MONASH University
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LEARNER DRIVER EXPERIENCE PROJECT

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Abstract:

It is well documented that young and/or inexperienced drivers represent a significant risk of crash involvement. MUARC was commissioned to conduct a longitudinal study to assess two driver-related cognitive perceptual skills, hazard perception and situation awareness. Three assessment sessions were conducted over a three-year period using a computer package to test hazard perception and situation awareness. Novices were assessed before they gained their learner permit, during the learner permit period, and once they entered the probationary licence period. Whilst novices were accurate in detecting hazards in the joining lane their performance on hazards in their own lanes was quite poor. Experienced drivers were significantly faster than novices to detect the primary hazard, and they were also significantly more accurate than novices in detecting hazards overall. For the situation awareness tasks there were differences in performance depending on the type of task (photographs versus videos), because participants were watching scenes for different purposes (to remember versus predict the location of cars). Results are discussed in relation to improving driver training programs.

Key Words:

Young drivers, cognitive skills, hazard perception, situation awareness, driving experience, driver distraction.

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Preface

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EXECUTIVE SUMMARY

MUARC were commissioned to conduct a longitudinal study to assess two driver-related cognitive perceptual skills, hazard perception and situation awareness over three separate assessment sessions. The major focus was to investigate how these two skills develop as novices accumulated driving experience in the first 18 to 24 months of driving.

There were 35 novices and 16 experienced drivers that completed all three assessment sessions. Novices were assessed before they gained their learner permit, during their learner permit period, and once they entered the probationary licence period.

For the non-distraction condition participants were instructed to click on up to three hazards or potential hazards in the scene and to click on the worst hazard first (the primary hazard). For the distraction condition participants were instructed to count and recall the number of red, blue and green, circles in addition to the task of identifying any hazards or potential hazards in the photographs.

Whilst novices were accurate at detecting hazards in the joining lane their performance on hazards in their own lanes was quite poor. Experienced drivers were significantly faster than novices to detect the primary hazard, and they were also significantly more accurate than novices in detecting hazards overall.

Analyses of the situation awareness data included participants that had completed the first assessment session only. There were 86 novices and 20 experienced drivers. Two situation awareness tasks were devised. For the situation awareness location task, participants were instructed that after the photograph disappeared they would need to provide information about the road layout, including the number of lanes on the driver's side of the road, the position of the lane in which the driver's vehicle was located, and the locations of up to three closest vehicles. This task was then repeated, adding the same distraction task as used for the hazard perception task. For the situation awareness prediction task, participants were informed that, after a 10-second interval, the video would be blank for five seconds. They were instructed to predict the road layout and the location of the closest three cars relative to their own car five seconds after the video had ended. This task was then repeated with the distraction task.

The main findings of the situation awareness tasks were that there were differences in performance depending on the type of task (photographs versus videos), because participants were watching scenes for different purposes (to remember versus predict the location of cars). Despite these differences in the nature of the visual information presented (i.e. digital photographs versus videos), the results reported above indicate genuine differences between the cognitive requirements of remembering where vehicles were and predicting where they might be within the relatively near future.

1. INTRODUCTION

1.1 THE NATURE OF THE PROBLEM

It is well documented that young and/or inexperienced drivers represent a significant risk of crash involvement, both internationally (e.g. Mayhew & Simpson, 1995) and in Victoria (Cavallo & Triggs, 1995). The cause of novices' increased crash risk is generally attributed to a lack of driving experience. A further, and related, cause of novices' increased crash risk is that their driving skills are less well developed than those of an experienced driver. Both driving experience and driving skills are related in that driving experience is a key factor in the development of driving skills (Gregersen & Bjurulf, 1996). Researchers have identified several driving skills that are related to crash involvement amongst novice drivers. These include information-processing skills (e.g. Gregersen & Bjurulf, 1996), self-calibration (eg. DeJoy, 1992), hazard and risk perception (e.g. Quimby, Maycock, Carter, Dixon & Wall, 1984), and situation awareness (Treat et al., 1979, cited in Gugerty, 1997).

As driving experience is gained driving skills develop. This includes relatively simple vehicle control skills to more complex skills including driver-related cognitive-perceptual skills (e.g. Benda & Hoyos, 1983; Brown and Groeger, 1988; Forsyth, 1992). In terms of reducing crash involvement, driver-related cognitive perceptual skills, such as hazard perception and situation awareness, are among the most important driving skills (Brown & Groeger, 1988; Treat et al., 1979, cited in Gugerty, 1997). According to Hall & West, (1996) simple driving skills such as learning the road rules are estimated to take only 15 hours. In comparison, Evans (1991) has estimated driver-related cognitive-perceptual skills to take in the order of decades to develop.

Despite the existence of an estimated time frame to develop a particular driving skill, there is little empirical research that shows how drivers' cognitive-perceptual skills develop, and, how the development of these skills progresses with an accumulation of driving experience. It is clear that driving experience is essential to reduce crash risk and to develop a range of driving skills. It is necessary to understand how important driving skills such as hazard perception and situation awareness develop if driver training and licensing programs are to be improved and a subsequent reduction in novice drivers' level of crash involvement achieved.

1.2 OUTLINE OF THE PROJECT

MUARC were commissioned to conduct a longitudinal study to assess two driver-related cognitive perceptual skills, hazard perception and situation awareness over three separate assessment sessions. These skills were tested in a group of novice and experienced drivers. The major focus was to investigate how these two skills develop as novices accumulate driving experience in the first 18 to 24 months of driving. A secondary aim was to assess performance on hazard perception and situation awareness with varying levels of mental load. The project follows a smaller sample of young drivers than originally proposed, however, using more detailed measures.

1.2 STRUCTURE OF THE REPORT

The report focuses on the results from two cognitive-related driving tasks, hazard perception and situation awareness. The report is divided into two sections, one for each task. The hazard perception task is the first focus, then situation awareness.

2. HAZARD PERCEPTION LITERATURE

2.1 HAZARD PERCEPTION INTRODUCTION AND DEFINITION

The important role that driving experience plays in perceiving hazards cannot be overstated. In an analysis of police reports, failing to search the roadway was the single most common factor in crashes, especially amongst the young novice driver group (Lestina & Miller 1994, cited in Underwood, Crundall, & Chapman, 2002). It is not surprising then that the importance of hazard perception has led to its introduction into many driver-licensing systems worldwide. In Australia, hazard perception tests are a part of the licensing process in Victoria, New South Wales, and Western Australia (Senserrick & Whelan, 2003).

According to Brown and Groeger (1988, pg 589), "the internal processes by which traffic hazards are identified thus appear to change in complex ways, as drivers acquire experience on the road". The way in which this learning process develops is not yet clear, though they propose conducting research that focuses on how drivers scan the road during the acquisition of specific driving skills.

The identification of hazards is termed hazard perception, which can be defined as the process of identifying hazards and quantifying their potential for danger (Brown & Groeger 1988). This includes the ability to perceive and identify specific hazards in the driving environment. It is a complex task that involves scanning the road, evaluating other drivers' location, and predicting objects and other drivers' behaviour. Hazard perception is estimated to take decades to develop fully (Evans, 1991).

2.2 HAZARD PERCEPTION RESEARCH METHODS

There have been a variety of methodologies used to test hazard perception (see Farrand & McKenna, 2001). These include the identification of hazards encountered on a test drive (Soliday, 1974), the ranking of photographed traffic scenes on a scale of hazardousness (Armsby, Boyle, & Wright, 1989), the presentation of video scenes requiring various ratings including the danger and difficulty involved in the scene (Groeger & Chapman, 1996), rating of risk presented in video or photographed traffic scenes (Finn & Bragg, 1986), and the measurement of visual search patterns whilst driving a test route (Mourant & Rockwell, 1972; Underwood, Crundall, & Chapman, 2002) or when watching video traffic scenes (Chapman & Underwood, 1998).

Research into hazard perception can be generally categorised as measuring two aspects of this skill. Firstly, there is a performance-based aspect, which involves testing drivers' reaction times to detect hazards, and their accuracy in detecting hazards as identified by experts. This is similar to Brown and Groeger's (1988) view that hazard perception is the ability to perceive and identify specific hazards in the driving environment. The second major aspect is concerned with what method drivers' use when searching for hazards and what type of hazards they report. That is, whether drivers have a tendency to primarily scan straight ahead of their vehicle, or further into the distance, or whether they scan from left to right. Also, whether there are hazards that drivers immediately identify as being more hazardous than others, e.g. the presence of a motorcyclists or vehicles indicating. Historically, as indicated in the literature reviewed below, hazard perception research has tended to focus on these aspects separately.

2.3 HAZARD PERCEPTION RESEARCH FINDINGS

In a well-controlled study Quimby, Maycock, Carter, Dixon, & Wall, (1984) recruited 366 accident-involved drivers with varying age levels, driving experience, driving exposure, and accident involvement rates. A simulator was used to test drivers' hazard perception, which required the participants to view a film from the driver's viewpoint and make a continuous assessment of the level of risk. The reaction time to detect each hazard and the number of hazards (from a total of 16) were assessed. The results showed that experienced drivers perceived hazards faster than less experienced drivers, and drivers with less accident involvement were faster to detect hazards than drivers with recent accident involvement (the past five years). Finally, the results showed that when a range of driver-related visual skills were used to predict accident involvement, hazard perception was the most successful predictor than simple visual capabilities (e.g. the perception of movement, glare sensitivity).

The Quimby et al., (1984) study demonstrates how important hazard perception is, in terms of crash reduction when compared to simple visual skills. However, the accuracy of participants hazard perception was not measured, only reaction time to detect hazards. McKenna & Crick, (1994) have conducted a study that comprehensively investigated varying levels of driving experience in relation to drivers' perception of hazards. Reaction time and accuracy to detect hazards was assessed across all groups. A driving simulator was used to show a 30-minute video from the driver's viewpoint of everyday traffic situations, which also provided sound and car-body vibrations. Twenty novices (mean driving experience 2 years), 13 experts, recruited from a Police driving school (mean driving experience 22 years), and 25 experienced drivers (mean driving experience 23 years) were instructed to look for hazardous situations and to press a response button as soon as they saw a hazardous situation. Participants were provided with a definition of a hazardous situation, defined as "a risk of an accident or near accident; one in which you might consider it necessary to take some kind of evasive action, by braking or steering etc" (McKenna & Crick, 1994, pp 28).

Results revealed a significant difference between all groups for reaction time to detect a hazardous situation (McKenna & Crick, 1994). That is, novices had significantly slower reaction times than experienced and expert drivers, and experienced drivers had significantly slower reaction times than expert drivers. Mean reaction times ranged from 1.2 seconds for the experts to 1.8 seconds for the novice drivers. Novices were also less accurate in detecting hazardous situations than the experts and experienced drivers. This study in particular shows that there are clear differences in drivers' perceptions of traffic scenes, which are mediated by driving experience. McKenna and Crick argued that the finding that experts were faster to detect hazards than the experienced driver group was likely to be due to the intensive training that the experts have undergone throughout their profession as Police officers.

Both the Quimby et al (1984) and McKenna and Crick (1994) studies have assessed performance based aspects of hazard perception, focussing on how accurate and quickly drivers respond to hazards. The following three studies were interested in the method by which drivers search for hazards, including where they look and what objects they regard as traffic hazards (Soliday, 1974; Mourant & Rockwell, 1972; Chapman & Underwood, 1998).

Soliday, (1974) recorded participants' roadway comments during a 12.1-mile test drive, which included mainly urban streets and some suburban roads. The 18 drivers were aged from 16 to 70 years. Their driving experience ranged from half to 36 years, with a mean of 13 years. Participants were asked to identify any potentially dangerous situations to the driving instructor who accompanied them on the test drive. Responses were recoded and performance was correlated with demographic factors of age and driving experience. Results from the Spearman correlations indicated that older and more experienced drivers perceived moving objects as more dangerous than fixed objects. Soliday concluded that danger encountered when driving is perceived differently between drivers dependent on their driving experience. He proposed that if experience in responding to traffic hazards develops with exposure to driving situations, then increasing novice drivers' experience via education may help to reduce crash risk.

In a similar experiment, Mourant & Rockwell, (1972) investigated the visual search patterns of novice and experienced drivers using a 2.1-mile suburban and 4.3-mile freeway route. The eye movements (i.e. blinks and glances into the vehicle's mirrors and speedometer) of six novices and four experienced drivers were videotaped. The novices had little (less than 15 minutes) or no driving experience and were tested three times, once every fortnight. The first assessment was prior to the commencement of an on-road commercial education course. The second assessment was halfway through the course, and the final assessment was conducted at the end of the training course. The experienced drivers had driven at least 8, 000 miles a year for the past five years. The experienced drivers were tested twice, at the first and second assessments with the novices. The results showed that the novices concentrated their eye fixations in a smaller area, looked closer to the front and more to the right of the vehicle compared to experienced drivers. They also glanced at their mirrors less frequently and made pursuit eye movements (relatively long fixations of more than 440 msec) on the freeway route whereas the experienced drivers made none. Mourant and Rockwell (1972) concluded that the novices' eye movements were unskilled and overloaded and they were not as safe as the experienced driver group.

Whilst Mourant and Rockwell's findings are widely cited in the literature as demonstrating differences between novice and experienced drivers' visual search, some of their conclusions have been questioned in a more recent study by Chapman and Underwood (1998). Particularly, Mourant and Rockwell have argued that their mean fixation location results indicate that novices search in a smaller area and closer to the front of the vehicle. Chapman and Underwood (1998) have questioned the notion that mean fixation locations correspond to a preference for one region of the scene than another. They argued that differences in mean fixations are related to objects and not regions of the visual scene. Mourant and Rockwell tested a small sample overall, and at the first testing session novices had less than 15 min driving experience. As a result, Chapman and Underwood regard Mourant and Rockwell's findings as plausible, but their applicability to real world driving situations tentative.

Chapman and Underwood's study is one of very few to focus on both the performance-based aspects of hazard perception (including reaction time) and visual search patterns in detecting hazards. They recruited fifty-one novice drivers (all within three months of gaining a full licence) and 26 experienced drivers (all had held a driving licence for between five to ten years) who viewed 13 videos, which were selected randomly from a pool of 39, depicting everyday traffic scenes from the driver's viewpoint. Participants were instructed to press a button as soon as they saw a hazardous event. Eye movements were monitored as well as reaction time to detect hazards. Results indicated that novices' fixations were significantly longer than experienced drivers, and novices showed greater variance in vertical fixation location. Two results emerged which are in contrast to previous research. Firstly, they found no difference between novice and experienced drivers' reaction time to detect hazards. This is interesting because differences in reaction time generally exists when comparing performance of novices and experienced drivers on a hazard perception test, whereby experienced drivers are faster to detect hazards (McKenna & Crick, 1994).

Secondly, Chapman and Underwood (1998) found that novices tended to fixate further ahead of the vehicle. In comparison, Mourant and Rockwell's study (1972) indicated that novices fixated more towards the front of the vehicle. Chapman and Underwood (1998) argued that their novice participants might have fixated further ahead because they had just undergone driver training in order to gain their full drivers licence, which emphasises looking as far ahead of the vehicle as possible to detect hazards. However, they argued that the magnitude of these differences was relatively small in practical terms. In terms of novice experience differences in mean duration of fixations, Chapman and Underwood argued that their results are consistent with the tentative findings of Mourant and Rockwell (1972).

2.4 SUMMARY AND STUDY AIMS

Studies investigating performance on a hazard perception task between drivers with varying levels of driving experience have shown that less well developed hazard perception has been found to correlate to accident involvement, that hazard perception is a good predictor of accident involvement compared to simple visual skills, and that novice and experienced drivers differ in their accuracy and reaction time to detect hazards. However, little research to date has investigated how this important driving skill develops.

Few studies have tested learner drivers' cognitive skills. Rather, research of novice drivers has tended only to include probationary-licensed drivers, or drivers who have recently obtained their full licence. Brown and Groeger (1988) have proposed that understanding the changes in how drivers perceive hazards will require baseline knowledge of how drivers perceive traffic scenes when first learning to drive. The current study tracks a group of drivers starting from when they have minimal, if any, driving experience (pre-learners), and assesses how their perception of hazards changes over the course of learning to drive, by assessing their skills at the learner driver phase and probationary licence phase. An experienced driver group is included for comparative purposes, and tasks to increase mental load whilst detecting hazards. There are several aspects of interest, including the nature of hazard perception development, differences between novice and experienced drivers' in detecting hazards, and the effect of varying mental load on hazard perception performance.

3. PROJECT SAMPLE

3.1 PARTICIPANT RECRUITMENT

3.1.1 Learner (novice) drivers

Novices were recruited from secondary schools within a 10-kilometre radius of Monash University, Clayton. This was largely due to the expectation that participants who remained in the study after finishing their secondary schooling would continue their assessments at the Accident Research Centre. Limiting the distance to the school was considered likely to limit the travel distance required and, therefore, the inconvenience of travel to MUARC. This, in turn, was considered likely to help maximise the participant retention rate.

The project was presented to students during school or class assemblies at six suburban secondary schools, including, boys only, girls only, and co-educational schools. An incentive was offered (a movie voucher for each assessment session). Sign-up sheets were circulated after the presentation for students to register their interest. Students were given a letter providing details of the project and were encouraged to discuss the project with their parents.

Recruitment continued until 123 students enrolled for the study. It was hoped that this would result in a final sample of 80 students after attrition. Each student was phoned to cover any questions and confirm their interest before an introductory package was sent. This included a preliminary questionnaire on demographic details and other baseline measures, in addition to a consent form and postage-paid envelopes. If received, the student was registered as a participant and followed up for assessments. In total, 102 participants returned details agreeing to participate in the study, however, only 86 continued with the study at this stage. Several factors contributed to these reduced numbers:

- Several students enrolled for the study even though they had already had several hours of driving experience and, therefore, needed to be excluded;
- A small number of students left the school before assessments commenced;
- Some students simply chose not to continue;

Novices were contacted between assessment sessions, on average two phone calls between each assessment. The purpose was to remind them of the study, check how their driving was going, and to encourage them to continue completing their logbooks. Whilst the intention was to contact participants more regularly this was sometimes difficult as often participants were not available when calls were being made. Table 3.1 shows the number of participants assessed at each session. There were equal numbers of males and females in each group.

Table 3.1 Final Sample Size for Each Assessment Session

	Assessment Session			
Driver Group	**First**	**Second**	**Third**	**All Assessments***
Novice	86	62	35	35
Experienced	20	18	16	16

*Note: All assessments denotes participants who completed all three assessment sessions.

3.1.2 Experienced drivers

In addition to the novice driver participants, 20 experienced drivers (10 male, 10 female) were recruited to complete the computer package. Ages ranged from 29-35 years and driving experience from 8-10 years. This sample was drawn from friends and acquaintances of the researchers who had varied experience with the use of a laptop and/or mouse, as did the novice sample. This sample was chosen for several reasons:

- There is likely to be more variance in the responses of drivers with fewer years experience.
- Drivers somewhat older than this age range (with more years driving experience) have been found to display decreases in skill levels associated with automatic processing of driving information.
- Older drivers' driving-related cognitive skills may deteriorate as part of the aging process.
- As the main criterion for selecting this sample was the selected range of driving experience, it was not considered essential to use random selection methods.
- Budget and time constraints determined the need for a convenient sample known to meet the criteria

There were four participants that did not complete all three-assessment sessions. These participants had either moved away from Melbourne, or were no longer contactable, and in one case had not driven much recently.

3.1.3 Timing of assessments

The three assessment sessions were conducted over a three-year period. Novices were assessed:

- Before they gained their learner permit – First assessment session
- During learner permit period – Second assessment session.
- Once they entered the probationary licence period – Third assessment session.

Experienced drivers were tested during the same period as the novices for each of the three assessment sessions.

3.1.4 Expert raters

Experts were used to develop the tests administered to novice and experienced drivers. All five expert raters, three males and two females, were staff at Monash University Accident Research Centre, with expertise in the field of novice drivers and/or driver licensing.

4. HAZARD PERCEPTION METHODOLOGY

4.1 DEVELOPMENT OF HAZARD PERCEPTION TASK

4.1.1 Construction of task

The photographs used in the hazard perception task were taken using a digital camera mounted on a tripod on the dashboard of a passenger vehicle. The scenes were taken from the driver's perspective (the view through the front windscreen) on main roads and at major intersections in outer Melbourne suburbs. The photographs were predominantly taken on two and three-lane roads separated by a median strip. Scenes included the driver approaching traffic lights, roundabouts, and driving along two-way roads with turning lanes and entry points. Vehicles included cars, trucks, buses, and motorcycles. Additional objects in the scene included roadwork signs, and school crossing supervisors. All scenes were taken in dry weather conditions during the day with sufficient light. The photographs were displayed using a laptop-based mouse driven program.

4.1.2 Expert ratings

In order to ascertain correct responses to the hazard perception task, experts were used to identify all the hazards inherent in each traffic scene. Several computer programs were written to assist with analyses. First, a program was developed to superimpose a grid over each digital photograph. Experts were asked to click on every square in the grid that contained a potential hazard, and to identify which object was the most hazardous. The operational definition of a hazard given to the experts was:

"A*n object (car, person, etc) that you would be watching out for if driving in that situation. That is, it does not have to be at the point of a possible collision or the like to be rated as a hazard, just what you would be monitoring as you drive*".

Each expert studied the traffic scenes separately. Responses from the five experts were collated and the primary hazard in each photograph was determined from the sum of the most hazardous object in each photograph across the raters. This most hazardous object was termed the primary hazard. Secondary hazards were then identified from the sum of the raters' responses to the remaining hazards in each photograph. Each photograph had at least one hazard.

A second program was then developed in order to display the results so that qualitative inferences could be drawn about the types of hazards that were selected. Finally, a program was written to match learner and experienced drivers' responses with expert responses and compile them in a file suitable for statistical analysis. A program to display the results of matches and mismatches was developed so that the types of hazards the learner and experienced drivers were identifying and failing to identify could be determined.

4.2 PROCEDURE

4.2.1 General assessment procedure

All participants completed the assessment sessions individually. For the novices, first assessment sessions were conducted at school during regular class hours. The majority of the second assessment sessions were also conducted at school, with a small proportion being conducted at MUARC due to students having finished their secondary schooling. The third assessment sessions were either conducted at MUARC or public libraries. For all assessment testing conditions, the setting was usually a small quiet room with a table and chairs. For the experienced drivers the assessments were completed at the driver's home at a convenient time (usually early evening on a weekday or during a weekend afternoon).

For all participants and assessment sessions, the researcher provided instructions and demonstrated practice tasks. After ensuring that the participant was proceeding correctly, the researcher sat away from the view of the laptop screen so as not to unduly influence responses. (For example, often the researcher read a book between computer tasks.) On average, participants required about 60 minutes to complete all tasks. All participants received a movie voucher after each assessment session for their participation.

4.2.2 Hazard perception task procedure

All participants completed the hazard perception task under two conditions, non-distraction and distraction, respectively.

4.2.2.1 Non-distraction

Twenty-five photographs were presented in random order. Participants were informed that they would see a series of photographs and that each photograph would appear for five seconds only. They were instructed to click on up to three hazards or potential hazards in the scene and to click on the worst hazard first. This potentially allowed one primary and two secondary hazards to be identified. The co-ordinates of the click and response times were recorded. No training was given on a specific definition of a hazard; it was simply explained that the hazards did not have to be major such that it looked like a crash was about to occur but that they should click on "what you would be looking out for" in the scene. Participants were told that the photographs may not include any hazards or may include many, but that they could only click on the image up to three times. If the participant clicked three times on the scene in less than five seconds, the program would move immediately to the next photograph. This was also explained to the participants.

4.2.2.2 Distraction condition

After the non-distraction condition participants completed the hazard perception task as for the non-distraction, but this time viewing a different set of photographs and concurrently completing a distraction task. Circles coloured red, blue or green (approximately 15mm in diameter) were presented randomly in a central position below the photograph. Participants were instructed to count and recall the number of circles by colour in addition to the task of identifying any hazards or potential hazards in the photographs, with each task of equal importance. After each photograph was displayed, participants were prompted to enter the number of red, blue and green circles.

5. HAZARD PERCEPTION ANALYSES

5.1 DATA ANALYSES

Two types of analyses were conducted on the hazard perception task, qualitative and quantitative. The qualitative analyses aimed to investigate what types of objects novice drivers regard as hazards, compared with experts and experienced drivers. The quantitative analyses investigated differences in hazard perception skill, that is, accuracy and reaction time. The analyses generally reflect the two aspects of hazard perception measured; the method of identification and performance-based, respectively.

5.2 DATA SAMPLE

The qualitative analysis was conducted when only the first assessment data was complete (see Appendix A for summary table). The quantitative analyses assessed only those participants that had completed all three-assessment sessions, due to the repeated measures design.

6. HAZARD PERCEPTION RESULTS

6.1 QUALITATIVE ANALYSES

The aim of the qualitative analyses was twofold; first, to gain a better understanding of the patterns of hazards identified by novice and experienced drivers' based on the expert ratings; second, to investigate aspects of the images participants identified as hazards that were not considered as such by the expert raters; hereafter referred to as non-hazards. The following seven categories and varying subcategories were devised to code the location and type of object that participants clicked on (Table 6.1.). It should be noted that these categories are independent of the expert ratings gained for each photograph.

Table 6.1 Definition of Categories and Subcategories used to Classify Hazards and Non-Hazards

Category	Subcategory	Definition
Road Location	Left	objects off the road from the left of the driver's own lane
	Joining	objects appearing in a lane intersecting with the driver's lane
	Side Road	any object in a slip lane, or road separated by a median strip that is not the oncoming lane
	Median	includes any object on the median strip (ie: grass/concrete)
	Own Lane	objects in the driver's own lane or other lanes in the same direction of multi lane road
	Oncoming Lane	objects appearing in the driver's oncoming lanes
	Right	objects appearing off the road past the oncoming lanes
General Location	On Road	objects appearing in any lane (median, own, side, etc)
	Off Road	objects appearing to the 'left' or 'right' of the road layout
Distance	Near	objects in the bottom half of photograph (defined as the length of the driver's own car to the end of visible roadway)
	Far	as above, but objects in the top half of the photograph
Size	Small	any object that could be moved/picked up
	Large	objects not able to be picked up or moved
Movement	Fixed	all objects that are not vehicles
	Moving	vehicles located on the road and not parked, and pedestrians
	Semi-fixed	parked vehicles (vehicles with the potential to move)
Vehicle Type	Car	all cars including 4WDs
	Truck/Bus	all trucks and buses
	Motorcycle	all motorcycles
Miscellaneous	1	clicks on the driver's own car (approximately 17 in total, all Novice drivers)
	2	clicks in the sky (6 Novice drivers, 1 Experienced driver)

Each click was coded into one or more of the above categories. For example, if a participant clicked on a traffic light on a median strip which was located far away from the driver's position, it would be categorised as: median, on road, far, large, fixed.

Alternatively, if participants clicked on a car immediately in front of them in the same lane, it would be categorised as: own lane, on road, moving, near, car.

The total numbers of clicks in each of these categories were then calculated and compared between novices and experienced drivers. Clicks on hazardous features (as identified by the experts) were analysed separately to clicks on non-hazardous features. The sum of the novice and experienced drivers' clicks in each category was obtained, separated for the non-distraction and distraction conditions, in addition to proportions of clicks within each major category (location, moving, size, and distance). This allowed for comparisons of moving/fixed objects, near/far objects and so on to be made across groups, and secondary task conditions.

Using the categories in Table 1, binomial distribution tests were used to compare the proportion of clicks on primary and secondary hazards for novice and experienced drivers, and to assess the proportion of clicks in the various categories on objects that were non-hazards.

6.1.1 Drivers' clicks on hazards identified by experts

In the non-distraction condition, the proportion of correct responses to moving objects for novices was 57%. The equivalent figure for experienced drivers was 78%, which was reliably different, ($p<0.01$, binomial test). For the distraction condition novice drivers identified 60% of moving hazards. The equivalent figure for experienced drivers was 83%, which again was reliably different ($p<0.01$, binomial test).

For on-road hazards in the non-distraction condition, the proportion of correct responses for novices was 55%. The equivalent figure for experienced drivers was 75% ($p<0.01$, binomial test), which was significantly different. In the distraction condition, the proportion of correct responses to on road hazards from the novice driver group was 59%. For the experienced drivers this figure was 81% ($p<0.01$, binomial test), again significantly different. Table 6.2 presents the proportion of clicks in each category for the different road lanes.

Table 6.2 Proportion of Clicks for Location Category for Novices and Experienced Drivers

Category	Novices		Experienced	
	ND	D	ND	D
Own lane	46%	56%	72%	83%
Oncoming lane	67%	61%	82%	85%
Joining lane	80%	72%	84%	78%
Median	12%	8%	5%	8%

Note: ND = Non-distraction condition; D = Distraction condition. There were no side road hazards.

It can be seen that when hazards were present in the joining lane novice drivers were highly accurate. However, their accuracy for hazards in the joining lane was not matched in the other categories, particularly in their own and median lanes. It is interesting to compare experienced drivers' performance in identifying hazards in their own lane versus the joining lane. Of all the hazards that the experts identified 67% were in the driver's own lane. Only 19% were in the joining lane. Experienced drivers were accurate across all categories except for hazards in the median lane. These latter types of hazards only made up 3% of all the hazards that the experts identified. Differences in the proportion of joining and own lane hazards identified by novice and experienced drivers across both conditions were significantly different ($p<0.00$, binomial test). In addition, significant differences between novices and experienced drivers on the proportion of hazards identified in their own and oncoming lanes were also found ($p<0.00$, binomial test).

6.1.2 Novice and experienced drivers' clicks on non-hazards

Results now turn to a focus on non-hazards. Regardless of driving experience and task condition over 80% of clicks on non-hazards were located on the road. Thus, when participants were not clicking on primary or secondary hazards as identified by experts, they were predominantly identifying objects on the road as hazards. Table 6.3 presents the proportion of clicks in each category for the different road lanes.

Table 6.3 Proportion of Clicks for Location Category for Novices and Experienced Drivers For Non-Hazards

Category	Novices		Experienced	
	ND	D	ND	D
Own lane	36%	48%	53%	58%
Oncoming lane	20%	22%	24%	21%
Joining lane	17%	8%	8%	13%
Median	16%	15%	5%	6%

Note: ND = Non-distraction condition; D = Distraction condition. There were no side road hazards.

Clicks in the driver's own lane and oncoming lanes were combined to assess the proportion of non-hazards identified in this area of the road. Comparison revealed that for the non-distraction condition, 56% of non-hazards identified by novices were on the driver's own or oncoming lane. The equivalent figure for experienced drivers, 77% ($p<.00$, binomial test), was reliably different. For the distraction condition, some 70% of non-hazards identified by novices were in the driver's own or oncoming lane, reliably different to the equivalent figure for experienced drivers: 79% ($p<0.00$, binomial test).

Differences were also found between the proportion of clicks on the joining and drivers own lane: 17% of non-hazards identified by novices, while only 8% for experienced drivers, a reliably different result ($p<.00$, binomial test). For the distraction condition this trend was reversed whereby 8% of non-hazards identified by novices were on the drivers joining lane, while the equivalent figure for experienced drivers was reliably different at 13% ($p<0.00$, binomial test). Thus whilst novices tended to click on hazards in the joining lane, (as identified by experts) in comparison to experienced drivers, the pattern for non-hazards was not as clear. In the non-distraction condition novices clicked on more non-hazards in this lane than experienced drivers, but in the distraction condition experienced drivers clicked on more non-hazards in the joining lane.

6.1.3 Summary of qualitative analyses

Novices were less accurate than experienced drivers overall. Whilst novices were accurate at detecting hazards in the joining lane their performance on hazards in their own lanes was quite poor. Importantly, expert raters identified substantially more hazards in the driver's own lane compared to the joining lanes, which increases the impact of the finding that novices were poor at detecting hazards in their own lane. Novices consistently clicked on non-hazards in the joining lane in comparison to experienced drivers. Novices also fared consistently worse on identifying moving hazards compared to experienced drivers, however this pattern was not significant in the analysis of non-hazards.

6.2 QUANTITATIVE ANALYSES

The quantitative analyses investigated the differences between novice and experienced drivers in their ability to detect hazards. Three aspects of hazard perception were considered for novice and experienced drivers: (i) participants' reaction time to detect a primary hazard, (ii) participants' accuracy for detecting hazards, and (iii) participants' ability to detect hazards under non-distraction and distraction conditions. A forth aspect of the study investigated the changes in drivers' hazard perception that occur over time by testing participants at three separate sessions.

6.2.1 Reaction time to detect hazards

The amount of time (in seconds) taken for each participant to detect the primary hazard in each traffic scenario was recorded by the computer program. Mean reaction times for novice and experienced drivers were compared for each of the three testing sessions for both non-distraction and distraction conditions using a mixed design analysis of variance (ANOVA). The ANOVA consisted of two repeated measures: Viewing Condition (2 Levels: Non-Distraction vs. Distraction) and Assessment Session (3 Levels: Assessment Session 1, Assessment Session 2, Assessment Session 3), and one dependent measure: Driving Experience (2 Levels: Novice vs. Experienced).

The ANOVA revealed a significant main effect of Driving Experience [$f(1,49) = 12.169$, $p < .01$), and a significant Viewing Condition by Driving Experience interaction ($f(1,49) = 4.91$, $p<.05$). As can be seen in Figure 6.1, experienced drivers had significantly lower reaction times than novice drivers to detect primary hazards in both non-distraction and distraction Viewing Conditions. Post-hoc comparisons found that mean reaction times were significantly less in the distraction condition compared to the non-distraction condition for novice drivers ($p<.001$), and experienced drivers ($p<.05$). Figure 6.1 also shows that the difference in reaction times between novice and experienced drivers was greater in the non-distraction Viewing Condition than in the distraction Viewing Condition.

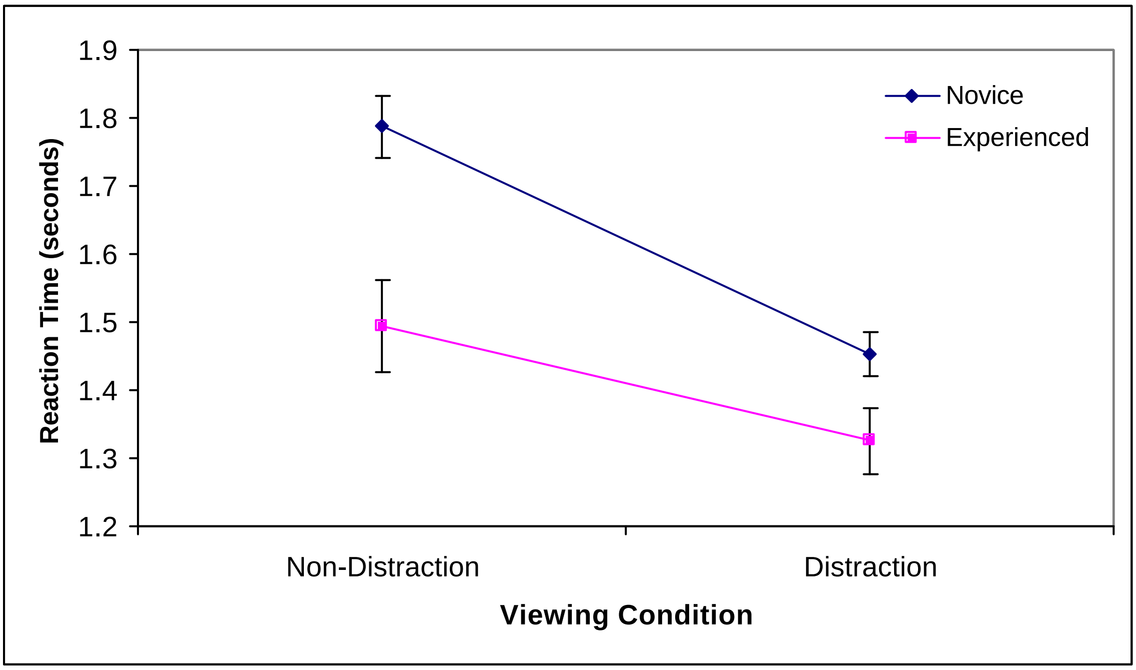

Figure 6.1 Mean reaction times (in seconds) to detect the primary hazard by Viewing Condition.

The ANOVA also revealed a significant main effect for Viewing Condition ($f(1, 49) = 45.86$, $p<.001$), and a significant Viewing Condition by Testing Session interaction ($f(2,98) = 3.75$, $p<.05$). As can be seen in Figure 6.2, mean reaction times were significantly faster in the distraction condition than in the non-distraction Viewing Condition. Furthermore, mean reaction times in the distraction and non-distraction Viewing Conditions varied as a function of Assessment Session. Post-hoc comparisons revealed that, in the non-distraction condition, participants' mean reaction times at Assessment Session 3 were significantly less than Assessment Session 1 and Assessment Session 2 ($p<.05$). In the distraction condition, mean reaction times were significantly faster at Assessment Session 2 compared with Assessment Session 1 and Assessment Session 3. ($p<.05$).

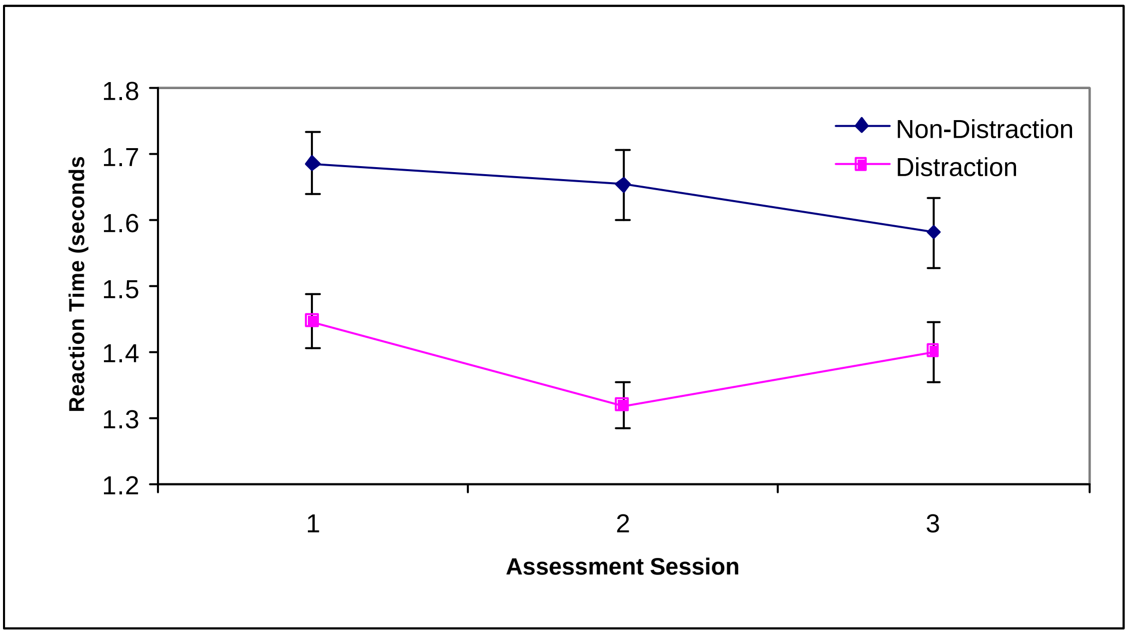

Figure 6.2 Mean reaction times (in seconds) to detect primary hazard by Assessment Session and Viewing Condition.

6.2.2 Accuracy to detect hazards

For each participant, the computer program recorded the number of correct mouse clicks (i.e., hits) on the primary and secondary hazards in each traffic scenario (based on the expert ratings). Mean hit-proportions for each participant were then calculated from the ratio of correctly identified primary and secondary hazards for each traffic scenario to the total number of possible hits in each traffic scenario. Hence, a higher hit proportion indicates more accurate performance at identifying primary and secondary hazards. Mean hit proportions for novice and experienced drivers were compared using a mixed design ANOVA with the same factors as in the reaction time analysis.

The results of the ANOVA show that there was a significant main effect of Driving Experience ($f(1,50) = 11.35$, $p<.01$). Figure 6.3 shows that experienced drivers were significantly higher hit proportions for detecting primary and secondary hazards than novice drivers.

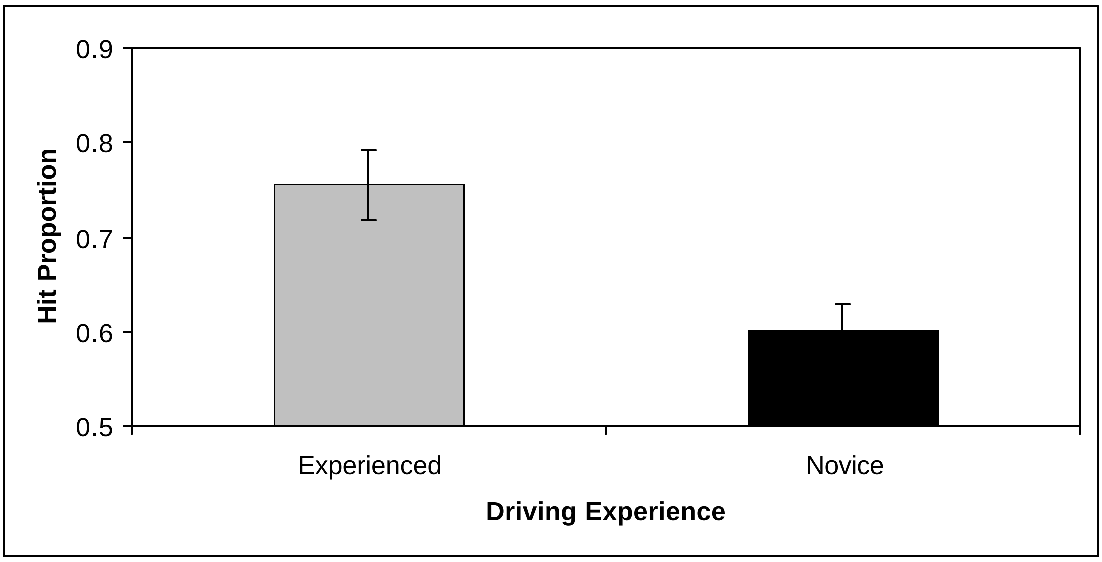

Figure 6.3 Mean hit proportions as a function of Driving Experience

The ANOVA also found a significant main effect for Viewing Condition ($f(1,50) = 7.71$, $p<.01$) and Testing Session ($f(2,100) = 5.29$, $p<.01$). There were no significant interactions. The results of the ANOVA show that, irrespective of driving experience, mean hit proportions were significantly higher in distraction conditions that in non-distraction conditions (see Figure 6.4). Furthermore, post-hoc comparisons revealed that participants' hit proportions were significantly greater in the final testing session than in the first or second testing session ($p<.01$) (see Figure 6.5).

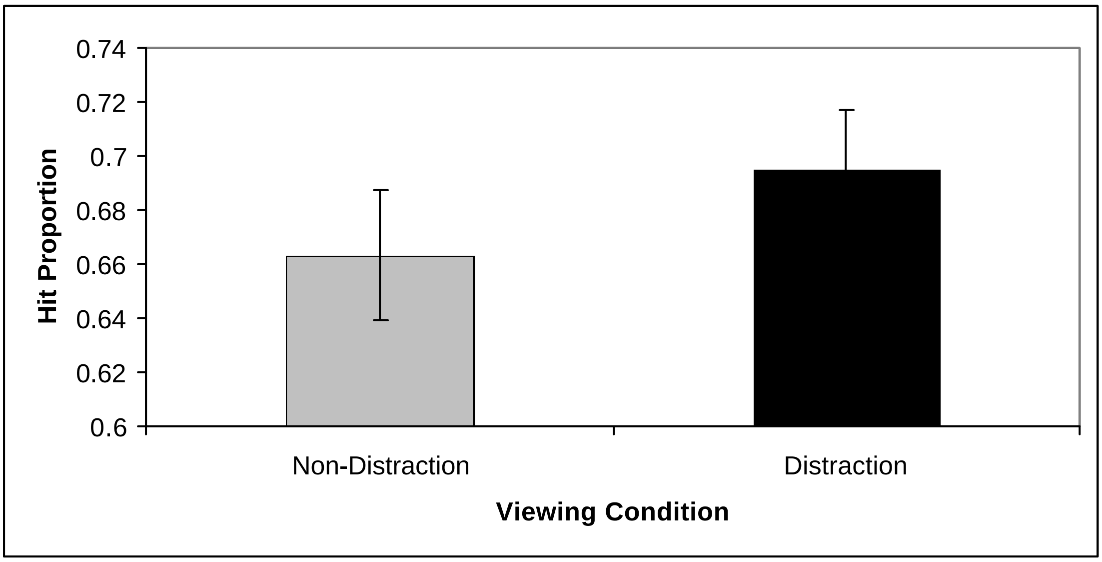

Figure 6.4 Mean hit proportions as a function of Viewing Condition

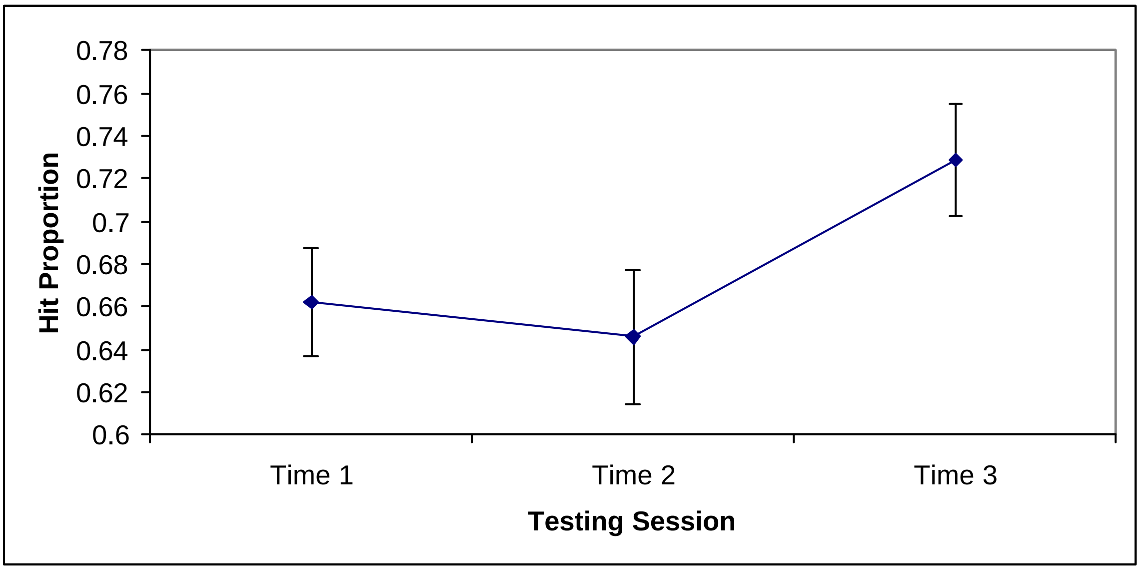

Figure 6.5 Mean hit proportions as a function of Testing Session.

6.2.3 Summary of quantitative results

The major finding of the quantitative analysis has shown that experienced drivers are faster and more accurate at detecting hazards than novice drivers. Additional findings were that the presence of distracters in the traffic scenarios influenced both reaction times and hit proportions. Irrespective of driving experience, faster reaction times and higher hit proportions were observed for detecting hazards when distracters were present in the traffic scenarios. Both groups of drivers also demonstrated improved performance over time. Participants' reaction times to detect the primary hazard improved over time in both distraction and non-distraction conditions, and hit proportions recorded in the final testing session were significantly higher than in the previous testing sessions.

7. HAZARD PERCEPTION DISCUSSION

The aim of the qualitative analysis was to gain a better understanding of what type of objects novice and experienced drivers considered hazards. This included an assessment of the size, location, vehicle type, whether the object was stationary or moving, and whether the object was near or far. A consistent finding was that novices focus attention on hazards in the joining lane and subsequently are significantly poorer than experienced drivers at detecting hazards in their own lane. This may partly contribute to the finding that novices have a tendency to be involved in rear-end collisions (Evans, 1991). That is, it is possible that they expect hazards to arise from joining lanes and therefore pay more attention to these lanes, and less attention to their own lane, resulting in collisions with the vehicle immediately in front. It is possible that they have a general preference for areas other than the driver's own lane. Indeed Mourant and Rockwell (1972) found that novices had a tendency to fixate to their right when searching for hazards. Whilst the joining lane in the current study was generally on the driver's left hand side, Mourant and Rockwell's (1972) findings lend support to the notion that novices have a tendency to fixate away from the driver's own lane.

Novices performed worse at detecting moving hazards in comparison with experienced drivers. This finding is consistent with Soliday (1974), who found that novices tended to report fixed objects as more dangerous but experienced drivers identified more danger from moving objects. This indicates that novices may have difficulty in understanding the hazardousness of a moving object (e.g. a vehicle in the traffic flow), particularly because the medium used here was photographs.

The results of the quantitative analyses show consistent differences between novices and experienced drivers in their hazard perception skills in that experienced drivers were faster in detecting the primary hazard than novices and were also more accurate in detecting hazards overall. That is, on both performance-based aspects of hazard perception a consistent difference was found between drivers as a function of the amount of driving experience. This is consistent with the research of Quimby et al., (1984) and McKenna and Crick (1994).

The finding that all participants were consistently faster to detect the primary hazard in the distraction condition and also more accurate in detecting hazards is less clear. When participants were asked to detect hazards and concurrently monitor and recall the number of red, blue and green circles, they detected the primary hazard faster than when they were not required to recall the number and colour of circles and they also detected hazards more accurately overall. There are two interpretations of this finding.

The first interpretation is that participants perform better in the distraction condition because of the order that they completed the tasks, non-distraction and distraction conditions respectively. Such a practice effect cannot be ruled out without further investigation. A sample of drivers would need to be assessed with the order of tasks (non-distraction and distraction) counterbalanced. The second interpretation is that under the increased pressure, participants were more motivated to detect the hazards quickly and were also able to detect hazards more accurately. Neither interpretation is conclusive but both are equally plausible.

Assessments of participants' hazard perception ability using both a quantitative and qualitative approach provides richer support for the notion that novices misperceive particular hazards, are less accurate and are slower in identifying hazards compared to experienced drivers. Use of a hazard perception photograph task with a concurrent distraction task has been successful in measuring differences in novice and experienced drivers' hazard perception, however, firm conclusions as to the way this skill develops requires further research, and from more dynamic tasks (videos, simulator using eye-movement technology). The aim of the video hazard perception task, which will be analysed in a subsequent stage of the project, is to add to our understanding of how hazard perception develops.

8. SITUATION AWARENESS LITERATURE

Drivers' immediate memory of their environment, and their ability to predict the immediate future actions of other road users is a critical skill for real-time tasks, such as driving, flying or air traffic control. Immediate memory and prediction are two keystones of the concept of situation awareness (Endsley, 1995). According to Endsley, situation awareness can generally be understood as the performer's knowledge of "what is going on". Endsley (1995) defines situation awareness as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p. 36). Thus there are three levels within situation awareness, perception, comprehension and prediction. Therefore, situation awareness requires perceiving the status, attributes and dynamics of relevant features in the environment. It also requires understanding of the importance of these features in the environment with respect to the perceiver's goals, and the projecting of future actions of the elements in the context based on previously stored knowledge and/or information gained from perception and comprehension (Endsley, 1995).

According to Endsley, the three levels depend upon pre-attentive processing, attention and working memory. Similarly, Adams, Tenney, & Pew, (1995) argue that attention and memory modulate the comprehension of the flow of events in situation awareness. For this reason, many studies of situation awareness have employed a dual task paradigm, in order to assess the extent of the attentional demands of particular tasks. Initially research effort on situation awareness has been largely confined to the assessment and improvement of pilot performance. However, situation awareness has been invoked more recently to account for differences in prediction between novice and expert tennis players (Rowe & McKenna, 2001) and, more relevantly, by Gugerty, (1997) in an investigation of how people monitor changing spatial information in a simulated driving task.

Gugerty, (1997) investigated drivers' knowledge of the location of traffic cars with direct recall measures and indirect measures of performance in a driving simulator through a personal computer. Participants viewed animated driving scenes from the driver's viewpoint and were able to view the rear, left and right side mirrors to track the location of cars behind them. The scenes lasted from 18-35 seconds and participants were instructed to imagine that their car was on automatic pilot so that their attention was not directed toward steering. At the end of each scene knowledge of other vehicles in the traffic scene was assessed on three different conditions: recall, performance and combined performance-recall.

For the recall condition the participants used a mouse to indicate the location of the cars present at the end of the scene using a bird's-eye view layout of the road, afterwhich they received feedback by viewing the correct locations of the cars. In the performance condition participants were able to make driving responses (i.e. accelerating, decelerating) whilst the moving scenes were being viewed. For some of the trials, a driving response would be required due to a hazardous incident. If participants responded whilst watching the scenes the scene stopped and they received feedback as to their accuracy. Both methods were combined whereby participants gave driving responses whilst viewing the scenes and then recalled the location of cars at the end of each scene. In these performance-recall conditions, feedback was postponed until the participant had recalled the location of cars.

Results indicated that participants' ability to recall location of cars accurately was effected by the level of traffic. That is, with increase in memory load there was a decrease in the percentage of cars recalled and accuracy in estimating their location. Moreover, this increase in number of cars affected memory load more significantly in the performance-recall condition than the recall only condition. That is, when participants were required to both remember and recall the location of cars and concurrently avoid hazards they were more affected by an increase in the number of cars than when they were required to recall the number of cars alone. When traffic levels were high, participants focussed their attention on a small number of the cars. This attention focussing was also more pronounced in the performance-recall condition.

Gugerty (1997) also investigated how participants' recall ability changed when they were not actively controlling the traffic scene (recall condition) compared to when they had active control over the traffic scene (performance-recall condition). According to Gugerty (1997), previous research suggested that participants were more attentive and generally more accurate when actively controlling a driving situation (Triggs & Drummond, 1993; Larish & Anderson, 1991, cited in Gugerty, 1997). When recall from the recall-performance condition was compared with the recall only condition, the recall-performance condition revealed poorer overall recall performance and greater decrease in the number of cars recalled (as memory loads increased), suggesting that active control over the driving situations did not increase participant's attention and accuracy. However, participants' ability to recall the location of cars was better when participants were recalling nearby cars for those situations where there was a hazard. As a result, Gugerty concluded that when active control was given for a driving situation, participants focussed attention on the specific relevant information required for safe driving (the location of the nearest cars in hazardous scenes) more so than when they have less control.

This study by Gugerty (1997) is particularly important because there are very few studies that have comprehensively investigated situation awareness in driving tasks. The research provides insight into how drivers' situation awareness is affected by memory load and how their ability to view traffic scenes changes depending on whether they have active control of the driving situation. It did not, however, control for driving experience, and therefore does not provide insight into differences between novices and experienced drivers, or how this complex driving skill may develop. The literature on novice-expert differences in non-driving related tasks has found that novices and experts differ vastly on their ability to perform tasks in dynamic decision-making environments (Bransford, Brown, & Cocking, 1999). Importantly, it is suggested that these differences may be due to the differences in perceiving meaningful information patterns and to associate a required action with such patterns. Furthermore, the ability to perceive and associate actions with these patterns is developed through experience and practice (Bransford et al., 1999). This is a fundamental assumption for the study into novice and experienced drivers situation awareness.

The current study is related to Gugerty (1997) in that the aim is to investigate how drivers' situation awareness is affected by memory load, using a secondary task. In addition, the current study assesses how situation awareness affects memory load for novice versus experienced drivers. The participants are taken from the same sample from the hazard perception tasks (see Chapter 3). The current study tracks a group of drivers starting from when they have minimal, if any, driving experience (pre-learners), and assesses how their situation awareness changes over the course of learning to drive, by assessing their skills at the learner driver phase and probationary licence phase. An experienced driver group is included for comparative purposes, and tasks to increase mental load. There are several aspects of interest, including differences in novice and experienced drivers' ability to understand the traffic environment around them, and the effect of varying mental load on performance of the situation awareness task.

9. SITUATION AWARENESS METHOD

9.1 PARTICIPANTS

All participants were from the same sample that had completed the hazard perception tasks (when participants were assessed on the hazard perception task, they also completed the situation awareness tasks). For specific details of the sample see chapter 3. Analyses of the situation awareness data included participants that had completed the first assessment session only. There were 86 novices and 20 experienced drivers.

9.2 DEVELOPMENT OF SITUATION AWARENESS TASKS

Two situation awareness tasks were devised. The situation awareness location task aimed to test drivers' ability to remember the location of vehicles after a brief display of a traffic scene using digital photographs. The situation awareness prediction task aimed to test drivers' ability to predict the location of vehicles after brief display of a traffic scene.

9.2.1 Situation awareness location

The photographs used in the situation awareness location task were taken using a digital camera mounted on a tripod in the front of a passenger vehicle, similar to the scenes used in the hazard perception task. The scenes were taken from the driver's perspective (the view through the front windscreen) on main roads and at major intersections in outer Melbourne suburbs. The photographs were predominantly taken on two and three-lane roads separated by a median strip. Scenes included the driver approaching traffic lights, roundabouts, and driving along two-way roads with turning lanes and entry points. Vehicles included cars, trucks, buses, and motorcycles. Additional objects in the scene included roadwork signs, and school crossing supervisors. All scenes were taken in dry weather conditions during the day with sufficient light.

9.2.2 Situation awareness prediction

The videos used in the situation awareness prediction task were taken using a video camera mounted on a tripod in the front of a passenger vehicle. The characteristics of the traffic scenes were generally the same as the digital photographs (i.e. characteristics including road types, vehicles included, weather conditions).

9.3 PROCEDURE

9.3.1 Situation awareness location

For the situation awareness location task, participants viewed 25 photographs for five seconds each. Similarly to the hazard perception task, there were two conditions, non-distraction and distraction (completed second). Each individual viewed the same photographs, which were presented in random order. They were instructed that after the photograph disappeared they would need to provide information about the road layout, including the number of lanes on the driver's side of the road, the position of the lane in which the driver's vehicle was located, and the locations of up to three closest vehicles. A number of road layouts then appeared on the screen, representing a choice of number of road lanes and the position of the driver's vehicle within the lanes (see Figure 9.1).

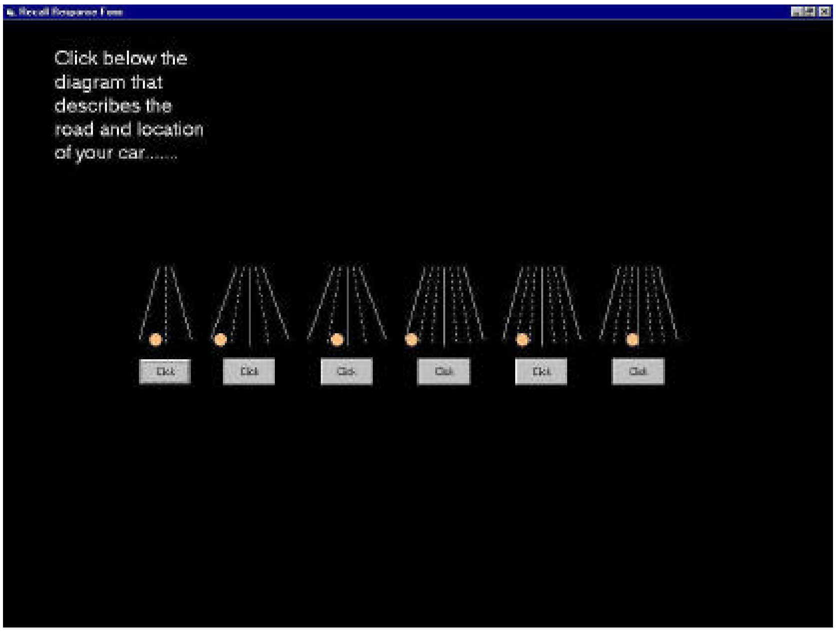

Figure 9.1 Road layout options for the situation awareness location task

After the participant selected a layout, a grid appeared which corresponded to the road layout selected, with the driver's vehicle in the bottom row. Participants were asked to click on the grid squares corresponding to the location of up to three other vehicles in the scene (see Figure 9.2).

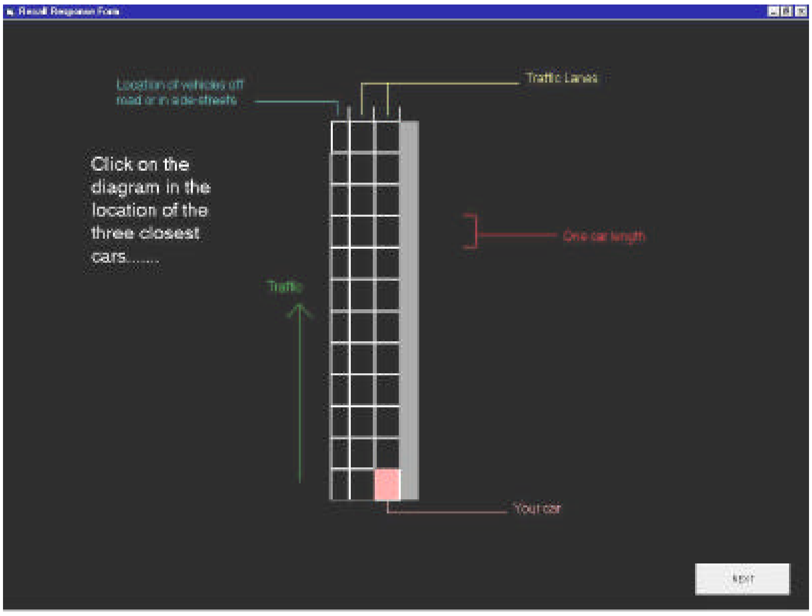

Figure 9.2 Grid to input location of closest three cars

This task was then repeated using a second set of 25 photographs and adding the same distraction task as used for the hazard perception task. Participants were instructed to count and recall the number of circles by colour whilst memorising the road layout and vehicle positions, with each task equally important. For the distraction condition, circles coloured red, blue or green (approximately 15 mm in diameter) appeared randomly in a central position below the photographs. For this condition, after selecting a layout and completing the grid locations, participants were prompted to enter the number of red, blue and green circles. Check the flow of points here

9.3.2 Situation awareness prediction

Participants next viewed eight videos clips that ran for 10 seconds each. They were informed that, after a 10-second interval, the screen would be blank for five seconds. They were instructed to predict the road layout and the location of the closest three cars relative to their own car *five seconds after the video had ended*. That is, they needed to predict how the scenario progressed during the five-second period while the screen was blank. Response options were the same as those for the situation awareness location task. The same eight video clips, presented randomly, were shown to all participants. The prediction task was then repeated with a second set of eight video clips (presented randomly) with the addition of the distraction task (as for the still photographs). Participants were instructed to treat the situation awareness and distraction tasks as equally important.

10. SITUATION AWARENESS DATA ANALYSES

As previously indicated, the results only include the first assessment session. In order to assess the accuracy of driver's responses to either the actual (situation awareness location) or the predicted location (situation awareness prediction) of the vehicle, the mean Euclidean distance between the remembered positions of the closest three vehicles to the actual position of each vehicle was calculated and averaged for each picture. These were subsequently aggregated into the three different categories of road layout; single, two or three lanes. Novice and experienced drivers are compared, for both situation awareness location and situation awareness prediction, on performance on the distraction task, the effects of the distraction task on memory for own position, road layout, memory for actual location of other traffic or prediction of location.

11. SITUATION AWARENESS RESULTS

11.1 SITUATION AWARENESS LOCATION TASK

11.1.1 Distraction task

There was no difference between novice and experienced drivers performance on the distraction task (t_{103}= 0.377, ns).

11.1.2 Own position

Drivers remembered their own lane position very well in the non-distraction conditions (5% error), but reliably less well under distraction (10% error; $F_{1,103}$= 12.153, p<0.001). Novice and experienced drivers performed this task equally well (F<0.3).

Novice and experienced drivers are compared, for both situation awareness location and situation awareness prediction, on the effects of the distraction task on memory for own position, road layout, and memory for actual location of other traffic or prediction of location.

11.1.3 Road layout

By selecting only those cases where drivers remembered their own position accurately, the ability for drivers to remember the road layout can be assessed. A mixed three-way ANOVA (layout, distraction, experience) revealed that experienced and novice drivers remembered road-layouts equally well ($F_{1,103}$= 1.256, n.s.), but that more complex layouts were less well remembered than simple layouts ($F_{2,206}$= 3.738, p<0.05), and that memory for layout was worse in the distraction conditions ($F_{1,103}$= 20.945, p<0.001). Only one statistically reliable interaction was observed. This showed that the effects of distraction on road-layout memory were to make all situation layouts equally difficult ($F_{2,206}$= 6.633, p<0.005, see Figure 11.1).

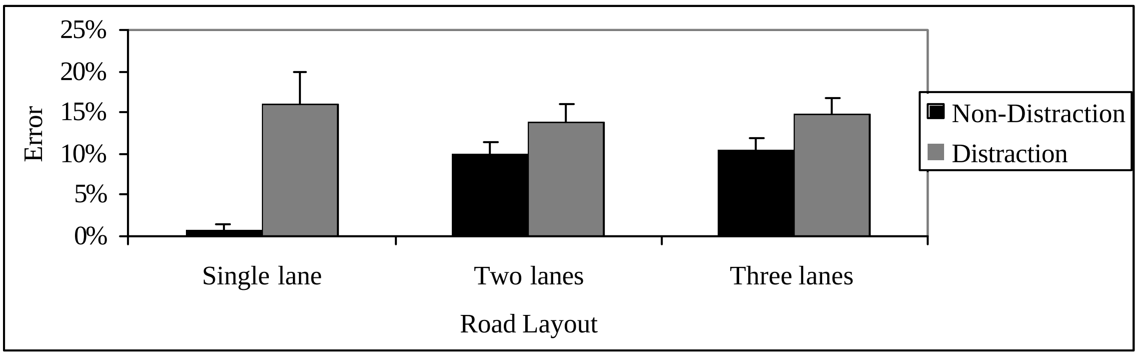

Figure 11.1 Effect of distraction on memory for road layout

11.1.4 Occupation of lanes

By virtue of specifying where the closest three vehicles were located, participants indicated which lanes were occupied with vehicles. Before considering errors in actual location, it is worth considering memory for position of vehicles at a more coarse level, i.e. whether participants correctly identified empty lanes and those with traffic. Distraction substantially reduced memory for whether the lanes seen were occupied ($F_{1,98}$= 128.289,

p<0.001) and performance was better on single-lane roads than multi-lane roads ($F_{2,196}$= 39.275, p<0.001). These two main effects interacted reliably ($F_{2,196}$= 29.297, p<0.001, see Figure 11.2). Although reliably reduced for each road type, memory for whether lanes were occupied was effected the most for single lane roads. Experienced drivers (83%) were more accurate than novices (80%) at remembering whether or not lanes were occupied ($F_{1,98}$= 4.227, p<0.05). No other results were statistically reliable.

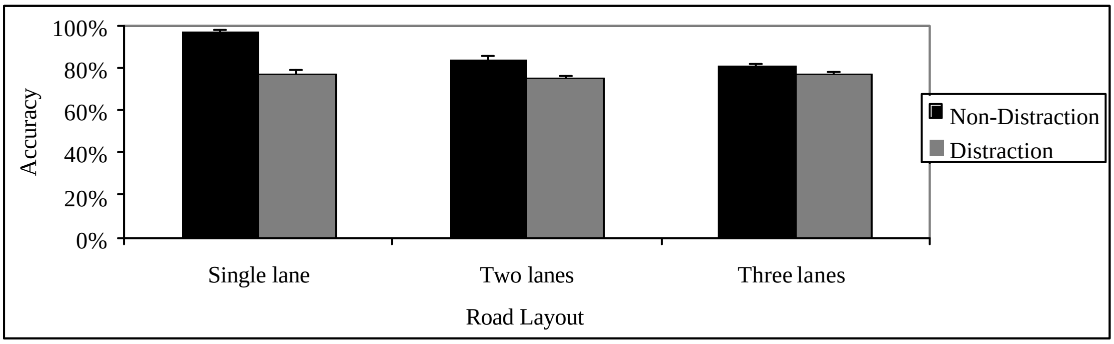

Figure 11.2 Effect of distraction on memory for lane occupation

11.1.5 Memory for location

The mean Euclidean distance between the remembered positions of the closest three vehicles to the actual position of each vehicle was calculated and averaged for each picture. These were subsequently aggregated into the three different categories of road layout. Mean remembered location error was affected by road layout ($F_{2,206}$= 56.720, p<0.001) and distraction ($F_{1,103}$= 69.439, p<0.001). These main effects interacted reliably ($F_{2,206}$= 95.382, p<0.001, see Figure 11.3).

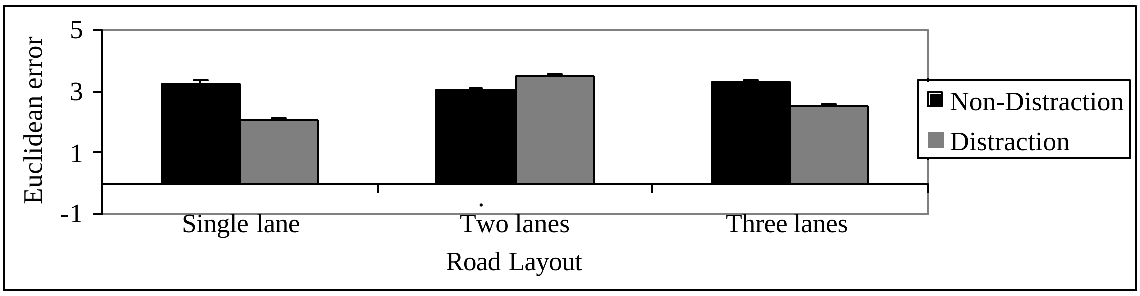

Figure 11.3 Effect of distraction on memory for vehicle location

Although there was no main effect of driving experience on remembered location error (F<1), there was an important interaction between the effect of distraction and driving experience ($F_{1,1030}$= 5.395, p<0.05, see Figure 11.4), which revealed a much larger effect of distraction on novice drivers than on experienced drivers. The effect of distraction is, somewhat surprisingly to make remembered locations more accurate. This arises because both novice and experienced drivers tend to remember vehicles as being closer to them than they actually were, with novices having a greater tendency to do this than experienced drivers. This bias is reduced when drivers are distracted, such that their underestimation of remembered distance is reduced.

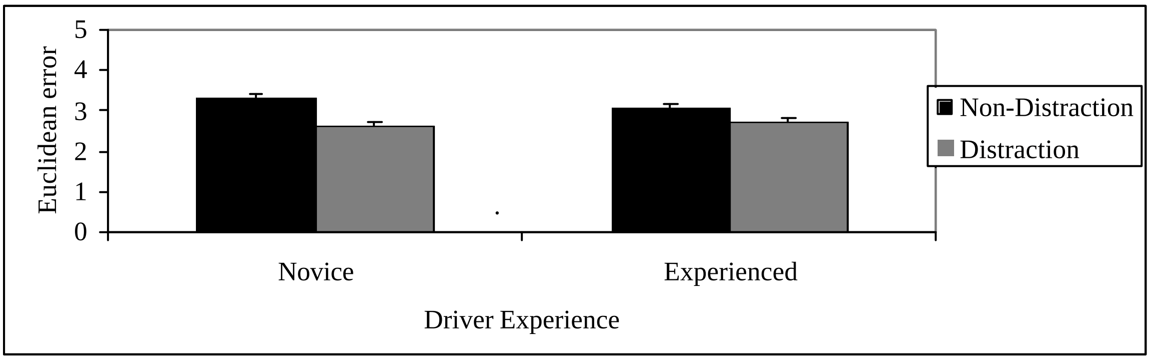

Figure 11.4 Effect of experience and distraction on memory for vehicle location

11.1.6 Summary of situation awareness location task

In summary, drivers memory for their own location, their road environment and particularly the location of other traffic is disrupted by concurrent distraction, and is also influenced by complexity of the road layout. Experienced drivers were more accurate than novices at remembering whether or not lanes were occupied. An interaction was found between distraction and driving experience in that distraction effected novice drivers more than experienced drivers ability to remember the location of the closest three cars.

11.2 PREDICTION OF FUTURE LOCATION

11.2.1 Distraction task

In contrast to the effect of watching and attempting to remember the location of cars from viewing digital photographs, performance of the distraction task was substantially disrupted when drivers watched videos in order to be able to predict the future locations of the vehicles they saw. More importantly, the concurrent demand of the prediction task lead to worse performance by novice drivers more than it did for experienced drivers (t_{103}= 2.619, p<0.01).

11.2.2 Own position

There are also noteworthy differences between the results reported above for the memory tasks and performance on the prediction task. Drivers' memory for their own position was disrupted by distraction ($F_{1,101}$= 11.054, p<0.001), with drivers remembering their position as being further to the right than it actually was, but was uninfluenced by driving experience (F<0.01).

11.2.3 Road layout

Drivers' memory for number of lanes was unaffected by distraction ($F_{1,101}$= 2.400, p>0.12). There was a marginal effect of driving experience ($F_{1,101}$= 3.256, p<0.074), such that experienced drivers were marginally more accurate (85%) than novices (79%). This was unaffected by concurrent distraction.

11.2.4 Prediction of location

Drivers predictions of the positions of the three closest vehicles were compared with the actual position those vehicles would have occupied had the video continued. These were averaged across vehicles and videos and submitted to a two-way ANOVA to assess the effects of distraction and driving experience on prediction accuracy. Predicted positions were less accurate when the videos were watched under the distraction condition ($F_{1,103}$= 12.237, p<0.001), but were unaffected by driver experience (F<0.1).

A further analysis was carried out in order to assess whether drivers' predictions of position were closer to the predicted value, or to the position those vehicles occupied when the film ended. Assuming that drivers were attempting to predict positions after five seconds had elapsed, rather than merely remembering where the vehicles had been when the film ended, the error between drivers' estimates and actual future positions should be less than that between drivers estimates and remembered final position. A highly reliable main effect demonstrates that this was the case ($F_{1,103}$= 23.456, p<0.001). The remaining results are similar to those reported earlier, with one exception: that distraction increased the difference between predicted and actual future position ($F_{1,103}$= 4.607, p<0.05, see Figure 11.5). That is, accuracy of predicted position deteriorates in the distraction conditions, and the predictions made tend to be closer to what drivers would have most recently seen. This result was unaffected by driving experience (F<0.01).

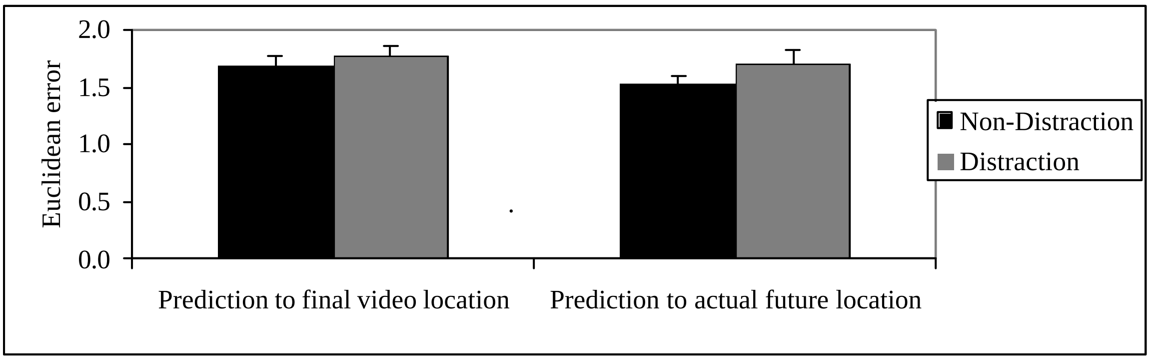

Figure 11.5 Effect of distraction on memory for prediction

11.2.5 Summary of situation awareness prediction task

The situation awareness prediction task has shown that all drivers remembered their position as being further to the right than it actually was. Experienced drivers were more accurate than novices in predicting the road layout. No other effects of experience were found. The ability to predict the location of the closest three cars was less accurate when the videos were watched under the distraction condition. Participants' predicted positions of the closest three vehicles were compared with the vehicles' actual positions when the video ended. This indicated that for the distraction condition predictions tended to be closer to what drivers would have most recently seen.

12. SITUATION AWARENESS DISCUSSION

In terms of differences between novice and experienced drivers' situation awareness, the results revealed that experienced drivers were more accurate than novices in remembering whether or not lanes were occupied and predicting the road layout. Distraction effected novice drivers more than experienced drivers' ability to remember the location of the closest three cars. The reader is reminded that the novice driver sample had none or very little driving experience, compared to the experienced drivers with at least ten years driving experience.

The concurrent demand of the distraction task led to poorer accuracy in remembering the location of their car, road layout, and particularly remembering and predicting the location of the closest three cars. In addition, when required to predict the location of the closest three cars in five seconds time, these tended to be closer to what drivers would have most recently seen in when concurrently completing the distraction condition.

An interesting finding from the situation awareness location task revealed that the effect of the distraction condition was to make all road layouts equally difficult. This is interesting in that a typical pattern of dual task interference is to amplify tasks that are already difficult, whereas what the results showed was that memory deteriorated reliably for each layout type, but substantially the greatest deterioration was in the simplest condition. This may have arisen because of the forced choice nature of the task.

Novices were significantly more accurate in remembering the location of the closest three vehicles when under distraction. This occurred because both novice and experienced drivers tend to remember vehicles as being closer to them than they actually were, with novices having a greater tendency to do this than experienced drivers. This bias is reduced when drivers are distracted, such that their underestimation of remembered distance is reduced. Gugerty (1997) also found such a bias whereby participants underestimated the location of far cars and marginally overestimated the location of cars that were near.

The results revealed that accuracy in remembering location of cars decreased with traffic level. Thus performance on the situation awareness task was affected by memory load. This finding is also consistent with the research findings of Gugerty (1997). However, Gugerty found that under high memory load situations, where participants had to concurrently detect hazards and recall the location of cars (performance-recall condition), participants focussed their attention on a subset of cars (near cars) for hazardous situations and recalled more accurately their location than if they were passively recalling them. That is, with more attentional demands the participants were more accurate in remembering the location of cars if they were near. Thus, for far cars this pattern was not maintained.

Gugerty (1997) attributed this pattern to the notion that in the performance-recall condition, participants had active control over the driving situation, which is what he hypothesised based on previous research (e.g. Triggs & Drummond, 1993). The results from the current study suggest that when participants are required to concurrently count the number of red, blue and green circles as well as remember or predict the location of the closest three cars, they perform worse than without concurrent distraction. The distraction condition is not considered to be an active control component of the task. Despite these differences between the Gugerty study and the current study, the increase in accuracy in the distraction condition reflects a real world driving environment. That is, with driver distraction the ability to drive safely, including monitoring a cars location, deteriorates.

A further finding of the results was that there were differences in performance depending on the type of task (photographs versus videos), because participants were watching scenes for different purposes (to remember versus predict the location of cars). Under distraction, participants' performance was more affected by watching videos in preparation for making predictions than it was affected by watching digital photographs with a view to remembering their contents. There are two plausible accounts of this result. Firstly, watching moving images is more demanding of cognitive resource than watching static scenes. Secondly, memory and prediction requires different amounts of cognitive resource. There is little doubt that processing moving and still images exerts different types or amounts of cognitive demand. Venturino (1997), for example, has conducted research that suggests that memory capacity for static information may be different for dynamically changing information and argued that humans cannot remember many changing values without external aid. However, since memory for own position was subject to greater interference by the same distraction task when making predictions rather than "merely" remembering, it seems reasonable to conclude that the cognitive demand of the tasks being carried out, as well as the demand imposed by particular formats (photographs versus videos), both influence performance.

Despite these differences in the nature of the visual information presented (i.e. digital photographs versus videos), the results reported above indicate genuine differences between the cognitive requirements of remembering where vehicles were and predicting where they might be within the relatively near future. This is of considerable theoretical importance, since it would seem that the different components of situation awareness, first identified by Endsley, do indeed have different resource requirements and are thus properly regarded as separate from each other. This separation also has important practical implications, for areas as different as the education and training of learner drivers and the design of in-car systems. In part, the significance of these differences depends on whether the results are showing differences in relevant abilities on the part of the novice and experienced drivers who participated in this study, or a skill that has undergone minimal or substantial development. By analysing the results of the second and third assessment sessions will provide insight into this issue.

13. GENERAL DISCUSSION AND CONCLUSIONS

Accumulation of driving experience is essential to develop safe driving habits and important driving skills shown to correlate with crash involvement, such as hazard perception and situation awareness. This longitudinal study has provided insight into the role of driving experience in the development of hazard perception and situation awareness skills. It is the first study to track the development of these skills starting before the novice has their learners. Such research is essential for the development of driver training and licensing.

The results show clear differences between novice and experienced drivers' performance on a hazard perception and situation awareness task which are consistent with past research. This study has built on the knowledge from previous research in two major ways. It has provided clues as to the location of hazards novices may have a preference for detecting (i.e. the joining lane). If this pattern of results can be validated in subsequent studies, it will provide direction for developments in education and training programs for novices before licensure. Training by instructors could include clearer specification and identification of different types of hazards and areas of the road environment to search when driving.

Secondly, this is one of very few studies to investigate situation awareness in drivers with varying levels of driving experience. In terms of novice experience differences, the results revealed that novices are less accurate in remembering the number of lanes and whether a lane was occupied by a car. Furthermore, novices' ability to remember the location of vehicles is more affected by distraction than experienced drivers.

Whilst this study has improved our understanding of how novices' driver-related cognitive-perceptual skills develop, there are several general recommendations for future research. It would be interesting, and worthwhile for training purposes, to pursue the issue of how specific components of hazard perception develop (e.g. speed in identification and accuracy in identification). The finding that participants were more accurate in the distraction condition should be investigated by pursuing issues of practice effect or motivational factors. It is important to understand how novices' understanding of hazards change over time. The hazard perception qualitative results included data from the first assessment session only. It is critical to conduct an analysis on the third assessment session data in comparison to the first assessment session to gain further insight into the what type of objects novices perceive as hazards, and most importantly, how their perception of these objects changes over time.

Our understanding of situation awareness in drivers could be improved by adopting a similar methodology to previous research that includes a concurrent recall and hazard perception component to assess the effects of active control on attention. The existence of a bias in remembering the location of vehicles should also be investigated. This may assist in training novice drivers to be aware of vehicles in a particular area of the traffic scene. In the long run, findings and further research as mentioned above may assist in reducing the crash involvement of novice drivers.

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APPENDIX A

Table A. Data Used For Analyses

	T1	T2	T3	All Assessments
Hazard Perception Quantitative	✓	✓	✓	✓
Hazard Perception Qualitative	✓	-	-	-
Situation Awareness	✓	✓	-	-

*Note: All assessments denotes participants who completed all three assessment sessions.