburban road. A van is parked ahead on the left hand side. The door of the van suddenly opens and the driver steps out.	When the door begins to open.
8	Car reversing into lane	The film car is travelling on a 30 mph suburban road. At a crossroads ahead a car is reversing, invading into the lane.	When the car starts reversing.
9	Pedestrian enters the road 2	The film car is travelling on a 30 mph suburban road. A pedestrian, hidden from view by a van parked on the left hand side of the road, enters the road and crosses in front of the film car.	When the pedestrian steps out from behind the van.

10	Right of way violation at crossroads.	The film car is travelling on a 30 mph suburban road, approaching a crossroads. A car enters the crossroads from the right, violating the right of way of the film car.	When the car crosses the give way line onto the main carriageway.
11	Motorbike undertaking	The film car is travelling on a 40 mph suburban road. As the road opens to become a dual carriageway a following motorcycle undertakes the film car. The motorcycle can be seen simultaneously in both the rear view mirror and left side mirror, before entering the left lateral screen and then the central screen.	When the motorcycle speeds up to undertake.
12	Car approaches from slip road and undertakes	The film car is travelling on the right hand lane of a 40 mph dual carriageway road. A car in the left hand lane speeds up to undertake the film car and then moves into the right hand lane without due warning or headway. The car can be seen in both the rear view mirror and the left view mirrors, before entering the left lateral screen and then the central screen.	When the car speeds up to undertake.

2.1.3 Results

Accuracy rates, calculated as the percentage of HP clips that obtained a pedal press, did not differ between groups ($p>0.05$), suggesting that all groups were equally capable of detecting hazards.

In a univariate ANOVA performed on the number of pedal presses per clip, the main effect of experience was significant ($F(2,68)=3.10$, $p=0.05$). the post-hoc analysis (Tukey correction) showed that only experienced drivers (M = .84; SD =.31) pressed the foot pedal more often than novice drivers (M = .63; SD =.32; p=0.04), while motorcyclists (M = .68, SD=.24) did not press the pedal more often than novices (p>.05).

A 3x(3) ANOVA (experience x (location)) was performed on the gaze latencies on the objects that later developed into hazards. The main effect of Location was significant (F(2,136)=261,60, p<0.001)., Pairwise comparisons (corrected with Bonferroni procedure) showed indicated that lateral hazards (M=5.53, SE=.29) were spotted later than peripheral hazards (M=0.88, SE=.04; p<0.001), which were spotted later than central hazards (M=0.47, SE=.02; p<0.001). The main effect of Experience was significant (F(2,68)=6.99, p<0.005). Pairwise comparisons (corrected with Bonferroni procedure) indicated that the experienced drivers' group (M=1.89, SE=.18, p=0.002) and, marginally, the motorcyclists' group (M=2.19, SE=.180, p=0.051), were both quicker in detecting a potential hazard than the novices' group (M=2.80, SE= .17). The interaction between Location and Experience was significant (F(4,136)=7.17, p<0.001). Figure 2 displays mean gaze latencies for novice and experienced drivers and for motorcyclists, for the hazard appearances in the three location conditions. Pairwise comparisons (corrected with Bonferroni procedure) indicated that for each experience group gaze latencies were shorter for central hazards with respect to peripheral hazards (p<0.01) and for peripheral hazards with respect to lateral hazards (p<0.0001). Corrected pairwise comparisons between the three experience groups within the lateral hazards condition indicated that novices were slower in directing gaze to the hazard than both experienced drivers (p<0.001) and motorcyclists (p<0.05), but the difference between motorcyclists and experienced was not significant (p>0.05).

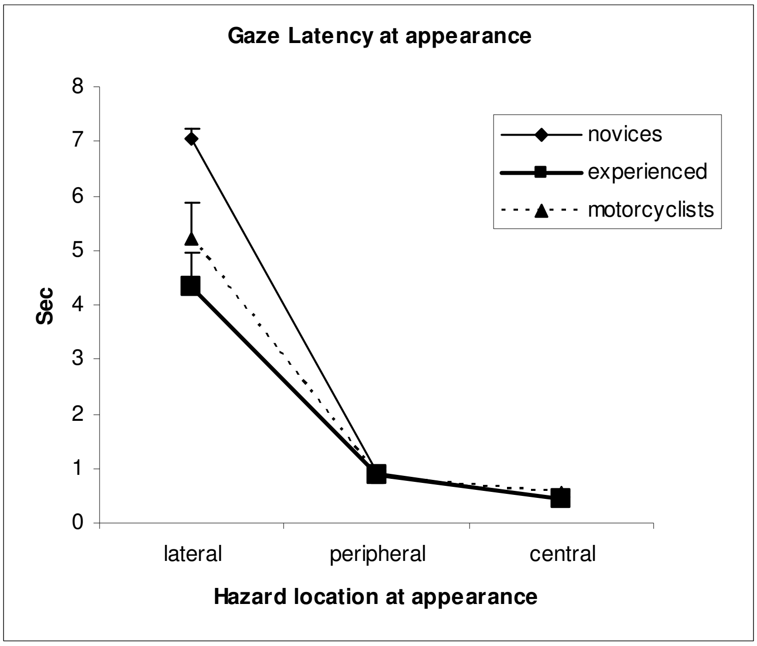

Figure 2. Mean Gaze Latencies for novice and experienced drivers and for motorcyclists, for the appearance of lateral, peripheral and central hazards. Error bars represent standard errors of means.

A 3x(3) ANOVA (experience x (location)) was performed on gaze latencies after hazard onsets. The main effect of location was significant ($F(2,136)=140,28$, $p<0.001$), indicating that gaze latencies to lateral hazards ($M=1.83$, $SE=.12$) were longer than latencies to both peripheral ($M=.27$, $SE= .03$, $p<0.001$) and central hazards ($M=.35$, $SE= .01$, $p<0.001$).The difference between the peripheral and central condition only approached levels of significance ($p=.08$). The main effect of experience and the interaction were not significant [$p > .05$]. Figure 3 displays mean gaze latencies for novice and experienced drivers and for motorcyclists, for hazards onsets in the three location conditions.

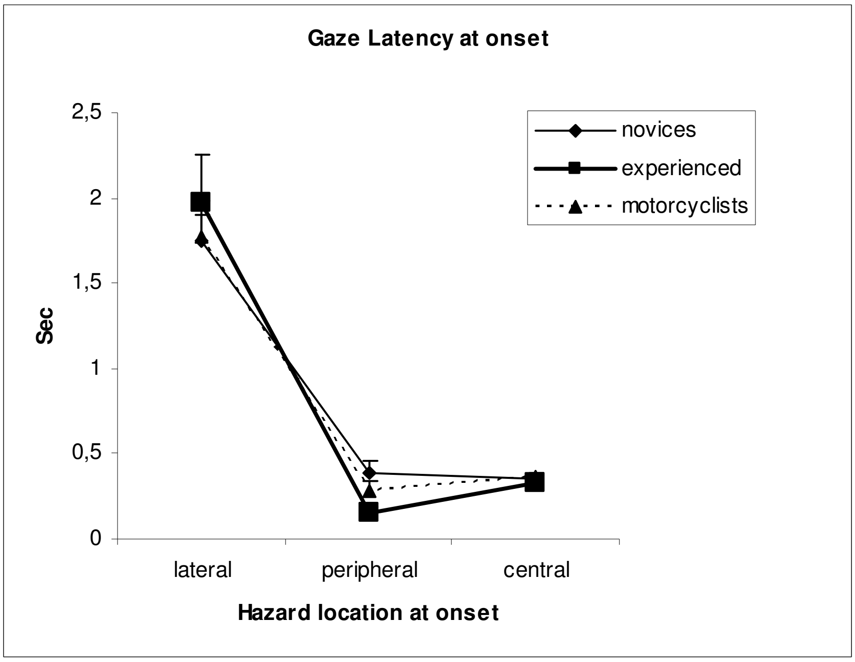

Figure 3. Mean Gaze Latencies for novice and experienced drivers and for motorcyclists, for the onset of lateral, peripheral and central hazards. Error bars represent standard errors of means.

A 3x(3) ANOVA performed on RTs for the pedal presses yielded a significant main effect of Location (F(2,136)= 465.167, p <0.001). Pairwise comparisons (corrected with Bonferroni procedure) showed that RTs were slower for lateral hazards than for peripheral (0.001) and central (0.001) hazards. The main effect of Experience was also significant, (F(2,68)=8.12, p<0.001), with novices (M=4.48; SD =11) responding to the hazards slower than experienced drivers (M= 3.95; SE =,12; p=.008) and motorcyclists (M= 3.85; SD =.12; p=.001). The interaction was also significant (F(4, 136)=2.881, p<0.05) . Figure 4 displays mean reaction times for novice and experienced drivers and for motorcyclists, in the three location conditions. Pairwise comparisons (corrected with Bonferroni procedure) showed a difference between the lateral and the peripheral hazards and between the lateral and the central hazards for the three experience groups. Only for hazards onsets in the peripheral location, motorcyclists' (p=0.001) and, marginally, experienced drivers' (p=0.057) RTs were shorter than novices'; while motorcyclists' RT did not differ from experienced drivers' RT (p>0.05) .

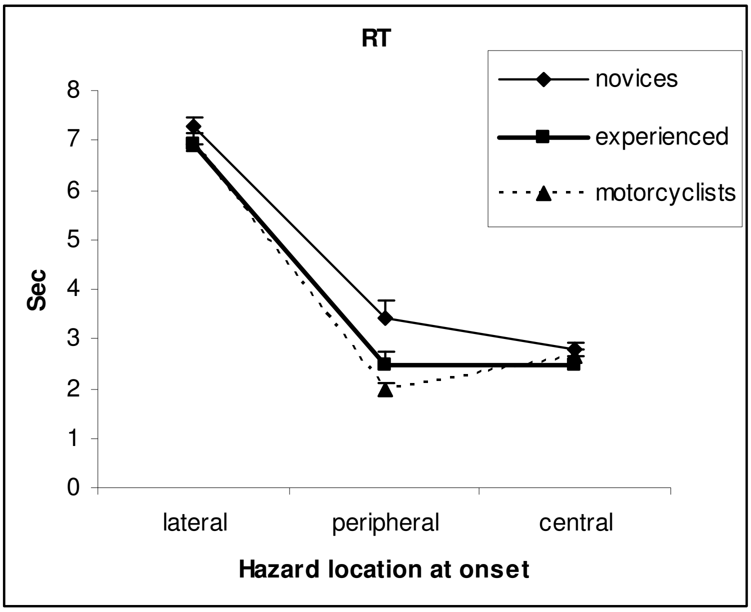

Figure 4. Mean RTs for novice and experienced drivers and for motorcyclists, for lateral, peripheral and central hazards' onsets are displayed . Error bars represent standard errors of means.

Table 3. Mean Gaze Latencies and RTs for lateral, peripheral and central hazards.

	Gaze Latency- apperance	Gaze Latency- onset	RT
Lateral	5.53	1.83	7.05
Peripheral	0.88	0.27	2.61
Central	0.47	0.35	2.61

Table 4. Number of participants directing gaze to the hazard after appearance, after onset and responding to the hazard for each clip.

	1	2	3	4	6	7	8	9	10	11	12
Gaze after appearance	57	65	56		67	59	60		59	59	17
Gaze after onset	59	67	61	39	67	58	68	55	66	49	17
RT	42	35	52	38	53	25	67	46	66	23	8

2.1.4 Discussion

The results indicate that the first gazes at to-be-hazardous events are impaired differently for the different experience groups, depending on eccentricity (hazards in the side and rear mirrors were considered the most eccentrical positions). Compared to experienced and motorcyclists, novices took longer to fixate at objects (prior to becoming hazardous) that appeared on the outermost position on a three screen setup. This finding demonstrates an initial delay in detecting potential dangerous situation when displayed peripherically in the visual field. The difference between the experience groups disappears as the potential hazard becomes a hazard.

While the three groups have similar gaze latencies after hazard onset, suggesting that participants of the different groups detected the hazard at the same time, the analysis of pedal pressed indicated a difference between groups in the peripheral location where on average novices were slower to press the pedal than the other groups. The absence of apparent differences in gaze latencies for peripheral hazards suggests that the delay in responses to peripheral hazards reflects group differences in defining an event as hazardous (i.e., higher thresholds amongst novices) rather than visual search impairments.

The analysis on the button responses, that signal hazard recognition, show a difference between groups: while all groups are equally good at perceiving an existing hazard situation, when the presence of the danger is to be signalled novices show later responses than the other groups. And this effect is asymmetrical between locations resulting particularly relevant for peripheral hazards: while central hazards obtain a prompt response by all groups, novices show a late recognition for peripheral hazards. The absence of the effect for gaze latency data suggest that this delay cannot be considered as due to visual search impairments, but some other reason should be identified. One explanation could be a difference in response criterion, as reported by Wallis and Horswill (2007): novice drivers are less willing to label traffic scenarios as hazardous or do not experience the same urgency to respond to them. This explanation does not take into account the eccentricity effect though. Further explanations which take under account the role of the availability of a wider field of view are developed in Chapter 4. Briefly, the presence of lateral information may provide a more realistic experience, possibly influencing arousal and alertness, or alternatively enhancing scanning of the scene. Yet another alternative corresponds to making use of the more available environmental cues (i.e., situation awareness, Endsley, 1995) that provide more information about the interaction between the driver and the environment (for more details on all of these explanations, see Shahar, Alberti, Clarke & Crundall, Submitted) . It is possible that novice drivers make less use of the lateral information due to less efficient spread of search over a wider space. In respect to Endsley's situation of awareness theory (1995), the asymmetry between locations for the experience groups in Experiment 1 could be reflect either perception processes (Level 1), or higher level stages such as comprehension or projection.

For example, a novice driver might be less capable of achieving the same level 1 SA as an experienced driver, as suggested by the longer gaze latencies to objects before these become hazardous. Alternatively, a novice driver might be able to achieve the same level 1 SA as an experienced driver, but fail to comprehend the significance of objects and events or fail to integrate the various data elements with pertinent goals, as suggested in the current experiment by the fact that groups do not differ in gaze latencies after onsets but do differ in response times to peripheral hazards.

Endsley (1995) considers how SA is "highly temporal in nature" and "highly spatial in many contexts" (p.7). SA in driving, as well as in other fields, is concerned with the spatial and the functional relationship between environmental components such as the location and speed of other vehicles relative to the car and the car's goals. In this way elements may vary in their relevance across time and through space. In addition to the explanations detailed above it is quite possible that novices' slower responses to peripheral hazards reflect the narrowing of visual attention (tunnel vision) due to mental load which is higher in novice drivers as compared to experienced drivers and motorcyclists, as novices use more attentional resources to the task of driving which has not yet become automatic. In other words, the high load could thus lead to a reduction of the resources' distribution, damaging primarily the periphery of the visual field. Consequently, novices might detect peripheral hazards, and yet due to less processing capacity not consider them as such.

While based on this explanation one would expect the same and even a more robust pattern for lateral hazards, it is likely that the absence of such an effect reflects a floor effect, possibly due to the characteristics of the lateral hazards in our clips: the hazards appeared in the mirrors and in the majority of the times participants did not respond to these hazards. Nevertheless, such a pattern (poorer performance amongst novices to lateral hazards) was found in the analysis of the appearance of the hazards: novices were slower (than the other groups) to look at the lateral objects before these became hazardous.

The difference between the lateral and the other hazard categories is depending on the lateral hazard development: the hazard is appearing in the rear and wing mirror and it takes time to be initially spotted as it is in a very peripherical and less checked position (the back of the car), and even when the first hints are given that the to-be-hazard is turning into an hazard the probability of it being spotted are very low, or if gaze is directed on it, it has a late latency, and the responses on the button are consequently late. Therefore the results for lateral hazards can be interpreted as follows: distant and (apparently) less influential objects require more time to be seen or are not perceived at all and this time is even larger for people who are not used to take into consideration such locations.

Our results overall confirm that the presentation of video clips is still a good diagnostic technique for evaluating HP but without the support of the wide-view setup it looses a lot of its diagnostic power.

In sum, thanks to this setup we put in evidence the dissimilarities in spotting ability and response times between hazards presented in different screen locations for the different experience groups.

Thanks to eye measures we could develop interpretations not only on the HP response times but also on the process of hazard monitoring, and gain some results that would have not been observed otherwise.

3 Chapter 3

3.1 Using eye-tracking to assess the effectiveness of practice on a riding simulator designed for hazard perception training.

3.1.1 Introduction

Lack of experience look to be a key factor in road safety. For example, the higher involvement of young people in accidents is not solely related with personal (e.g. risk-taking behavior) and social background (e.g. group affiliation, role expectation, social dependence) but mainly to a lack of experience (Cooper, Pinili & Chen, 1995). Experienced drivers show a major number of driving practices, a refined capability of self-assessment, an increased automatization of drive-related actions with a consequent reduction of request for cognitive (mainly attentive) resources and a diminished mental workload (Gregersen & Bjurulf, 1996). Young drivers, that are typically a low experienced group, are the population most involved in accidents and the percentage of fatalities within young population (16-24 years old) reach 20,8%, a big proportion compared with the 51.3% of fatalities that interested people between 25 and 65 (Hoeglinger, Angermann, Weiss, Bos, Berends, Yannis, Evgenikos, Broughton, Lawton & Walter, 2006).

The use of simulators provides new possibilities to train users to a dynamic task such as driving. Using a set of driver controls (i.e., steering wheel and pedals), the user interacts with a simulated vehicle and navigates it in real-time through a virtual driving environment. The advantages that this training technique has over traditional methods (e.g using real cars) are first of all the possibilities to experience driving behavior in a safe environment, without stress or real risk for person or property and permitting a more efficient learning by reassuring the trainees during the driving. Second advantage offered by simulator is the possibility to easily create several different scenarios, bringing learning in more or less dangerous situation, and permitting several kind of experiences and different opportunities to monitor driving behavior (e.g. simulator normally permit to replay our action and to observe it from different prospective) . These two advantages permit to train people to situations that would normally be too cost-prohibitive or too dangerous to perform in a real vehicle on an actual road. Another advantage is the possibilities offered by simulator to be readapted to drive different vehicles: with a small effort it is possible to permit training with motorbikes, cars, trucks, airport vehicles, ambulance or other "special" vehicles.

Complex driving simulator have also an extensive use in scientific research; a review of recent development in the design of simulators for research purposes, including a chart summarizing the features of recent driving simulator and their pro and cons., have been recently provided by Pinto, Cavallo and Ohlmann (2008) that promote the idea of a multisensory stimulation (visual, motion, tactilo-kinesthetic, and sound stimulation) to design state of the art simulators. Anyway basic computer-based driver simulator look to offers an easier and cheaper, but actual solution for hazard perception training purpose. Because of their accessible price this kind of simulator can be adopted by school,

driving school, training center offering a real contribution to train inexperienced drivers. Several works clearly indicates that PC-based training systems have a significant impact on driving behaviors of novice drivers (Allen, Rosenthal, Park, Cook, Fiorentino & Viirre, 2003; Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002; Regan, Triggs & Godley, 2000). Training offered by these systems can also have more appeal, especially on young people that are more familiar with videogames and simulator; from this prospective driving simulator could be considered as persuasive technologies, tools able to persuade people in to change their behavior and their attitude (Fogg, 2003).

Compared to other training systems (e.g. video-based training) simulator offer the potential of provide an active learning, involving participant during all the tasks sequence. The potential of driving simulator, in term of active processing during training, have been investigated by Ivancic and Hesketh (2000). In this work authors investigate the relative effectiveness of error training on driving skill and self confidence. A reduction in the number of traffic offence is observed when providing an active training, with respect to when the participants are trained on video-clips. Driving simulator appears to be a suitable and effective interface also for elderly people (Liu, Watson & Miyazaki, 1999).

Anyway also some limits have been identified (Kemeny & Panerai, 2003); for example because of the existence of several different simulators prototypes a lack of standard is registered (Pinto, Cavallo & Ohlmann, 2008). This factor makes difficult to generalize result on the efficacy and efficiency of these machines. In order to avoid problems that could arise with the adoption of uncommon simulators, we decide to adopt the Honda Riding Trainer (HRT) whose efficacy as tool to improve hazard perception and awareness have been recently demonstrated (Vidotto, Bastianelli, Spoto, Torre & Sergeys, 2008; Liu, Hosking & Lennè, 2009); we also consider the role of the social context of the training situation, adopting the most favorable setting as suggested in recent works (Spagnolli, Bertoli, Chalambalakis, Scottini, Turra & Gamberini, 2007).

Although several description have been provided, hazard perception construct still suffer because of the absence of a common shared definition. It is generally described as the ability to perceive, understand and anticipate risky situations, or the ability to quickly perceive and respond to a potentially dangerous driving event.

Hazard Perception often refers to the identification of dangerous traffic events as they arise (Soliday, 1974; McKenna & Crick, 1994; Velichkovsky, Rothert, Kopf, Dornhöfer & Joos, 2002) representing a human factor of extreme relevance for driving activities and road safety. Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stanisfer, and Castellan (1977) in a five years long study found that on a 2258 automobile accidents cases only a very small percentage of them can be ascribed to mechanical fault (2.4%) or environmental factors (4.2%) when human error was a contributing factor of error in 92.6% of cases and the sole cause of accident in 57% of all the considerate cases. On this last percentage, 90% of the accidents were depending on "perceptual" errors and only 10% were caused by human response error. Similar results have been found in research that have been applied to industrial work activities (Heinrich, 1959), to medical contexts (Cooper, Newbower, Long & McPeek, 1978) and to maritime transportation (Rothblum, 2000).

According to the field analysis of McKnight and McKnight (2003) on 2000 police crash reports the largest fraction of accidents involving young drivers was due to failures of attention and visual search and not to high speeds and risky behaviour.

According to Sagberg and Bjørnskau (2006) hazard perception can be composed by two separable components: "the degree of perceived hazard associated with the situation" and “the perception/reaction time to the perceived hazard”. The idea of a multi-component composition of hazard perception is common in recent literature; for example Deery (1999) introduced a two-component model based on both driving skill like hazard perception latency, and subjective experience like the evaluation of danger potential. Also the Situation Awareness and Hazard Perception model proposed by Endsley (1995) refer to a multi level description of these constructs: level 1 “perception”, level two “comprehension” and level three “projection”, where level 1 is normally considered the most important because “without seeing and perceiving the necessary information it will be difficult, perhaps impossible, to achieve level 2 and 3” (Jackson, Chapman & Crundall, 2009).

Eye-tracking systems have been extensively used to investigate drivers’ behaviors and their skill. In this work, adopting a well know simulator, we will focalize on the perceptual level discussed above, considering as dependent variable the first fixation latency, that is the time spent by subject to fixate (with their eyes) the visual area of the danger since it onset. In this way we would like to in deep understand the origin of the training efficacy of the HRT demonstrated by Vidotto et al. (2008) According to Nagayama (1978) 50% of all collisions in road traffic arise from a missing or delayed hazard perception. This drivers failure in to perceive road-traffic hazards is often due to the fact that the drivers failed to attend, because of their lack of experience and because their mental resources were focused elsewhere, a failure that could be particularly relevant in low level experience drivers. We will consider eyes fixations moving from the central position of the visual field (when users control the road) to periphery, in the area where the hazard position appear; consequently, we will take into account fixations that only happen when the participants identify that peripheral events like possible hazards (comprehension-level two in Endesly, or the evaluation of danger potential in Deery). If the origin of the training capabilities of the HRT to improve driving performance in avoiding accidents (Vidotto et al., 2008) come from their potentialities to create experience in perceiving and recognizing hazards, the fixation latency of the hazard that we will record with the eye tracking should decrease.

3.1.2 Methods

Participants

A group of 14 students from the University of Padua voluntarily took part at the experiment. Participants were between 20 and 25 years old (7 females and 7 males; *M* = 23.28 years, sd= 1.59). They were selected because they reported no driving experience on mopeds and had not a motorcycle license. Participants covered a mean of 25.35 km (sd=16.34) in a week and reported the bicycle as the most used means of transportation. None of the participants was discarded as good eye tracking data are available. Participants had normal or corrected to normal visual acuity. The experiment was undertaken with the written consent of each participant.

Apparatus and stimuli

Eye tracking apparatus

Eye movements were recorded with a remote eye monitoring system (Tobii 1750, Tobii®) based on combined corneal and pupillary reflection. Tobii 1750 integrates the camera and infrared lighting into a TFT 17" monitor (1024x768 resolution). The system has an accuracy of 0.5°, a sampling frequency of 50 Hz and a reacquisition time inferior to 100 ms. The system permits a relatively high freedom of movements as the camera has a recording field of 20x16x20 cm, the chinrest is not necessary. We used the Clearview 2.7.0 software (Tobii®) to record data on x and y user's gaze screen coordinates; the same software also recorded the video. From gaze coordinates an algorithm was used to extract fixations considering the co-existence of more gaze-points within an area of 1.58° visual angle, for a period of at least 100ms. Eye position was calibrated at the beginning of the experiment by asking the participants to follow with the eyes a moving dot on the screen.

Driving simulator

Honda Riding Trainer (HRT), in Figure 1, is a compact driving simulator with the commands of a real motorcycle; it was created by Honda for the prevention of a risky driving behaviour, as a consequence of the agreement on the European Road Safety Charter in 2005. Different traffic situations are proposed in the HRT interactive environment; it is possible to select among different traffic scenarios like "Avenue", "Path" or "Touring", and different visibility conditions like daylight, night or foggy. The HRT allows the selection of automatic or manual riding mode. Each route contains a certain number of hazards scenes; their occurrence and gravity depends on the driving style (mostly on speed). For this work we asked participant to ride a moped (automatic mode) in city main streets and in daylight condition.

Figure 1. shows the experimental apparatus, with the Honda Riding Trainer and the Tobii eye-tracker

Stimuli

The environment was presented on the 17'' monitor of the Tobii eye-tracker, located at a distance of 60 cm away from the participant eyes, therefore it subtended an area of 31,6 x 25,3 degrees visual angle; the video had a frame-rate of 24 Hz.
The speedometer and the wing mirrors were visualized at the bottom and on the sides of the screen. Urban main roads were usually single-carriageway roads with different kinds of vehicles, bicycles and pedestrians running in. We consider all the hazards that matched the criterion to emerge from the screen periphery and heading toward the moped. Each of the routes we selected contained four hazards filling this criterion.

Procedure

First each participant had a practice session during which participants had to ride on a desert road in order to get acquainted with the commands.
After practice participants had four riding sessions during which they faced traffic situations and some hazards appeared along the route.
Participants were asked to maintain a speed between 30 and 40 Km/h when on the back straight and when possible. Usually the completion of a route took 4-6 minutes driving at the suggested speed.
Selected routes were presented once to each participant and the order of presentation was counterbalanced between participants. Eye movements were recorded during the experimental sessions.

Design

Participants had four sessions. Fixation latencies were recorded in the first and last sessions. The latency of the first fixation on the hazard area from the starting of the hazard temporal window was measured. As a consequence of the interactive driving in the simulator, the time window for each hazard was varying between participants, therefore we had to define which was the onset of each hazard for each participant. We defined as onset the moment in which the hazard appeared on the screen or the moment in which it started moving if it was already visible but still.

Fixations located less than 3.57° away from the central vertical axis of the screen were not included in the analysis. Fig. 2 shows a frame extracted from the video representing an hazard within the area of interest (AOI), the sequence of fixations on the hazard is displayed.

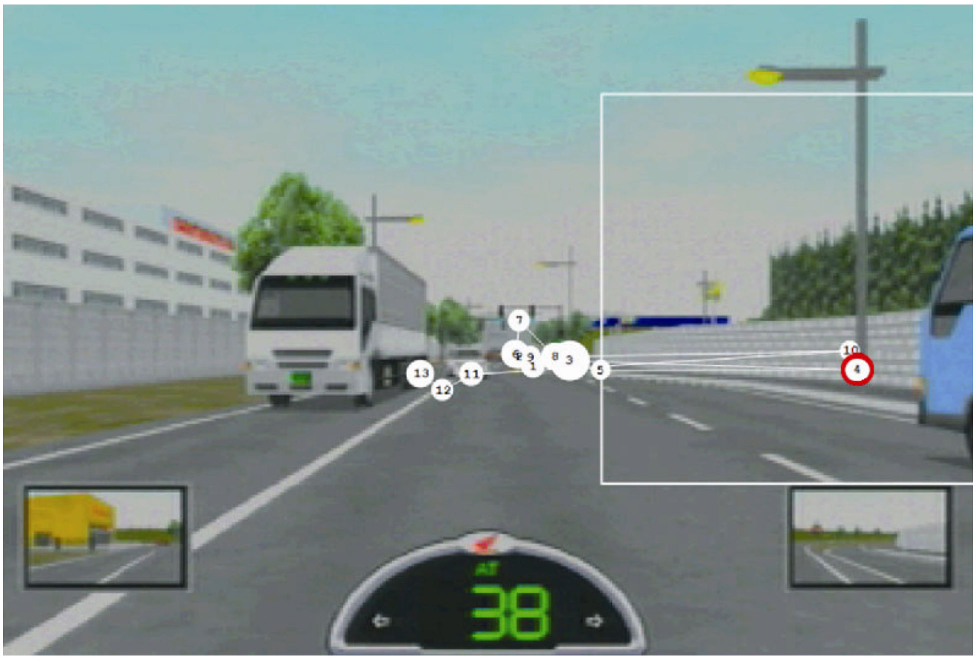

Figure 2. A frame extracted from the video with the AOI and the sequence of fixations on the hazard, the first fixation on the hazard is highlighted in a circle.

3.1.3 Results

In order to determine the effect of the simulator training on hazard perception the presence of fixations on hazard areas and the latency of these fixations were considered. From a first analysis on the number of hazards fixated it resulted that 94% of the hazards were fixated in the first session and 98.11% in the last. Wilcoxon matched-pairs, signed-rank test showed that there is not a difference between the first and the last session in the number of hazards fixated (exact $p>.05$, one-tailed).

Fig. 3 shows the mean fixation latency on the areas of the hazards for the first (M= 2909.43 ms, st.error= 1022.18) and for the last session (M= 1022.56 ms, st.error= 121.46). A paired-samples t-test demonstrated that the time required in the last session to perceive an approaching hazard is significantly lower than the time required in the first session ($t=1.84$, $df=13$, $p=0.04$). The Cohen's *d* measure of effect size suggests that the training has an effect on fixation latencies and that after four sessions the hazard perception improves (Cohen's $d = 0.49$; Cohen, 1988).

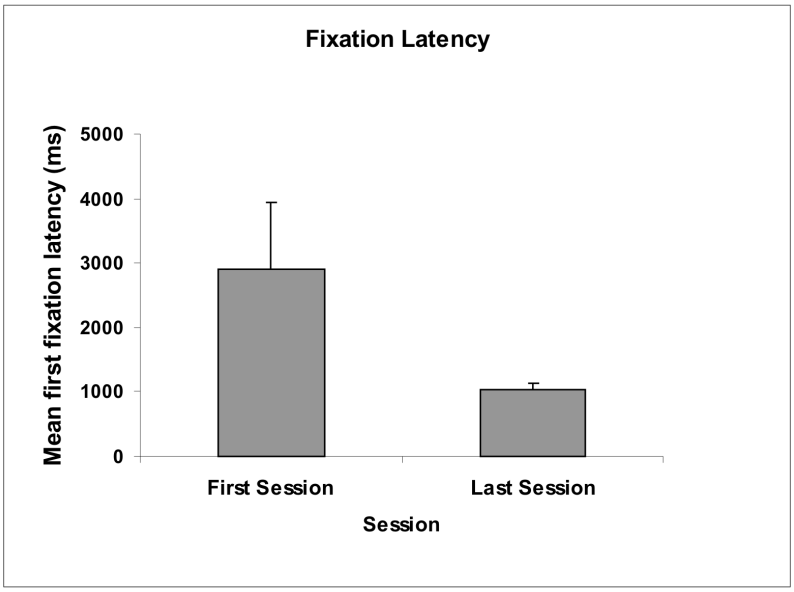

Fig. 3 shows the mean fixation latency on the hazards' AOIs in the first and last sessions.

Results on the number of crashes shows that there is not a difference between the first (14% of hazards determined an accident) and the last session (9.43%; Wilcoxon matched-pairs, signed-rank test >.05).

3.1.4 Discussion

Our experiment demonstrated that after a relatively short practise the time needed to spot a hazard decreases. To our knowledge this is the first time in which it is demonstrated that a training consisting merely in exposure to hazards situation can improve the ability of spotting hazards. Previous experiments have demonstrated that the ability to fixate the hazard area within an appropriate time window can be trained with a PC-based training program where trainees are coached to realise where they should be looking in order to reduce risk (Pollatsek, Fisher & Pradhan, 2006). Our training shows how the same result can be obtained just with practise on a simulator designed to train hazard perception where hazards appear very frequently and more often than in normal riding conditions. Whether the effect of the training is persisting for longer period of time and can be generalized to actual riding behaviour on the road is to be tested in future experiments. By now this study suggests that the simulator at hand could be a precious instrument for riding practise but also a tool for ameliorating hazard perception ability of young users at their first riding experience; while it was already demonstrated that it is a valid assessment instrument (Liu, Hosking & Lennè, 2009).

Accident rate might not be a reliable indicator of training effectiveness (af Wåhlberg, 2003) as might be related with factors not considered during the training or due to causes that are unrelated to riding skill (Liu, Hosking & Lennè, 2009). Consistently the results by Vidotto et al. (2008) were obtained after a long practise (12 sessions) and after the rider had sufficient experience in coping with hazards in scenarios specifically designed to test hazard perception in which, consequently, dangerous events appeared very frequently.

The advantage of getting information about hazard perception ability from ocular response is that this measure is independent from the level of inclination of the participant to press the button that depends on the criterion of answer. And as a measure it is more related with predictive ability than to reaction effort (Pollatsek, Narayanaan, Pradhan, & Fisher, 2006).

4 Chapter 4

4.1 Hazard Perception on a car simulator as a function of the field of view. Measuring driver's behaviour and eye movements.

4.1.1 Introduction

While some of the experiments on drivers' scanning patterns have been conducted on the road, for safety reasons experiments on drivers' reaction to hazards typically are conducted in laboratory settings, either on video-clips or on driving simulators. Likewise, in the current study Experiment 1 used HP clips. As most of the studies that test HP do not provide the same amount of visual information that is available on the road, Experiment 1 extended the view which is missing in typical HP tests and added information from the sides and from behind the vehicle. Naturally, however, as compared to video-clip based HP tests, driving simulators allow to record drivers reaction to hazards while driving and with more realistic measures (braking, speed decrements).

Allen, Cook and Park (2005) compared the performance of novice drivers in three types of simulator platforms: a single-screen (Narrow Field of View Desktop, 45° field of view, 50% image size), three-screens (Wide Field of View Desktop, 135° field of view, 50% image size) and a large screen display (Wide Field of View + vehicle cab, 135° field of view, 100% image size). Their results indicated that participants adopted faster speeds, broke more harshly, reduced time-to-collision and had more accidents in the single screen condition. Allen et al. (2005) ascribed these results to the poor realism of the single screen condition that determined more aggressive and less suitable behaviours.

More recently, Shahar, Alberti, Clarke & Crundall (submitted) tested the effect of the field of view size on drivers responses in a HP test and demonstrated that response times in a HP test depend on the available visual information. More specifically participants were more likely to detect hazards, and did so faster, when a wider field of view was available. Different explanations have been proposed for these results (see Shahar et al.). Briefly, when a realistic scenario is provided attention covers meaningful positions of the environment, the levels of arousal and alertness are enhanced, the environmental cues allow a better estimation of speed and time-to-collision providing a better situation awareness. Yet another factor is related to evidence that perceived speeds are higher when a wider field of view is available (Pretto, Ogier, Bulthoff and Bresciani, 2009), that speed estimation is correct when a horizontal visual field of at least 120° is available (Jamson, 2000) and that TTC estimates are significantly more accurate with a wider field of view (Cavallo & Laurent, 1988). For more details on these explanations, see Shahar et al.

To further extend some of the findings of both Experiment 1 and the Shahar et al. study, from a clip-based HP task to a driving task, and to allow a more direct comparison between some of the findings of Experiment 1, the Shahar et al. study and the Allen et al. study, Experiment 3 examined driving performance as a function of driving experience and the field of view in a driving simulator. Half of the participants had a wide field of view and half had a narrow field of view. Half of the participants in each of the field of view conditions were novice drivers and half were experienced drivers. Based on the above, it was expected that driving performance and hazard perception would benefit from the enlargement of the field of view and that experienced drivers would benefit more than novices from the enlargement of the field of view.

4.1.2 Methods

Participants

Forty participants volunteered to take part in the experiment, 20 in the wide view (three screens) condition and 20 in the narrow view (single screen) condition. Based on a median split for years of driving experience, half of the participants in each group were assigned into the experienced and half to the novices groups. (Median = 3.5 years for both groups). The data of four participants (one from each condition), were excluded from the eye tracking analysis on the basis of poor calibration. The pattern of the behavioural results reported below remained unchanged also when the data of these participants were removed from the behavioural data analysis.

Table 1. Demographics for the four groups.

		Age	Male/female ratio	Car driving experience (years)	Annual mileage in car
novices	Single screen	23 (4.03)	8/2	1.7 (0.95)	4688.5 (5728)
	Multiple screens	21.8 (5.92)	5/5	1.5 (0.71)	1846 (2857)
experienced	Single screen	28.6 (9.24)	7/3	10.7 (9.46)	8550 (3515)
	Multiple screens	28.6 (11.05)	8/2	10.3 (11.01)	7850 (3496)

There age difference between the two experience groups was significant, $F(1,36) = 5.94$, $p < .05$; novices were also younger than the experienced drivers.. The annual car mileage was significantly lower for the novice drivers than for experienced drivers, $F(1,36) = 14.84$, $p < .001$. Participants received an inconvenience allowance of £5. All of the participants reported normal or corrected to normal vision.

Apparatus and stimuli

The Faros GB3 driving simulator (Faros Simulation System) was used. The Faros GB3 simulator is a fixed-base car simulator in which the virtual environment is displayed on three screens that can be separately handled. In addition to the front view from a driver's perspective and the rear mirror view which are available on the central screen, the view allowed by the simulator in the wide view condition also includes, the lateral view seen from the windows and the side mirrors' view. The rear and side mirrors' views were inserted in the front and lateral views respectively as in a normal car: the rear mirror was superimposed on the car's front view in the upper part of the central screen, the left wing mirrors at the bottom of the left screen and the right wing mirror at the bottom-left of the right screen.

These views were presented on three 19'' LCD monitors (37.5 cm x 30 cm). The participants faced the frontal screen while the other two were positioned to the sides, rotated with respect to the frontal plane. The central screen was located at a variable distance away from the participant eyes (between 50 and 80 cm), as participants were allowed to move the seat to get a more comfortable position for the driving.

The horizontal visual angle of the central screen from a distance of 65 cm was approximately 32 degrees and the lateral screens enlarged the visual field up to 81 degrees. The actual view from the car in the three screens condition was close to 180 degrees. In the single screen condition it was reduced to include just the front view of the road.

The simulator was endowed with all the instrumentation of a car.

Eye movements were recorded through a SMI iView XTM HED eye tracker, a 50 Hz video-based corneal reflection tracker (SensoMotoric Instruments®). Two cameras were mounted on the helmet, of which one recorded the movements of the right eye of the participants and one was oriented at the visual scene in front. The use of the helmet allowed free head movements during the driving. A 13-points calibration was performed before the recording. The minimum fixation duration was 100 ms. Fig 1 displays the simulator and eye tracking set-up.

Figure 1. The simulator and eye tracking set-up.

The route chosen for the experiment included different road conditions (e.g. 2-lanes or 4-lanes road, crossroads and turns) and a traffic situation where other vehicles and pedestrians were present. The driving session lasted approximately 11 minutes.

A series of HP scenes were presented during the simulation route. The dynamics of the hazards were custom for the Simulator Faros. Nine hazardous situations were included, most of which consisted in violation of traffic rules by other road users. As the simulator was programmed to actively react to driving behaviour, the hazards could arise in different timings and could also have a different run for different participants.

The hazards could appear first on a lateral screen and then move to the central screen, or could appear directly on the central screen. One of the hazardous events was excluded from the analysis as for some participants this hazard developed completely in the lateral screen (hence, not providing the relevant cues for participants in the narrow view condition). Table 1 summarizes the eight hazard events.

Before each hazard a precursor event was isolated and used to define a temporal window prior to hazard. Hazard onset depended on the specific driving of each participant but at the onset the hazard was always visible on the central screen. The precursor events and the hazard onsets were defined by three driving experts.

Table 1. Description of the hazards

	Prior to hazard	Hazard	Description
1	After the driver has passed the first car of a sequence of parked cars on the left.	Pedestrian enters the road	A pedestrian, standing on the left hand side near some parked cars, suddenly enters the road.
2	After the driver has passed the line signalling the start of a set of traffic lights near to which some pedestrian are walking.	Pedestrian enters the road	A pedestrian, hidden from view by a parked van, enters the road from the left hand side.
3	When the crossroads ahead is visible.	Right of way violation	A car, hidden from view by the traffic, crosses the give way line onto the main carriageway from the right hand side.
4	When it is clear that the motorcycle coming from the opposite direction is approaching the dual-carriageway road central line to cross.	Motorcycle crossing	A motorcycle, coming from the opposite direction in a dual-carriageway road, crosses in front of the driver.
5	When the bus driving in front of the driver starts to move to the left hand side of the road to the bus stop.	Pedestrian enters the road	A pedestrian, standing on the right hand side, suddenly enters the road.
6	When a car is first visible approaching from a side road.	Right of way violation	A car, approaching from a side road on the left, crosses the give way line onto the main carriageway.
7	When the driver passes the one-way sign.	Pedestrian enters the road	A pedestrian, hidden from view by a parked van, enters the road from the right hand side.
8	When the pedestrian walking	Pedestrian enters the	A pedestrian enters the road

	on the pavement is first visible.	road	from the left hand side.

Procedure

Each participant received the information sheet and subscribed the consent form. The instructions explained that participants would have to drive on the car simulator in a city environment which includes other road users. In the narrow view condition, participants were told that they would have the front view and the rear mirror available. Participants in the wide view condition were told the same but also that peripheral information and information from behind the vehicle would be available through the side screens. The participants were exhorted to drive as if in a real driving situation on the road for the time required to complete the route (approximately 10 mins), obeying all traffic regulations. Participants were reminded that the simulator operates similarly to a normal car including operation of gears, brakes and lights, and so forth. Participants were reassured they would receive a practice session before the assessment, and were told that route directions would be given via arrows which would be displayed on screen through the entire session. They were warned that each time they would commit a traffic offence the simulation will stop, in which case they would be required to restart the car and continue the assessment. Participants were instructed to keep an eye out for any hazardous events and that if a hazard was encountered they should try to avoid the collision. After instructions the participants had to wear the iView eye tracker while sitting in the car simulator, and complete the practise session. The adjustment of cameras and the calibration were carried out afterwards, and then the participant was ready to start driving. The experiment lasted about 30 minutes.

Design

The behavioural interaction with the simulator was studied using a Screen x Experience x (Distance) experimental design comparing experienced drivers and novice drivers for the two screen conditions (three screens and single screen). The within-subjects factor was the distance of the driver from the hazard in the simulated environment, far (100, 90, 80, 70, 60, 50, 40, 30, 20, 10 metres) and close distances (9, 8, 7, 6, 5, 4, 3, 2, 1 metres) to the hazard were analysed separately. The dependent variables were the speed (Km/h) and the braking pedal pressure (ranging from 0 to 100).

For the ocular interaction analysis a Screen x Experience x (Driving Situation) experimental design was used comparing the experience groups for the two screen conditions. The within-subjects factor was the Driving Situation comparing ordinary driving with a prior to hazard phase in which a precursor suggested that the driver was better watch out and drive safely, and the hazard phase that started at the onset and ended with a crash or when the hazard was no longer harming.

The dependent variables were the horizontal spread of fixations (in degrees of visual angle) calculated as the standard deviation of the x coordinates of the fixations for each temporal window.

4.1.3 Results

Behavioural results

A 2x2 (experience x screens) ANOVA performed on the total number of crashes in the simulation, yielded a significant main effect of screens ($F(1,36)=4.73$, $p<.05$), with less crashes in the three screens condition ($M=1.85$, $SD=1.26$) than in the single screen condition ($M=2.7$, $SD=1.26$). This result shows that in the single screen condition participants had more difficulties in handling the road situation than in the three screens condition. The main effect of experience approached significance ($p=.06$) suggesting that experienced drivers crashed less ($M=1.9$, $SD=1.02$) than novice drivers ($M=2.65$, $SD=1.49$).

A 2x2x(10) (experience x screen x (distance)) ANOVA was performed on the speed of participants at approaching distances to the hazard (100, 90, 80, 70, 60, 50, 40, 30, 20, 10 metres). The main effect of Distance was significant ($F(9,324)= 110.66$, $p<0.001$) indicating a decrease in speed as a function of distance. Although neither the main effect of Experience nor of Screen were significant, the Distance x Experience interaction was significant (F(9,324)= 2.68, p=0.005). Pairwise comparisons indicated that only for the last distance level (10m) there was a difference between experienced and novice drivers, with experienced decreasing speed more than novices (p<0.05).

The Screen x Experience interaction was also significant (F(1,36)= 4.26, p<0.05). Pairwise comparisons indicated that experienced drivers in the three screens condition maintained a lower speed as compared to the single screen condition (p=0.05), and they maintained a lower speed than novices in the three screens condition (p<0.05), there was no difference instead between the three screens and the single screen condition for novice drivers, and between novice and experienced drivers in the single screen condition. Figure 2 displays the speed maintained by experienced and novice drivers while approaching the hazards in the different field of view conditions

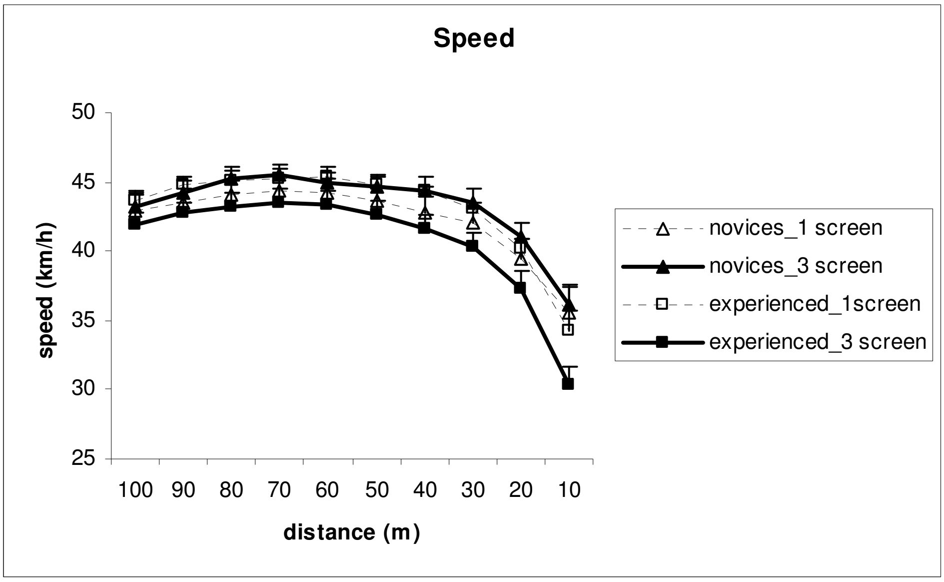

Figure 2. Means of the speeds (Km/h) maintained at approaching distances to the hazard (100-10 m) by experienced and novice drivers in the single and three screens conditions.

A 2x2x(9) ANOVA (experience x screen x (distance)) was performed on speed at closer distances to the hazards (9, 8, 7, 6, 5, 4, 3, 2, 1 metres). The main effect of Distance was significant (F(8,288)= 6.56, p<0.001), reflecting deceleration (braking).

The main effect of Experience was significant (F(1,36)= 4.61, p<0.05) indicating that the speed of experienced drivers (M=30 Km/h, SE=1.12) was lower than the speed of novice drivers (M=33.41 Km/h, SE=1.12). The Distance x Screen interaction was also significant (F(8,288)= 2.46, p=0.01). Pairwise comparisons indicated that at 1 m from the hazard drivers in the three screens condition travelled at slower speeds (M=27.90 Km/h, SE=1.60) than in the single screen condition (M=33.03 Km/h, SE=1.60, p=0.02); and that drivers in the single screen condition decreased their speed from 9 to 8 metres (.001) and from 8 to 7 metres (.004). Figure 3 displays the means of the speeds maintained at approaching distances to the hazard (9-1 m) by experienced and novice drivers in the single and three screens conditions.

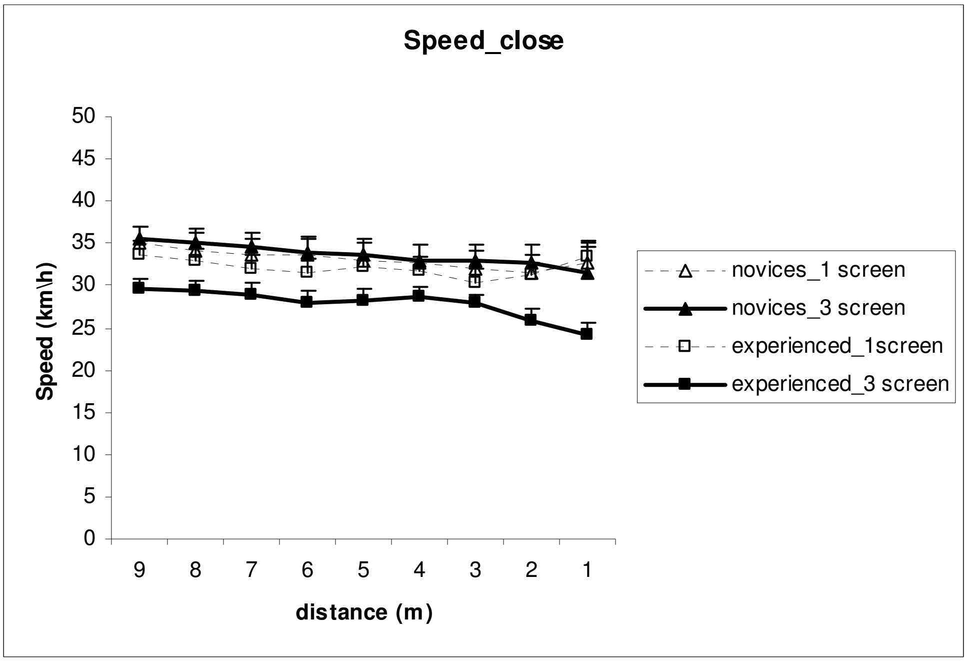

Figure 3. Means of the speeds (Km/h) maintained at approaching distances to the hazard (9-1 m) by experienced and novice drivers in the single and three screens conditions.

A 2x2x(10) ANOVA (experience x screens x (distance)) was performed on brake pedal pressure (values ranging from 0 to 100) at different distances from the hazard (100, 90, 80, 70, 60, 50, 40, 30, 20, 10 metres). The main effect of Distance was significant (F(9,324)=

141.07, p<0.001), indicating greater pressure at approaching distances to the hazard. The main effects of Screen and Experience were not significant.

The interaction between Distance and Experience was significant (F(9,324)= 2.61, p=0.006). Pairwise comparisons showed that at 10m from the hazard experienced drivers braked stronger than novices (.018), and that experienced drivers significantly increased brake pedal pressure from 40 m to 30 m (.012), from 30 m to 20 m (.019), and from 20 m to 10 m (p<.001), whereas novices had a difference between 40 m and 30 m (0.02) and between 20 m and 10 m (0.006). Figure 4 displays the means of the brake pedal pressures performed at approaching distances to the hazard (100-10 m) by experienced and novice drivers in the single and three screens conditions.

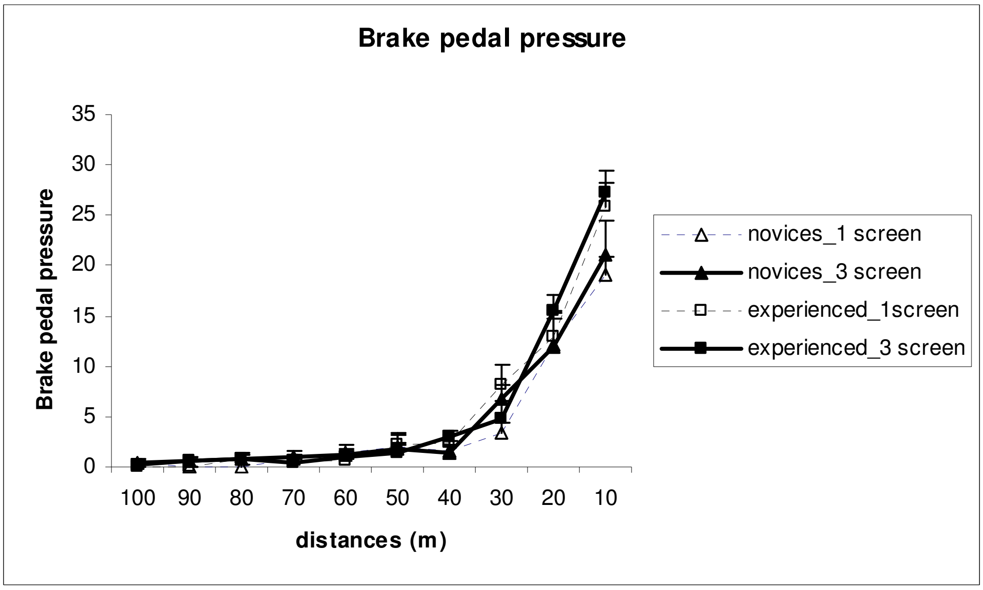

Figure 4. Means of the brake pedal pressures performed at approaching distances to the hazard (100-10 m) by experienced and novice drivers in the single and three screens conditions.

Eye tracking Results

A 2x2x(3) ANOVA (experience x screen x (driving situation)) was performed on the horizontal spread of fixations of participants while driving the route. The main effect of Driving Situation was significant ($F(2,64)=11.40$, $p<.001$). Pairwise comparisons showed that horizontal spread was wider during ordinary driving with respect to the prior to hazard temporal window (.002) and the hazard temporal window ($p<.001$).

The Driving Situation x Screen interaction was significant ($F(2,64)=4.57$, $p=.014$). Pairwise comparisons indicated that only for ordinary driving, the horizontal spread in the three screens condition was wider than in the single screen condition (.001) and that, when three screens were used, the horizontal spread during ordinary driving was wider than in the prior to hazard window ($p<.001$) and than the hazard window ($p<.001$).

Although the effect of Experience, and both the Experience x Driving Situation and Experience x Screens interactions were not significant, planned comparisons showed that for the ordinary driving situation experienced drivers in the three screens condition had a wider horizontal spread than novice drivers in the same condition ($F(1,32)=8.77$, $p=0.005$), and that experienced drivers had a wider horizontal spread in the three screens condition with respect to the single screen condition ($F(1,32)=13.49$, $p<0.001$). Figure 5 displays means of the variances in horizontal spread of experienced and novice drivers in the single and three screens conditions for the different driving situations.

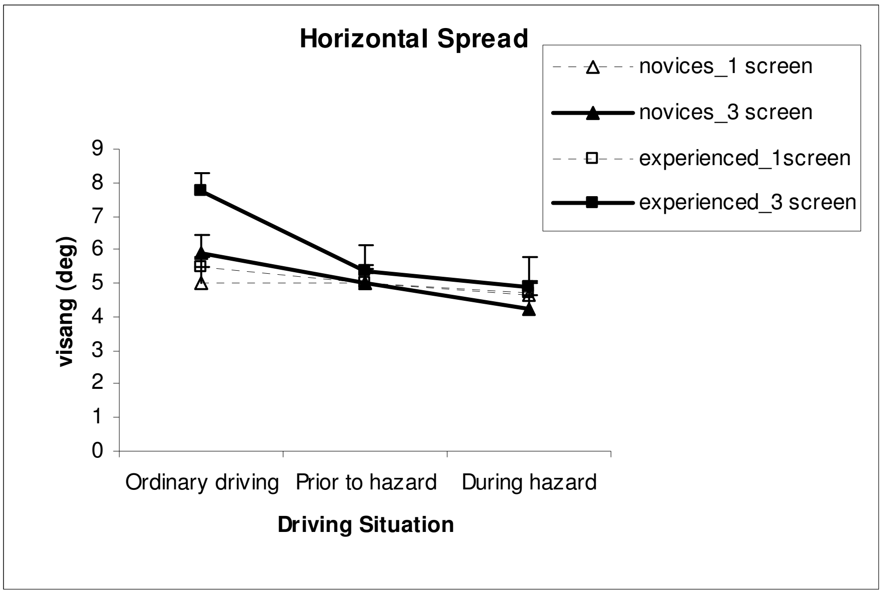

Figure 5. Means of the variances in horizontal spread of experienced and novice drivers in the single and three screens conditions for the different driving situations.

4.1.4 Discussion

The behavioural data from Experiment 3 indicated a number of patterns. Significant effects of experience with all three dependent measures, including speed at the last 100 meters and at the last 10 meters before the hazard and pressure on the brake-pedal, provide converging evidence to that experienced drivers decelerated more than novices before reaching the hazards. The pattern of the data also seem to suggest that while experienced drivers started pressing the brake decisively at a distance of 40 m from the hazard, novice drivers are more hesitant and pressed it less resolutely. The findings that experienced drivers reduced their speed to a greater extent than novices is also reflected by the main effect of number of crashes that tended to significance and suggested that experienced drivers crashed less than novice drivers.

These results are consistent with previous indications that experienced drivers brake more often than novice drivers (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy &

Brock, 2002), and that they are more inclined to label traffic scenarios as hazardous and have lower response criterion when responding to hazards in HP tests (Wallis & Horswill, 2007). The results are also consistent with Shahar et al (submitted) who found faster response times in a HP test when a wider field of view was available. The tendency to maintain slower speeds and to press the button earlier in the three screens condition could be ascribed to the same causes. Finally, the results of Experiment 3 are in line with Hosking, Liu and Bayly (2010) whose more experienced drivers/riders responded earlier to hazards than less experienced ones, and although they did not manipulate the visual field size their experimental set-up was using a wide visual field for hazard presentation.

The behavioural data also indicated a significant effect of Screens. Participants crashed less in the three screens condition than in the single screen condition, demonstrating how in the single screen condition participants had more difficulties in handling the road situation than in the three screens condition. Finally, the significant interaction between Screen and Experience indicated that only experienced drivers, but not novice drivers, drove slower in the three screens condition.

Thus the data suggests that the use of a single or a three screens setup may be a fundamental factor in determining the choice of speed for experienced drivers, but not necessarily for novice drivers.

In general, several of explanations can be provided for the field of view effect. Some explanations were discussed in more details in Shahar et al. (submitted). For example, by creating a more realistic driving environment, the wider field of view can encourage a more realistic driving behaviour (Allen, Cook & Park, 2005). Alternatively, the wide field of view provides the driver with more environmental cues which can be directly or indirectly related with the hazardous situation and contribute to a better situation awareness (Endsley, 1995). Yet another alternative is related to speed estimation, and to a more accurate speed and time-to-collision estimation (Cavallo & Laurent, 1988; Jamson, 2000; Pretto, Ogier, Bulthoff and Bresciani, 2009). Jamson (2000) suggested that a horizontal visual field of at least 120° is needed for correct speed estimation. These results apply to the simulator set up used in Experiment 3, in which the visual angle was larger than 120 degrees in the three screens condition, and smaller than 120 degrees in the single screen condition. While the results of Experiment 3 seem to contradict the findings of Allen et al. (2005) whose drivers (solely novice drivers), drove at higher speeds in the narrow- as compared to the wide- field of view condition, this difference could reflect the different set-ups. Specifically, while the Allen et al. single screen set-up consisted in a desktop station with a low level of realism in the interaction, our single screen condition (although presenting only a partial information of the road) was tested in a higher fidelity simulator, in which participants were sitting in a vehicle cab and used controls comparable to that of a real car. This suggests that providing a wider field of view and a more realistic experimental setting it is more likely to make experiential differences stand out in a HP test and in simulation.

Importantly, the finding that only experienced drivers, but not novice drivers, drove slower in the three screens condition, suggests that the experienced drivers made more use of the wide field of view (which thereby affected their choice of speed). This finding is also consistent with the finding that novice drivers scan the road less widely than experienced drivers on the horizontal plane (Mourant & Rockwell, 1972; Underwood, Chapman, Bowden & Crundall, 2002; Crundall & Underwood, 1998). This was further confirmed by the analysis of the horizontal spread of fixations over the different screens condition for the different experience groups in Experiment 3. The horizontal spread is an indicator of the extension of the visual scanning pattern on the horizontal coordinate and as mentioned above, previous studies have demonstrated that the horizontal spread of experienced drivers is wider than that of novice drivers (Mourant & Rockwell, 1972; Underwood, Chapman, Bowden & Crundall, 2002; Crundall & Underwood, 1998). As expected, during ordinary driving the experienced drivers in the three-screen condition spread their fixations along the horizontal coordinate (i.e., wider spread of search) more than the novice drivers, providing further support to the notion that the ability to take into consideration lateral information when available distinguishes between experienced and novice drivers.

In sum, the results of Experiment 3 support the prediction that driving performance and hazard perception benefit from the enlargement of the field of view and that experienced drivers benefit more than novices from the enlargement of the field of view.

5 Chapter 5

5.1 General Discussion

Three experiments are reported in this thesis. Experiments 1 and 3 were conducted during a visit at the Accident Research Unit laboratories, and supervised by Dr. David Crundall and Dr. Amit Shahar and the facilities described are owned by the Accident Research Unit at the School of Psychology in Nottingham University. Experiment 2 was conducted in the HTLab working under the supervision of Prof. Luciano Gamberini and the facilities described are located in the HTLab laboratories at the Department of General Psychology in the University of Padua.

The three experiments were presented in a sequence from the least immersive in terms of interactivity to the most realistic in term of interactivity and the demands which would be placed on the driver in the real world. In spite of this, in terms of the visual stimuli Experiment 1 was actually the most realistic as it was the only one of the three experiments which was based on real images rather than animation (which is the case for the simulator experiments).

Altogether these experiments shed light on a number of aspects of hazard perception. Specifically, the different experiments dealt with hazard perception measured through pedal presses in response to hazardous events, gaze and fixation latencies to hazards, speed decrements and braking responses. In addition to these measures, responses and gaze latencies to hazards at different locations within the horizontal field of vision were examined in Experiment 1 in order to provide a more profound understanding of hazard perception in general and as a function of driving experience in particular. Experiment 2 also assessed fixation latencies to the hazards after multiple simulator sessions, whereas horizontal spread of the gaze was assessed in Experiment 3 to account for different scanning patterns of novice and experienced drivers. Finally, Experiment 3 also assessed in simulated driving hazard perception as a function of the availability of the field of vision (i.e., narrow vs. wide), providing important insights relating the validity of typical hazard perception tests which are based on a relatively narrow field of vision. .

Effects of driving experience on the spread of gaze were found in Experiments 1 and 3. Novices failed to check some positions in the visual scene, like the rear and side mirrors (Experiment 1), and the horizontal spread of fixations was found to be narrower for novice drivers (Experiment 3). These results join those of former studies, which have suggested that novice drivers show a shrinkage in visual inspection (Mourant & Rockwell, 1972; Crundall & Underwood, 1998) and fail to take into consideration critical elements of the visual scene (Pradhan, Hammel, DeRamus, Pollatsek, Noyce & Fisher, 2005).

Experiment 2 tested whether inexperienced riders improve detection of hazard following practise on a riding simulator. Although we used a narrow view presentation, results suggest that it is possible to decrease fixation latencies to hazards.

Apart from eye movements, Experiment 1 also measured pedal presses response times for novice and experienced drivers. It was found that novice drivers are slower than other groups (experienced and dual drivers) when hazards are peripheral in the visual scene. The differences in pedal presses as a function of hazard location and driving experience, which were probably enhanced by the wide field of view was used in Experiment 1, are particularly interesting as these differences suggest that perceptual and appraisal levels in hazard analysis are biased by position.

To further explore the slower responses of novice drivers in the peripheral condition in Experiment 1, and the faster reaction times in the wider field condition in the HP test in Shahar et al. (submitted), Experiment 3 assessed driving performance and hazard perception in a driving task (in a simulator) as a function of driving experience and the field of view. The behavioural data from Experiment 3 indicated that experienced drivers decelerated more than novices before reaching the hazards, that experienced drivers tended to crash less than novice drivers, that participants crashed less in the three screens condition than in the single screen condition, and that only experienced drivers, drove slower in the three screens condition.

These results need to be addressed in relation to the results of Experiment 1. When the side-screens were not available (single screen condition in Experiment 3) the driving behaviour of experienced and novice drivers was not distinguishable using our measures, whereas when lateral information was available (Experiment 1 and three screens condition in Experiment 3) experienced drivers used the information from the side-screens responding faster than novice drivers and maintaining lower speeds. A number of explanations for the field of view effect were discussed by Shahar et al. (submitted) and in Experiment 3 (see Discussion, par. 4.1.3).

Another finding stood out in Experiment 3: experienced drivers independently from the screen condition brake harder and more resolutely than novice drivers. This difference in braking response between experienced and novice might reflect: a) greater skill of experienced drivers b) safer behaviour of experienced drivers with respect to novices on the road (Boyce and Geller, 2002). This is also reflected by the fact that they brake more often than novice drivers (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002), and that they have a lower response criterion when responding to hazards and generally they are more inclined to label traffic scenarios as hazardous (Wallis & Horswill, 2007).

The general patterns found in both Experiments 1 and 3 are also in line with those obtained in other studies. Differences in the responses provided by experienced and novice drivers/riders have been found in the HP test as experienced drivers usually have faster responses than novice drivers/riders (McKenna & Crick, 1991, 1994; Hosking, Liu & Bayly, 2010), experienced riders decrease their speed earlier than novice riders after hazard onset (Liu, Hosking & Lennè 2009), and experienced drivers tend to brake more than novice drivers (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002). It is not possible to conclude whether the quicker responses of experienced drivers in the hazard perception test (Experiment 1) and during the simulation (Experiment 3) were due to an early recognition of the level of hazardousness of the situation, or whether they resulted from a different response criterion (Wallis and Horswill, 2007). However, the horizontal spread of search data from experiment 3 and the findings from experiment 1 that experienced drivers looked at the to-be-hazards before the novices (and dual drivers even faster) strongly suggests that at least in regard to peripheral hazards experienced drivers were more perceptive of the hazards than novices.

In sum, the experiments described in this study, particularly Experiments 1 and 3 demonstrate deficiencies in novice drivers' ability to spot and to respond to peripheral hazards. These deficiencies however are less likely to be detected in simulations or hazard perception tests with restricted field of view conditions. In such conditions, the skills of experienced drivers may be underestimated whereas those of novices, which do not make enough use of peripheral information, might be overestimated. Experiment 2 suggests that novice drivers can be trained to use peripheral information and that they can therefore ameliorate their ablility to scan critical elements of the visual scene (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002); when an appropriate training was provided in Experiment 2, novices improved their hazard perception abilities for peripherally presented hazards. While this suggests that even when only a narrow field of vision is available training can still be efficient, such training would need to be further tested in a wider field of vision in order to fully evaluate to which extent this training indeed is efficient.

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