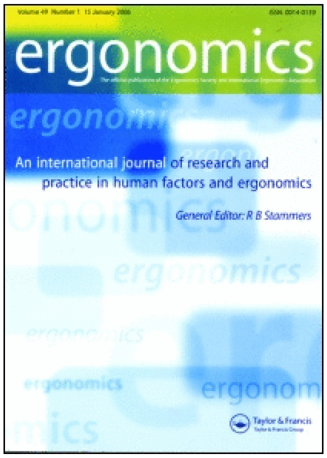

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Visual attention and the transition from novice to advanced driver

G. Underwood [a]
[a] School of Psychology, University of Nottingham, Nottingham, UK

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Visual attention and the transition from novice to advanced driver

G. UNDERWOOD*

School of Psychology, University of Nottingham, Nottingham NG7 2RD, UK

Inexperienced drivers are particularly vulnerable to road traffic accidents, and inattention emerges as a factor in these accidents. What do these drivers attend to and how can their observation skills be developed? When drivers scan the road around them, differences are observed as function of driving experience and training, with experienced drivers increasing their visual scanning on roadways of increasing complexity. Trained police drivers showed this effect of increased scanning even more than experienced drivers. This suggests that the driver's understanding of the task develops with experience, such that roads that demand increased monitoring (e.g. interweaving traffic on a multi-lane highway) receive more extensive scanning than roads that are simpler (e.g. light traffic on a straight rural road). Novice drivers do not show this sensitivity to road complexity, suggesting that they fail to attend to potential dangers involving the behaviour of other road users. Encouragingly, a simple training intervention can increase the visual scanning of novices.

Keywords: Attention; Driving; Road traffic accidents; Hazard perception; Situation awareness; Skill and experience; Driver training

1. Accidents and attention

The driver who is newly qualified is considerably more at risk from involvement in a road traffic accident than the same driver 10 years later. In the UK, novices are more than twice as likely to have an accident than a middle-aged experienced driver. A recent study found that drivers with 3 years of experience had three times the number of accidents per year than their counterparts with 20 years of driving experience (Crundall *et al*. 2003) and national casualty reports regularly point to the disproportionate accident involvement of newly qualified drivers. It is perhaps unsurprising that driving errors are associated with inexperience but the increasingly extensive UK driving examination is designed to reduce this risk by licensing only drivers who show knowledge of traffic regulations (the 'theory test'), who show awareness of driving hazards (the 'hazard perception test') and who can control a vehicle on the road with a set of prescribed manoeuvres and can negotiate the roadway and traffic environment (the 'on-road test'). What is it about novice drivers that

*Corresponding author. Email: geoff.underwood@nottingham.ac.uk

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makes them vulnerable and can we do more to reduce their accident liability? This discussion will focus upon a major factor in road traffic accidents, that of visual attention and distraction, and examine differences between novice, experienced and expert drivers in the distribution of their attention on the roadway. Distraction in this context includes attending to any task other than driving, such as tuning the radio, looking at roadside advertisements, talking to a passenger and, increasingly, using a phone or other communication technology.

Inattention is one of the single most cited causes of road traffic accidents. An early study by Lestina and Miller (1994) analysed 1396 police reports of accidents in California and found that not only was this an over-represented factor, but young novice drivers had inattention cited as a causal factor in their accident reports more often than older drivers. For drivers under the age of 20 years, the ordering of contributory factors was failure to search the roadway (39% of accidents), failure to comply with road regulations (18%), failure to control the vehicle (11%) and speed (7%). For drivers aged 35–54 years the figures were 10%, 15%, 11% and 10% respectively. These data come from police reports written some time after the event, of course, rather than being direct observation of behaviour at the time and as such must be treated with caution. The recollections and rationalizations of memories of those involved may contribute to errors in the formulation of accident reports written after the event, including the omission of transitory events involving inattention.

The higher susceptibility of inexperienced drivers to distraction-related accidents was confirmed in a second analysis of approximately 5000 US accident descriptions by Stutts *et al.* (2001), who identified around 15% of accidents as involving driver distraction. In evidence to the US House of Representatives Subcommittee on Highways and Transit, the Director of the National Highway Traffic Safety Administration (NHTSA) has concluded that: 'estimates that driver distraction in all of its various forms probably contributes to between 20 and 30 percent of all crashes' (Shelton 2001), citing a figure comparable to the Lestina and Miller estimate, when averaged over all age groups. This is a substantial contribution to the causes of accidents, but there is good reason to conclude that these figures underestimate the involvement of inattention and distraction.

The estimates of distraction-related accidents range from 15–40% on the basis of accident descriptions, but by observing behaviour directly the estimate is elevated. This conclusion comes from the '100-car naturalistic driving study' in Virginia, also funded by the US NHTSA, where cars were instrumented with sensors (longitudinal and lateral accelerometers, headway detection) and five video cameras (Klauer *et al.* 2006). A total of 241 drivers used the 100 cars and over the course of 1 year of observations more than two million miles were driven and recorded. During this time there were 82 crashes and 761 near-crashes recorded and analysed. Incidents were recorded immediately by drivers using an additional data channel and the film clips and other data were viewed by a team of analysts after the event. The dramatic result from this study was that 78% of the crashes and 65% of the near-crashes involved some form of inattention. The most common distraction involved the use of a mobile phone or PDA although passenger-related distractions also figured prominently. Other distractions included looking at external objects, smoking, eating, personal grooming and reaching for a moving object within the car. The discrepancy between the estimates of distraction-involved accidents from analyses of video recordings and from analyses of police narratives is striking and serves to underline the dangers of inattention while driving. The 100-car study also confirmed the high involvement of young drivers (18–20 years) in distraction-related crashes and near-crashes, with five times the involvement relative to older drivers.

Lestina and Miller (1994) identified a failure to search the roadway as the single most frequent factor in the accidents of young novice drivers, and the question arises of what differences can be observed in the roadway inspection patterns of drivers of varying experience. This question has motivated this research using eye-monitoring techniques and the remainder of the discussion will address this question about visual scanning and anticipating the behaviour of other road users.

2. Visual attention and driving experience

To be safe on the roads, one needs to be predictable to other road users, by staying in lane and maintaining a conventional speed and headway and by keeping the vehicle on course by navigating corners and bends by turning the steering wheel through the optimum angle and by being able to brake and avoid hazards as they occur. Drivers also need to be aware that the conventions of speed and traffic position vary under different road conditions and this predictability of the behaviour of other road users is used to identify safe pathways through the traffic. By following the conventions, drivers also make themselves predictable and therefore safer. The primary input to the motor-control tasks that maintain the vehicle's trajectory is visual, of course, with varying estimates of the extent to which driving is a visual activity, but it is sufficient to conclude that visual input is by far the most important source of information for the driver (Sivak 1996). The driver's visual attention is limited and every object visible in the driving scene cannot be given full processing. Indeed, much of the roadway and other road users may be passed by with only fleeting awareness of their presence. This does not pose a problem on a rural road with no traffic, as much of the visual information that is available is irrelevant. Under these undemanding conditions, the driver will have spare attentional capacity that could be easily devoted to interesting, but irrelevant, stimuli. Distraction from the driving task would be less likely to have critical consequences here. It has been found that when driving on rural roads, drivers characteristically have long eye fixations that are indicative of an absence of scanning for hazardous objects (Crundall and Underwood 1998). In such undemanding conditions, experienced drivers can devote up to 50% of their time to inspection of the scenery (e.g. Hughes and Cole 1986, Green 2002). On other roads, the demands placed on a driver can increase to a point where there are insufficient resources to monitor every relevant object in view. This may occur due to an increase in the number of task-relevant stimuli (perhaps involving an increase in traffic density or at complex junctions) or an increase in visual clutter that may mask potential hazards (such as driving through a congested urban street). Whatever the cause of the increase in demand on the driver's attention, critical decisions will need to be made about what to attend to and which vehicles are likely to present problems in the immediate future.

2.1. *Scanning strategies while driving*

The most common strategy for drivers in an undemanding situation is to look straight ahead at the position in the roadway where their vehicles will be in the next few seconds. The focus of expansion is generally synonymous with the direction of the vehicle, at least on straight roads, and this is the location of gaze most favoured by experienced and novice drivers (Mourant and Rockwell 1972, Underwood *et al.* 2003). When drivers are not gazing straight ahead, however, the majority of fixations tend to fall to the left and right of the focus of expansion, inspecting pedestrians, parked cars and other potential sources of hazards. This creates an elliptical inspection window, with the majority of fixations falling along the horizontal plane with relatively fewer fixations in the vertical plane (Chapman and Underwood 1998). Inexperienced drivers tend not to have such a wide spread of fixations in the horizontal plane and have been observed to make more fixations in the vertical plane (Mourant and Rockwell 1972, Evans 1991, Crundall and Underwood 1998). This suggests that the horizontal bias is developed or learned with experience, possibly as drivers learn to anticipate the locations of potentially hazardous road users.

One of the remarkable changes that occur as drivers develop their skills is the increase in visual scanning. The novice is relatively insensitive to changes in road traffic conditions, whereas the experienced driver will anticipate potential problems by looking to parts of the roadway where other road users may intersect. Experienced drivers, for example, use their exterior mirrors more than novices and while novices do not use their mirrors differentially when making different manoeuvres, experienced drivers make greater use of the exterior mirrors when information about traffic in an adjacent lane is required – they collect information appropriately (Underwood *et al.* 2002b). This analysis recorded the number of glances in each mirror, and their durations, as the drivers negotiated a number of lane changes at a complex intersection. A similar conclusion comes from an analysis of eye movements made on different types of roads: as experienced drivers encountered road layouts that varied in complexity, their eye movements changed, whereas novices were relatively insensitive. Crundall and Underwood (1998) reported that on quiet rural roads and on busier suburban roads, novice and experienced drivers scanned the roadway to a similar extent, but that on a dual carriageway with slip roads merging from both left and right only the experienced drivers increased the extent of scanning. It appeared that only the experienced drivers attempted to collect information about the presence of traffic in other lanes. The measure used here was the variance in locations of fixations, with higher variance indicative of greater scanning. The pattern of results is shown in figure 1, with a similar result being reported by Falkmer and Gregersen (2001) in a study of Swedish

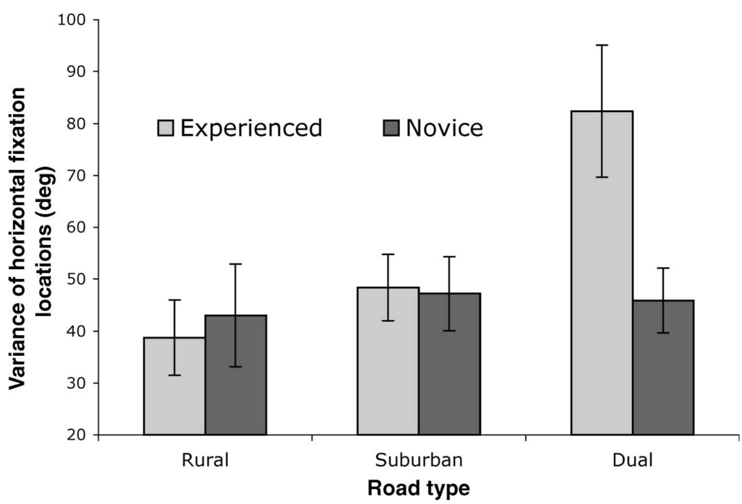


Figure 1. Differences in the scanning patterns of novice and experienced drivers on three types of roads as indicated by the variance of fixation locations along the horizontal axis (adapted from Crundall and Underwood 1998).

drivers that found that learners scanned the roadway less on a high-demand city road than on a quieter rural road.

Why do novices not look around them at the very point at which it is clearly important to do so? This paradox has prompted a number of studies. One option is that novices are unaware of the potential danger from other traffic changing lanes around them, and this can be described as a difficulty with situation awareness (Endsley 1995, Gugerty 1997, Horswill and McKenna 2004) in that they may have an incomplete mental model of the dangers that can occur on certain roads. They may not have been aware of the dangers presented by the needs of other road users and the risk of collision when vehicles merge over several traffic lanes. A second explanation of the paradox is that the novices were unable to allocate sufficient cognitive resources to scanning the roadway and collecting information about potential dangers because they had not had sufficient driving practice to have automatized the sub-skills of steering and speed control to be able to release capacity to navigation and road situation awareness. Recarte and Nunes (2003) found that a secondary task that increases mental workload has the effect of decreasing the driver's scanning behaviour and so it may have been that the novices were overloaded by driving on the dual carriageway in the Crundall and Underwood (1998) study and by driving on the busy city road in the Falkmer and Gregersen (2001) study. If overloaded by the task of vehicle control they may not have had sufficient residual mental capacity to collect information about the neighbouring traffic.

2.2. *Scanning strategies in the laboratory*

When eye movements are recorded in laboratory tasks, a difference is seen between experienced drivers and expert drivers. The expert volunteers in the Crundall *et al.* (2003) experiment were police pursuit drivers. These are the drivers who respond to emergency calls and who follow suspected law violators. Their task often requires fast driving in crowded traffic and they might be expected to have heightened situation awareness. This study used film clips recorded from a moving vehicle and eye movements recorded while participants watched, with the task of operating a sliding lever on a response box to indicate how hazardous the scene was, on a moment-to-moment basis. Three groups of drivers were tested, police pursuit drivers with a mean of 22 years of experience, a matched group of non-police drivers with similar experience and a group of less experienced drivers with a mean of 3 years of driving. The spread of horizontal fixation locations was similar for the two groups of non-police drivers, suggesting that the need to look around the driving scene was learned with just 3 years of driving experience, but the variance of locations was greatest for the police drivers. The durations of eye fixations of the police drivers were also shorter than those of the other drivers, again indicating that they were moving their eyes more and looking around the scene to a greater extent. The demands of the police pursuit driving task were associated with increased scanning over and above that seen in experienced non-police drivers.

Perhaps novices stereotypically look straight ahead when driving because they have inadequate or under-developed mental models of the driving task. As drivers interact with other vehicles and observe the behaviour of road users on varying road conditions, they accumulate memories of events that happen on different kinds of roads, and of their probabilities of occurrence. These situation-specific expectancies in driving can help guide drivers through environments that have not been encountered previously, but are sufficient to allow the generalization of behaviour. For example, entering an unfamiliar dual carriageway from a slip road can be performed by referring to a mental model or 'script' based on previous manoeuvres of this type. It may be that novice drivers have an impoverished set of scripts or mental models, in comparison with experienced drivers, having been accumulated mainly as a cyclist or passenger. It is possible that when novices scan the dual carriageway to a lesser extent than experienced drivers, it is because they are unaware of the special dangers from interweaving traffic that are associated with this particular type of road. If they have not driven on roads with other vehicles changing lanes and entering the main lanes at different speeds to the vehicles already in the main lanes, then they will not have a mental model to alert them to the dangers presented by the variations in speed and trajectory of other road users. They perhaps have had insufficient exposure to this kind of road with which to build a mental model of the probable behaviour of other vehicles, are unable to predict where other vehicles will be in a few seconds time and do not recognize the demands of interweaving lanes of traffic.

2.3. *Situation awareness in driving*

Do novice drivers fail to scan the horizontal plane because they have inadequate cognitive resources or because they have an under-developed mental model of the events that can occur on complex road layouts? Endsley's (1995) three-level model of situation awareness provides a basis for distinguishing between drivers with different skills and helps to clarify the causes of drivers who scan roads in different ways. Being able to predict the behaviour of other road users, and to anticipate how the current situation might develop as other vehicles manoeuvre around, would correspond to awareness at the third and highest level in Endsley's model. Differences in scanning behaviour may be indicative of differences at this level of situation awareness. Drivers would be comparable at the first level of situation awareness, which requires perception of the environment without interpretation of the relevance of the individual elements that are recognized. At this level the driver would be aware of other road users, for example, but would not calculate trajectories or risks. At the second level, the driver has an understanding of the current situation and will integrate the perceptions gained at the first level to develop an understanding of where other drivers have come from and what they are doing at the present time. The third level of situation awareness is associated with anticipation and prediction and enables the driver to plan a course of action. At this level, the driver will be able to predict the outcomes of various scenarios, knowing the risks associated with different manoeuvres and being able to calculate a safe pathway through the traffic. The anticipation of hazards and the planning of a safe route – knowing what other drivers will be doing during the next few seconds and therefore where the safe zones are likely to be – are characteristic of this level and may provide a description of the differences between novices and experienced drivers when they encounter complex traffic situations such as those involving multi-lane roads with slip roads and interweaving files of vehicles. It is at this level that experienced drivers will know where to look in order to collect the most salient information about other road users, and the possibility emerges that, in studies of scanning behaviour, the novices tend to look straight ahead because they are unaware of the need to build a mental model of the intentions of other drivers and where their trajectories are taking them.

Laboratory evidence was sought to help distinguish between the cognitive resources and mental model hypotheses of driver scanning behaviour using film clips and eye movement recordings (Underwood *et al.* 2002a). Earlier studies have demonstrated that novice and experienced drivers inspected different types of roads in different ways, but this may have been due to the resources required for vehicle control or to differences in their mental models of driving encounters. The study tested between the hypotheses by eliminating the need to control a vehicle and the task was essentially one of observation and prediction, as in the study with police drivers. Volunteers sat in the laboratory and watched film clips recorded from a car as it travelled along five different roads – including the roads used by Crundall and Underwood (1998) – again observing scanning differences between drivers. Their task was to make a key-press response if they saw an event that would cause a driver to take evasive action and while they watched the films their eye movements were recorded. If novices have restricted search patterns because their resources are allocated to vehicle control, then eliminating this component of the driving task should have resulted in visual search patterns in the laboratory that are equivalent to those of experienced drivers. However, if their search patterns result from a mental model that does not inform them of the particular hazards associated with dual carriageways, then they should continue to restrict the extent of their searches while watching recordings of these situations in this non-interactive, viewing-only task.

The results indicated that the two groups of drivers were thinking about the scene differently, even though their resources were not occupied by the demands of vehicle control. On the simplest of roads – a rural road and a traffic-free dual carriageway – there was minimal horizontal scanning by each group of drivers, but as the traffic conditions became more complex it was the experienced drivers who increased the extent to which they moved their eyes from side to side. A statistical difference between groups was seen only for the demanding dual carriageway, a result that reflected the pattern found by Crundall and Underwood when participants actually drove on these roads. It is not the need to control the vehicle that induces the reduced scanning of the novices – or, rather, increased scanning by the experienced drivers – so much as a difference in their situational awareness. The results from this study are shown in figure 2.

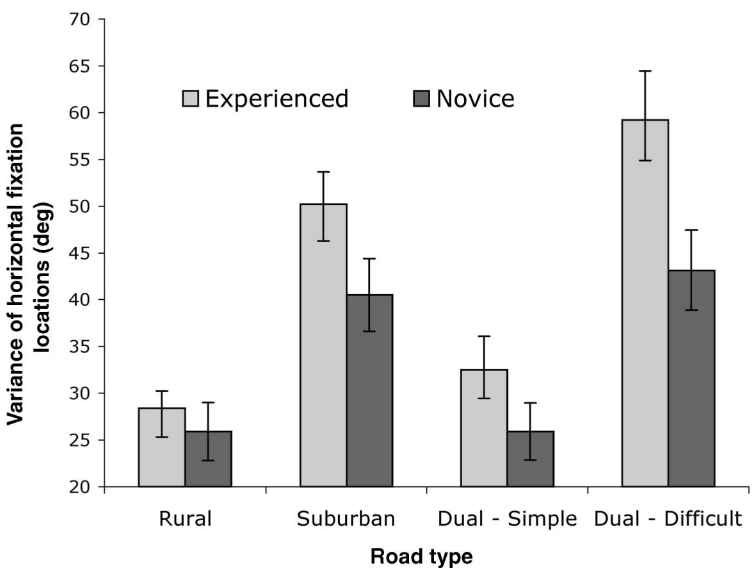


Figure 2. Differences in the scanning patterns of novice and experienced drivers watching film clips of four types of roads as indicated by the variance of fixation locations along the horizontal axis (adapted from Underwood *et al.* 2002a).

The more skilled a driver, the more they will scan widely. The progression from novice to experienced driver and then to professional expert driver is indicated in the measure of the variance in fixation locations. The more a driver looks around the scene, the greater will be the variance in horizontal locations of eye position. This is a crude measure, however, and indicates only a very general pattern of visual attention. It indicates that the attentional spotlight is in transit for more skilled drivers and tends to point straight ahead for novice drivers. To overcome this limitation in the nature of the data, a content analysis was also performed of the fixation patterns of the drivers who participated in the Crundall and Underwood (1998) study by recording what part of the visual field was being inspected. Underwood *et al.* (2003) analysed the eye fixation recordings of the novice and experienced drivers on the three types of roads, to identify differences not in the extent of scanning but in what was being inspected. In a study of scanpaths made in a driving simulator, Liu (1998) compared fixation transitions from one area of the visual scene to another and found that some of these transitions were statistically more likely to occur than others. These strings of fixations formed reliable scanpaths that would recur. The most robust pattern was characterized by a shift in the position of the eyes from the focus of expansion to either the left or right edge of the road. This procedure was used as the basis of the scanpath analysis of drivers' eye fixation transitions.

The scanpaths identified by this analysis supported the general observation that novices have restricted fields of interest. The process first identified fixations in one of 11 locations – left, ahead and right fields at near (up to 1 s ahead), middle (between 1 and 2 s ahead) and far distance (more than 2 s ahead), giving a 3×3 matrix of fixations located in two dimensions. In addition, glances at two other types of object types were recorded, mirrors and 'other objects', including other road users, the car's controls and specific roadway features such as signs and side roads. The analysis of interest identified fixation transitions that were statistically over-represented and two-fixation scanpaths were identified for the two groups of drivers on the three types of roads. Novice drivers showed dominant scanpaths on all three roads, which can be characterized as an eye movement from whatever they were looking at, to the roadway far ahead. This is especially noticeable on the rural road where a fixation on any of the ten possible locations resulted in fixation far ahead. There were no other reliable transitions on this road. On the other two roads, there was still a frequent pattern of looking next at the roadway at least 2 s in the future (eight out of the 11 reliable transitions on suburban roads and six out of the nine transitions on the dual carriageway). The experienced drivers did not show this dominating interest in the roadway in the far distance. On rural roads there were four out of a total of nine reliable transitions ending in the road far ahead, and on suburban and dual carriageway roads there were seven out of ten and three out of four reliable transitions respectively. The second notable feature emerging from this analysis, after the dominance of the road far ahead for novices, was the absence of a dominant pattern for experienced drivers, particularly on the dual carriageway. Stereotypical behaviour was less apparent in the scanpaths of the experienced drivers.

3. Attending to hazardous events

As well as controlling the vehicle itself, the driver must attend to various external events in order to maintain their situation awareness and here there may be differences between novice and experienced drivers. The mental model of the position and movement of neighbouring vehicles is built by acquiring information from the external world. Drivers need to actively monitor specific sources of information when they occur in the driving scene, to know that their current pathways are safe and to anticipate whether braking or steering changes will be required as events unfold. This can include the monitoring of speed limit signs to ensure the limit is being observed or more active monitoring of potentially dangerous areas of the visual field that may require a change of velocity. Monitoring activities include hazard perception, which has been described as situation awareness for dangerous situations during driving (Horswill and McKenna 2004). Drivers need to devote some attention to oncoming vehicles, even under demanding traffic conditions, as part of a need to update their mental model of the roadway situation. This involves estimating where the other road users will be during the next few seconds and evaluating whether any of the other road users look likely to enter an intersecting trajectory. Even though a driver may have no intention of crossing the opposing lane of traffic, the only way that they can anticipate the future behaviour of an oncoming driver is by looking at their current behaviour. Direction signals, lane position and speed need to be assessed for the driver to decide whether a change of velocity is required. If the oncoming driver is indicating to cross the driver's path and actually begins to move out of their anticipated safe course, then an evasive manoeuvre may be required. Likewise, if the oncoming driver is weaving erratically, or perhaps approaching a parked vehicle that must be overtaken, there is the possibility that an emergency response will be needed. Oncoming cars are therefore highly relevant objects that may need to be monitored in case a hazardous situation develops.

The identification of hazards is now recognized as a vital and complex skill that unlicensed drivers need to demonstrate as part of their driving test – a video-based hazard perception component was added to the UK driving test in November 2002. Several studies have demonstrated that experienced drivers respond faster to the appearance of a hazard on film clips taken from the driver's point of view (McKenna and Crick 1994, Renge 1998, but see also Chapman and Underwood 1998) and it seems that much of this benefit may accrue from experienced drivers' improved deployment of both overt and covert attention (Chapman and Underwood 1998, Underwood *et al.* 2002a, 2005). Differences can be seen in the responses to hazards by novice and experienced drivers, although the evidence from these studies does not fully support the use of hazard perception tests as part of the licensing process, because responses to filmed hazards do not discriminate clearly between drivers of different ability. It appears that new drivers need to learn the likely sources of hazards through guided practice and experience, so that they can search out these areas of the visual scene when driving and monitor their development over time.

Scanning behaviour changes when hazards occur, with attentional capture or increased focusing on the hazardous object indicated by longer eye fixations at the time of hazard detection. This effect of attentional capture is shown in figure 3. The data shown in this figure come from a study reported by Underwood *et al.* (2005), in which laboratory volunteers watched film clips of roadway scenes recorded from a moving vehicle and in which hazardous events occurred. For example, as the filming car travels down a suburban road, a cyclist might appear from a side road, requiring braking, or the car travelling in front might brake to allow a pedestrian to cross the road. The task in the experiment was to press a response button at the point where the driver would need to take action. Although this study compared experienced younger and older drivers, the pattern of responses was very similar for these two groups. As figure 3 indicates, at times before and after a hazard, eye fixations lasted less than 0.5 s, but at the time of the hazard response durations were doubled. This is the power of a hazard to capture the

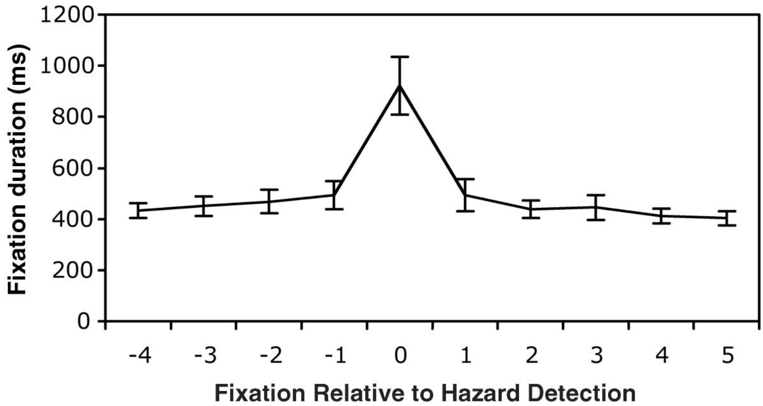


Figure 3. Fixation durations around the time of detecting a hazard. The experienced drivers in this study were watching a film clip showing a hazardous event, and the durations of fixations just before and just after the appearance of the hazard are shown here together with the fixation made at the time of pressing a response button to indicate hazard detection.

attention and it is entirely appropriate that drivers should attend closely to other road users whose pathways may intersect with their own. But they should not attend too closely or for too long, otherwise a secondary hazard may be missed. Suppose, for instance, that as the leading car in the example brakes in order to allow a pedestrian to cross the road and, as a consequence of this, other road users have to take evasive action themselves. When there are a number of road users in the scene, one abrupt change to the smooth flow of actions may have consequences for the behaviour of several other users and drivers need to monitor all potential paths of activity. By focusing closely on the one primary hazard, other road users may be ignored, even when they are becoming hazards themselves.

3.1. *Attentional capture and the anticipation of hazards*

The attentional capture of a hazard is greater for novices than for experienced drivers. Chapman and Underwood (1998) showed film clips of road hazards similar to those in the Underwood *et al.* (2005) experiment described above and again recorded hazard detection responses, as well as recording eye fixation behaviour. Hazard detection responses did not vary between novices and experienced drivers, leading to the conclusion that the hazards used in this study were unsuitable as the basis of a discriminative driving test. The hazards in this study frequently appeared abruptly and captured attention very effectively regardless of driving experience, whereas a more effective discriminator would involve hazards that could be anticipated if the driver's situation awareness included the projected movements of other road users. Novices and experienced drivers did differ in their eye fixation behaviour, as shown in figure 4.

As in figure 3, when the hazard appeared, fixations were longer, and this applied for both groups of drivers and for all three types of road hazard. Experienced drivers were less vulnerable to the effect of attentional capture, however, with fixations that were shorter than those of novices when the hazard was in progress. This means that they were better able to re-focus their attention on the rest of the roadway because their attention was locked on to the hazard for a shorter interval.

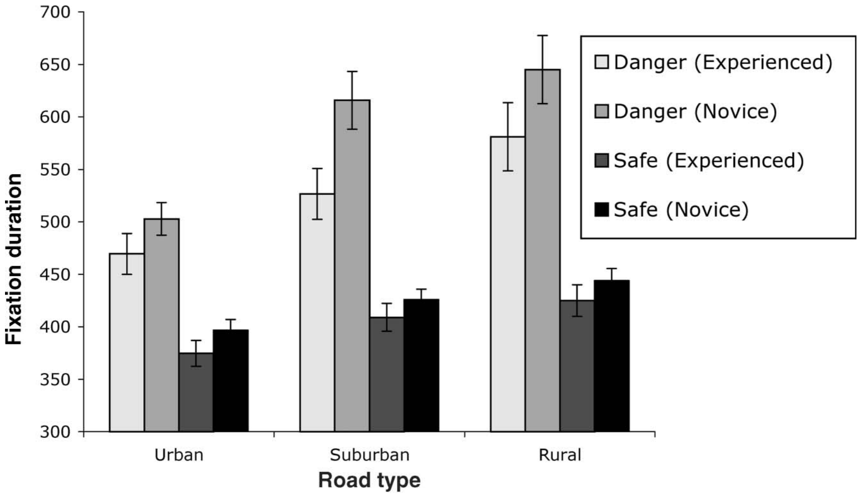


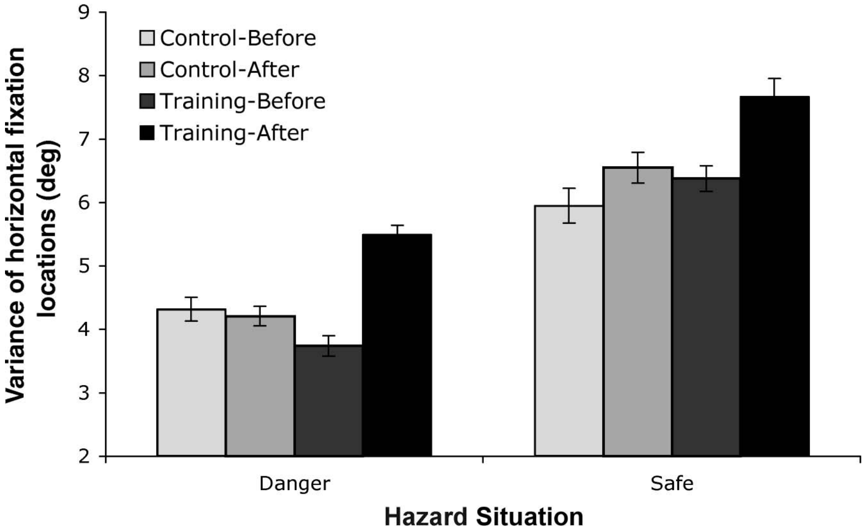
Figure 4. Fixation durations around the time of detecting a hazard. Participants in this study were watching a film clip showing a hazardous event. Fixations at the time of a hazard ('danger') and at other times ('safe') are shown for novice and experienced drivers looking at film clips showing three types of roads (adapted from Chapman and Underwood 1998).

The anticipation of a hazard is a valuable part of driving and experienced drivers show their awareness of the dangers inherent in traffic situations by scanning widely – by monitoring the behaviour of other traffic. Evidence was also found to suggest that highly experienced drivers are more likely to seek out and monitor potential hazard locations. In the study of expert drivers described above, the eye movements of police drivers (trained to pursuit standard) were compared with matched control drivers and novices while performing a hazard perception task (Crundall *et al.* 2003). Three different types of driving film clip were used: police pursuits; emergency responses; and control drives. During pursuits filmed from actual police cars involved in real incidents, all of the laboratory volunteers tended to look at the fast-moving leading vehicle for a high proportion of the time, although the police drivers made better use of those moments when they were not fixating the fleeing car, monitoring other potential hazard locations such as parked cars, pedestrians and side roads. This represents a schema developed by pursuit drivers that assigns priorities to secondary sources of hazard and is only possible when attention is not totally captured by the primary hazard. Whether attention is focused on the road straight ahead or on an abruptly appearing hazard, this is detrimental to scanning and to anticipating the behaviour of the neighbouring traffic. It is possible to train drivers in the anticipation of hazards in complex traffic situations, however, as has been demonstrated in a study of novice drivers.

3.2. *Learning to anticipate hazards*

Chapman *et al.* (2002) recruited two groups of novice drivers, giving one group a specifically designed hazard awareness training intervention. The training was film-based and used a set of hazard perception clips similar to those used in other studies. The training encouraged scanning and the anticipation of hazards, drawing attention to potentially hazardous

(A) Laboratory viewing of hazard perception film clips



(B) Driving on three types of roads

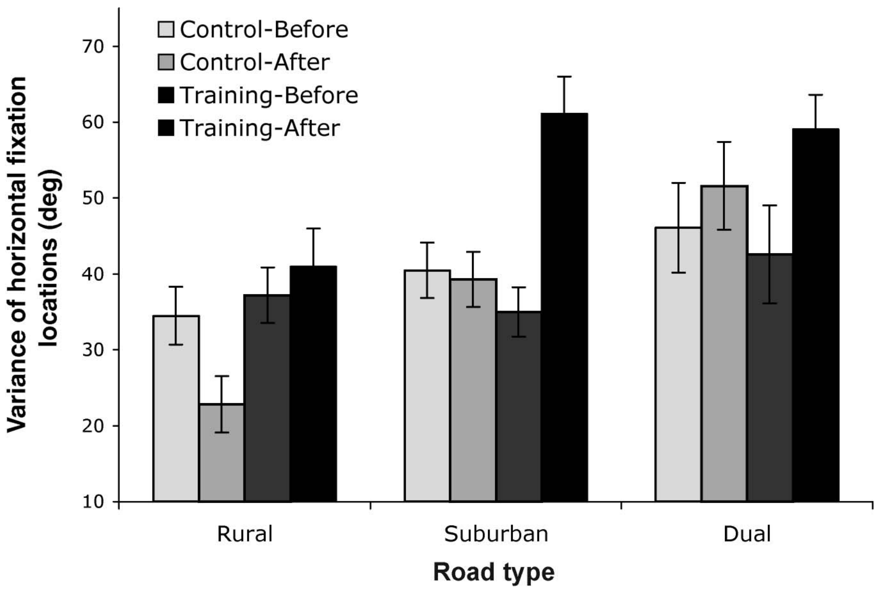


Figure 5. Effects of a laboratory training intervention used to emphasis roadway scanning and the anticipation of hazards. (A) shows the effects of training in comparison with a control group of novice drivers when tested using hazard perception film-clips similar to those used in the training; (B) shows the effects upon eye movements when driving (adapted from Chapman *et al.* 2002).

situations with circles superimposed on objects shown in each film. With multiple sources of potential hazards, multiple circles were used. For example, as the film-car travelled down a suburban road, circles were placed around parked cars and a commentary suggested that they be monitored in case a car door might open and a person might step out, or perhaps a child who is obscured behind the car might run out on to the road. When a manifest hazard occurred – a person emerges on to the road from behind a parked truck – then the circle changed colour to indicate that action would need to be taken. When there was just one potential hazard in view – a pedestrian walking along the pavement at the side of the road, for example, a circle would be used to identify the potential danger and a larger ellipse over the roadway was used to suggest that general scanning was possible.

After receiving the training in anticipation and scanning, both groups of novices were observed on two tasks, one of which used hazard perception film clips similar to those used in the laboratory and in the second task the novices were asked to drive around the same road circuit of rural, urban and dual carriageway roads that they have used previously. Eye movements were recorded on both tasks and the primary measure used by Chapman *et al.* (2002) was the extent of scanning – the variance in fixation locations, with high variance indicative of increased scanning. The results of this comparison of trained and untrained novices are shown in figure 5. Both in the laboratory and on the road, the intervention group who had received the training scanned the scene to greater extent than the untrained group. This simple laboratory training was seen to transfer to on-road driving behaviour. This advantage for the trained novices was observed on both tests immediately after receiving the laboratory training, but there was also an indication of a residual advantage when the drivers returned to be re-tested a few months later. Given that novices are most vulnerable to road traffic accidents, and specifically inattention-related accidents, within the first few months of gaining their driving licence, perhaps it is sufficient to elevate their scanning and anticipation behaviour with this artificial intervention for just a few months. Once they have gained a little more driving experience and have started to build their own catalogue of mental models of different situations, their own implicit knowledge of the probable behaviours of other road users and the dangers of specific situations will take over from the explicit scan-and-anticipate strategy recited during training.

4. Conclusions

Investigations of the characteristics of road traffic accidents lead to the conclusion that inattention is a potent factor. The increasing use of in-car technology, including navigation devices, mobile phones, PDAs and entertainment technology, such as the iPod, serve to increase the possible sources of distraction. Studies of police reports of accidents, based on statements made by participants and witnesses, estimate that between 20% and 30% of accidents are distraction-related. This is not to say that a distracted driver will invariably be involved in an accident. Activities, such as eating, smoking, applying makeup, looking for objects in the vehicle and looking at driving-unrelated objects on or near the roadway all constitute distractions from the task of maintaining control of the vehicle and responding to changes in the road environment, but any one of them may, on occasions, be performed without detriment to driving. The risk of an accident increases dramatically if, while the driver is distracted, an unexpected road event occurs, such as a non-monitored road user enters an intersecting trajectory. The distracted driver is then unable to respond promptly and a collision becomes probable.

The estimate of 20–30% of accidents being distraction-related, as disturbing as it is, now seems likely to be an underestimate. Video recordings of drivers over the course of a year suggest that three-quarters of accidents involve driver-distraction as a factor. Failure to devote full attention to the road environment increases the risk of an accident, and the second finding both from studies using police reports and from in-car video recordings is that distraction is a greater factor for novices than for more experienced drivers.

When the distribution of attention in drivers was looked at by recording their eye movements while driving, a different conclusion emerges, but again there is an attention-deficit in the behaviour of novice drivers. Novices scan the roadway less than experienced drivers, tending to focus on the road directly ahead of them. When the eye movements of expert drivers are recorded in the laboratory as they watch film clips of roadways, they scan the scene more than experienced drivers. As skill increases, so does scanning. The novices would not be expected to show signs of distraction in these studies, of course, because they had an observer with them at all times and so they might be expected to behave as they thought they should behave. A laboratory study that required only observation and hazard detection also found reduced scanning on the part of novices, leading to the conclusion that it was not the high demand of vehicle control that inhibited scanning, but that they had an undeveloped situation awareness, in which their mental model of the roadway did not have accurate estimates of the behaviours of other road users.

The novice's failure to scan the roadway as fully as experienced and expert drivers places them at a disadvantage when hazardous events occur. The attention of all drivers is captured by the appearance of other road users on trajectories that might result in a collision, but novices are more vulnerable to this hazard-focusing than are experienced drivers. A simple training exercise that emphasizes scanning and the anticipation of hazards can help overcome this focusing and increases the extent of searching the scene. This training has been seen to influence scanning in a laboratory test and when driving and, although the novices may soon forget the explicit instructions to scan widely and to look for potential danger, it may be sufficient to reduce their accident liability while they are at their most vulnerable. Accordingly, the conclusion from these studies is that novice drivers under training should receive specific instruction on the distribution of their attention while driving, to encourage visual scanning of the roadway to aid their anticipation of hazards and to develop their situation awareness. The purpose of this instruction should be to help novices to understand and predict the behaviour of other road users and to do this they need to scan the roadway extensively to determine their locations and probable courses of action.

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