Remembering and predicting vehicle location: Situational Awareness in distracted and non-distracted drivers

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ABSTRACT

Drivers both act directly on their environment, and rely upon some recollection of it in order to guide their action. Internal representation of the current environment is fundamental to the concept of 'situational awareness', which is the focus of much current human factors research, albeit outside the driving domain. Two aspects of drivers' situation awareness are investigated here: drivers' immediate memory of the vehicles in front of them, and drivers predictions of where those vehicles would be after some time has elapsed. These issues are central to a broad range of issues in driver behaviour, e.g. drivers understanding and assessment of risk, desirability of in-car systems that require long glance durations (i.e. less time watching traffic).

Novice (*N*= 86) and Experienced (*N*= 20) drivers watched briefly presented photographs of, or films of moving, normal traffic scenes. Immediately afterwards, participants were asked to specify the location of the vehicles they saw (still photographs) or to predict where those vehicles would be after 5 seconds of further travel (moving films) on a structured grid. Drivers were tested when able to devote their attention wholly to the situation awareness tasks, and when dividing their attention between the situation awareness tasks and a concurrent distracting task. Results indicate that drivers' memory for their current environment is relatively poor, and predictions made on the basis of such memories are inaccurate. The implications for current understanding of hazard perception are discussed, as are results on Experienced-Novice differences and the impact of distraction on situation awareness.

INTRODUCTION

The cognitive underpinnings of safe driving are being increasingly recognised, but detailed accounts of the cognitive requirements of particular driving tasks are still some way off (see Groeger, 2000, 2002). This paper reports results from a larger study of the developing cognitive skills of young inexperienced drivers, but focuses in particular on drivers' immediate memory of their environment, and their ability to predict the immediate future actions of the traffic participants they see. Immediate memory and prediction are two keystones of the emerging concept of 'situation awareness' - which Endsley (1995) summarises as the performer's knowledge of "what is going on". 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 for the present paper, by Gugerty (1997) in an investigation of how people monitor changing spatial information in a simulated driving task.

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). These elements: perception, comprehension and prediction, comprise the three levels within situation awareness. 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 the previously stored knowledge and/or information gained from perception and comprehension. According to Endsley, these levels depend upon pre-attentive processing, attention and working memory. Similarly, Adams, Tenney and 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, as we do here, in order to assess the extent of the attentional demands of particular tasks.

The studies reported here are the first we know of to address the issue of whether driver's situation awareness, particularly memory and prediction, develops with experience. Here we present the data from a group of young novice drivers, and a comparison group of experienced drivers. The first set of measures assesses drivers' immediate memory for their own road position, and that of other vehicles, from static road scenes. The memory for location performance of novice drivers was measured under single and dual task conditions, and contrasted with the performance of experienced drivers under the same circumstances. The second set of measures are used to contrast the ability of both groups - this time watching moving traffic scenes - to predict the position vehicles will have reached after a further five seconds have elapsed. Performance was again contrasted under single and dual task conditions.

METHOD

Participants

Eighty-six young Novice drivers and 20 Experienced drivers participated in the study. Novices, having little or no driving experience were recruited through secondary schools. Thirty-one novices who had recently obtained a learners permit (approximately within 2-4 weeks of recruitment) reported little on-road driving. They comprised 41 males and 45 females aged between 15-18 years. Experienced drivers were recruited from acquaintances and comprised 9 females and 11 males. They were aged between 28-35 years and had an average of 10 years driving experience. The five expert raters were Monash University Accident Research Centre staff with expertise in the field of novice drivers and/or driver licensing. Three were male and two were female.

Materials & Procedures

For the assessment task, Novice and Experienced drivers used a laptop-based, mouse-driven computer program. A digital camera and digital video camera were used to record images of everyday traffic scenes from the driver's perspective. The situational awareness tasks were presented first, using the still photographs, and second, using the video footage. Assessments were conducted individually on school premises for Novices and at home for Experienced drivers.

Memory for location: still photographs

Participants viewed 25 photographs for five seconds each. 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. After the participant selected a layout, a grid appeared with the driver's vehicle in the bottom row and participants were asked to click on the grid squares corresponding to the approximate locations of up to three other vehicles in the scene.

This task was then repeated using a second set of 25 photographs and adding a distraction task. For the distraction condition, circles coloured either red, blue or green (approximately 15mm in diameter) appeared randomly in a central position below the photographs. 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. After selecting a layout and completing the grid locations, participants were prompted to enter the number of red, blue, and green circles.

Prediction of future location: Moving films

Participants next viewed 8 videos clips that ran for 10 seconds each. They were informed that, after a 10-second interval, the screen would be blank for 5 seconds. They were instructed to predict the road layout and the location of the closest three cars relative to their own car *5 seconds after the video had ended*. That is, they needed to predict how the scenario progressed during the 5-second period while the screen was blank. Their response options were the same as for the still photograph responses. The same 8 video clips, presented randomly, were shown to all participants. The prediction task was then repeated with a second set of 8 video clips (presented randomly) with the addition of the distraction task (as for the still photographs). The situation awareness and distraction tasks were presented as equally important.

RESULTS

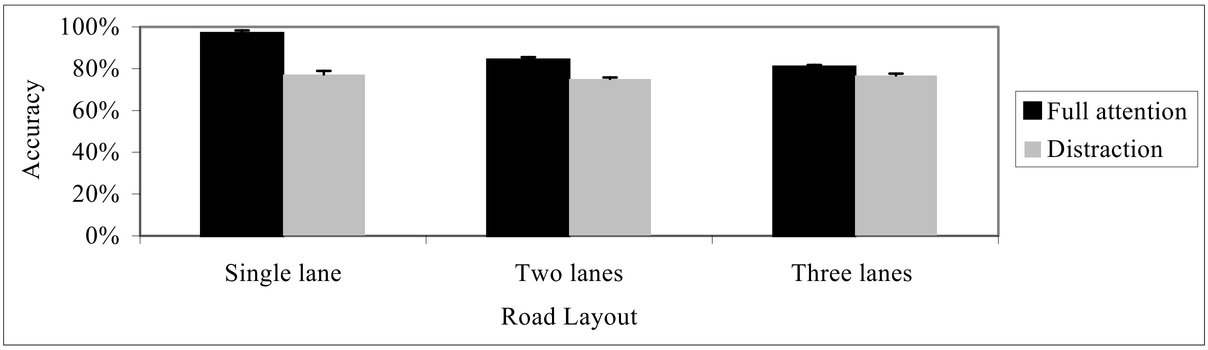
Space does not permit a full exposition of the results from these studies or detailed reporting of the full range of analyses carried out. Instead we concentrate on a number of key issues: the effect of watching the traffic stills or video on performance of the subsidiary visual attention task, the effects of performing this task on memory for own position, road layout, and memory for location of other traffic or prediction of where these vehicles would be located after a further five seconds had elapsed. These issues are addressed separately for the memory and prediction tasks, and in both cases, the performance of novice and experienced drivers is contrasted with a view to identifying whether driving experience affected the cognitive characteristics under study.

Memory for location

Both novice and experienced drivers performed the "subsidiary" memory task more or less perfectly when it was performed without distraction. Even when watching the still traffic scenes, with a view to being able, subsequently, to recollect the location of the three closest vehicles, experienced and novice drivers were able to perform the colour-memory task equally well (t_{103}= 0.377, ns).

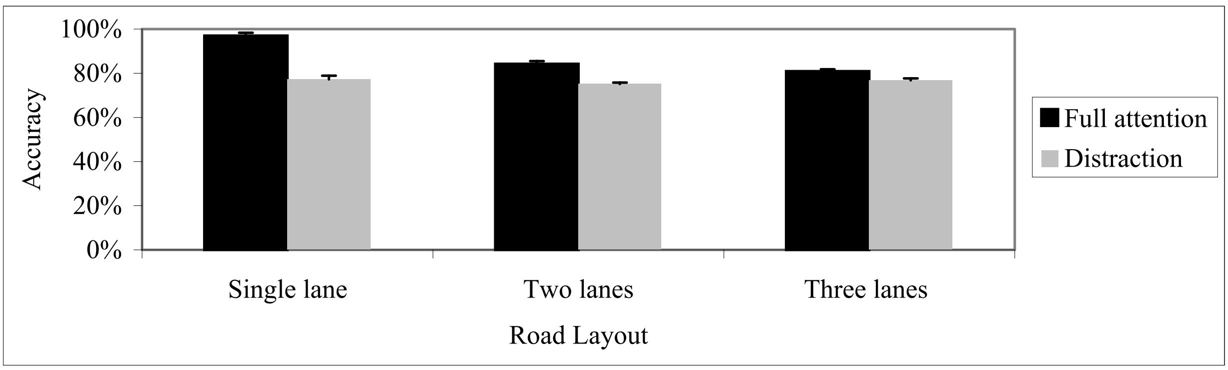
Drivers remembered their own lane position very well under single task conditions (5% error), but reliably less well with concurrent distraction (10% error; $F_{1,103}$= 12.153, p<0.001). Experienced and novice drivers performed this task equally well (F<0.3). By selecting only those cases where drivers remembered their own position accurately, we can assess how well drivers remember the road layout. A mixed three way ANOVA (layout, distraction, experience) revealed that experienced and novice drivers remembered road-layout 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 under dual task 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 1). This is interesting in that a typical pattern of dual task interference is to amplify tasks that are already difficult, whereas what we observed here, 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.

Figure 1 Distraction affects memory for road layout



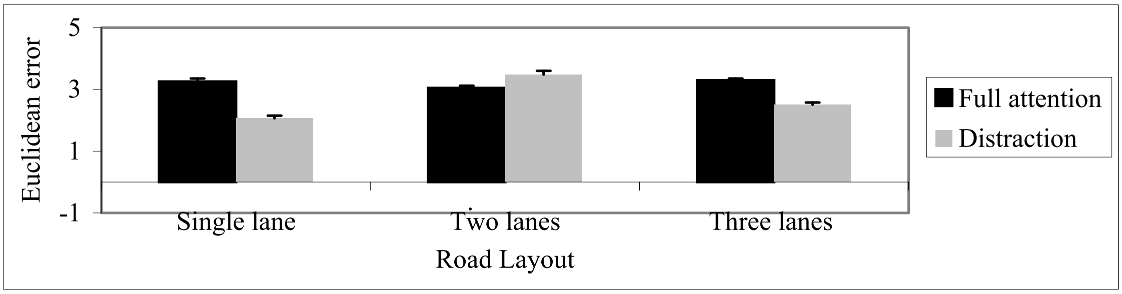
By virtue of specifying where the closest three vehicles were located, participants indicated which lanes were occupied with vehicles. Before considering errors in actual location, it is worth considering memory for position of vehicles at a more coarse level, i.e. whether participants correctly identified 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 others ($F_{2,196}$= 39.275, p<0.001). These two main effects interacted reliably ($F_{2,196}$= 29.297, p<0.001, see Figure 2). Although reliably reduced for each road type, memory for whether lanes were occupied suffered most for the single lane road. 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 2 Distraction affects memory for lane occupation



The mean Euclidean distance between the remembered position 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 3).

Figure 3 Distraction affects 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 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 so than experienced drivers. This bias is reduced when drivers are distracted, such that their underestimation of remembered distance is reduced.

Although we are unaware of any previous reports of such systematic biases in remembering of distance, there are interesting parallels here with the effect of concurrent distraction on the estimation of, and memory of temporal intervals. These typically increase when less attention is available during the encoding of the temporal interval (see Groeger, 1997, Groeger, 2002). 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. Driving experience offers some protection against these effects.

Figure 4 Experience modifies the effect of distraction on memory for vehicle location

Prediction of future location

In contrast to the effect of watching and attempting to remember static scenes, performance of the concurrent task was very substantially disrupted when drivers watched video tapes 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 it did for experienced drivers (t_{103}= 2.619, p<0.01).

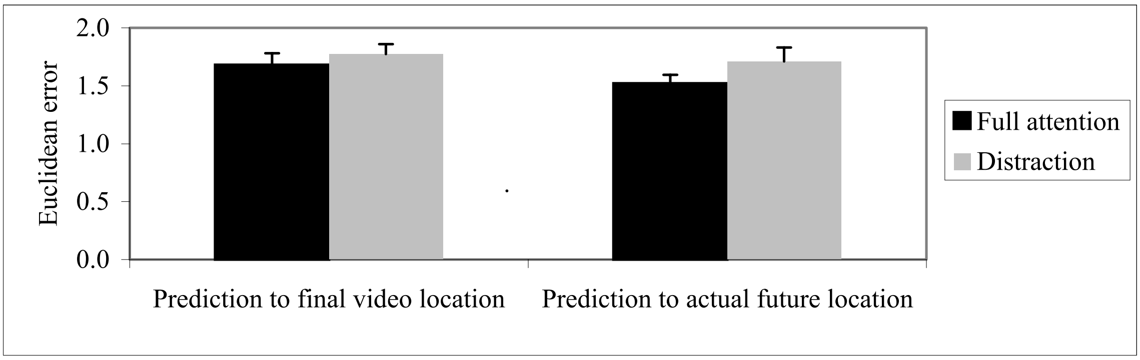
There are also noteworthy differences between the results reported above for the memory task and performance on the prediction task. Drivers memory for their own position was disrupted by distraction ($F_{1,101}$= 11.054, p<0.001), with drivers remembering their position as being further to the right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

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 films 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 films were watched under distracting conditions ($F_{1,103}$= 12.237, p<0.001), but were unaffected by driver experience (F<0.1). There was a substantial, but non-significant, statistical interaction between distraction and experience ($F_{1,103}$= 2.501, p= 0.114), which indicated a trend for a bigger decrement in performance with distraction among more experienced drivers.

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 the position 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). Otherwise the results were 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 5). That is, accuracy of predicted position deteriorates under dual task 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 5 Distraction increases reliance on memory for prediction



DISCUSSION

Differences between the impact of watching traffic scenes for different purposes, and the differential role distraction and driving experience play in remembering and prediction from what we see are the most important results reported above.

Ongoing performance of an identical distraction task was more affected by watching moving video in preparation for the making predictions than it was affected by watching static scenes with a view to remembering their contents. There are two plausible accounts of this result, watching moving images is more demanding of cognitive resource than watching static scenes, or that 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 can not remember many changing values without external aid. However, since memory for own position was subject to greater interference by the same secondary 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, both influence performance.

Despite these differences in the nature of the visual information presented (i.e. still frame versus video), 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 we are in effect witnessing a difference in relevant abilities on the part of the novice and experienced drivers who participated in this study, or whether we are actually witnessing a skill which has undergone minimal or substantial development. In part this issue can be addressed using a longitudinal methodology, in which the novice and experienced drivers taking part are reassessed several times as their exposure to driving increases. This is precisely the focus of the ongoing longitudinal project of which the results reported above form a part, and in future papers we hope to address this issue more formally.

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