Developments in hazard perception

Prepared for Road Safety Division, Department of the Environment, Transport and the Regions

F McKenna and J Crick (University of Reading)
The information contained herein is the property of the Transport Research Laboratory. This report has been produced by the Transport Research Laboratory under a contract placed by the Department of the Environment, Transport and the Regions. Any views expressed in it are not necessarily those of the Department. Whilst every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date at the time of publication, the Transport Research Laboratory cannot accept any liability for any error or omission.
CONTENTS

Executive Summary 1

1 General introduction 3

2 Experiment I: The use of video technology in developing the hazard perception skills of novice drivers 4
   2.1 Introduction 4
   2.2 Method 4
      2.2.1 Subjects 4
      2.2.2 Hazard perception test 4
      2.2.3 Procedure 5
   2.3 Results 5
   2.4 Discussion 5

3 Experiment II: Determining the critical components of the hazard-perception training package for novice drivers 6
   3.1 Introduction 6
   3.2 Method 6
      3.2.1 Subjects 6
      3.2.2 Procedure - Training 6
      3.2.3 Procedure - Testing 7
   3.3 Results 7
   3.4 Discussion 7

4 Experiment III: Dual-task performance and hazard perception 8
   4.1 Introduction 8
   4.2 Method 9
      4.2.1 Subjects 9
      4.2.2 Procedure 9
   4.3 Results 10
   4.4 Discussion 10

5 Experiment IV: Development of a measure of drivers’ choice of speed 10
   5.1 Introduction 10
   5.2 Method 11
      5.2.1 Subjects 11
      5.2.2 Procedure 11
   5.3 Results 11
   5.4 Discussion 11
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 General discussion</td>
<td>12</td>
</tr>
<tr>
<td>6.1 Driver training</td>
<td>12</td>
</tr>
<tr>
<td>6.2 Automaticity</td>
<td>12</td>
</tr>
<tr>
<td>6.3 Speed</td>
<td>12</td>
</tr>
<tr>
<td>7 Conclusions</td>
<td>12</td>
</tr>
<tr>
<td>8 References</td>
<td>12</td>
</tr>
<tr>
<td>Abstract</td>
<td>14</td>
</tr>
<tr>
<td>Related publications</td>
<td>14</td>
</tr>
</tbody>
</table>
Executive Summary

It has been found that in the early part of a driver’s career the ability to detect hazards is poorly developed. There appears little doubt that with experience hazard perception improves, but relying purely on experience may be a slow, inefficient and dangerous procedure. One of the aims of the present work was to determine if remedial measures could be readily designed. A hazard perception training programme was developed that incorporated the features of being relatively short in duration (total of four hours) and could be carried out off-road. In two experiments it was shown that the training programme was successful in improving the time taken to detect hazards. The specific ingredient that was shown to be successful was the requirement to make predictions of what would happen next.

A second aim of the research was to examine the widespread belief that driving is an automatic task. The claim here is that with practice the driving task becomes relatively undemanding, allowing the driver to carry out other tasks without interference. The present research examined whether hazard perception was disrupted by carrying out another task. It was found that there was interference in the time taken to detect hazards. This and subsequent research supports the notion that hazard perception is not an automatic process.

The final aim of the research was to determine if it was possible to use the same video methodology that has been used in hazard perception to develop an equivalent measure of driver speed choice. It is shown that the video based methodology can be used to assess driver speed choice.
1 General introduction

One of the important features of skilled performance in general, and driving behaviour in particular, is the ability to anticipate. By accurately predicting what will happen next the skilled driver is in a position to avoid potential hazards. Although it has long been difficult to assess this ability on the road the notion that a driver’s ability to anticipate road hazards might be measured in the laboratory through the use of simulation is not new. It was recognised as a viable and potentially fruitful idea at least as far back as 1974, when the first attempts to produce a simulation-based test were made (Pelz and Krupat, 1974). Further impetus for the development of a test of hazard perception, if needed, was to come from in-depth studies of the causes of road accidents, conducted in the late seventies, which suggested that perceptual errors are implicated in about 50% of daytime accidents (excluding those due to drink or drug-induced impairment) (Sabey and Taylor, 1980).

One interesting feature of hazard perception is that it may well be one of the few components of the driving task that may be better assessed through the use of laboratory simulation (with the use of film or video) than through direct observation on the road. This is likely to be so because laboratory simulation allows real world scenes to be taken into the laboratory under controlled conditions. This not only allows the test to be standardised but also the driver’s response to hazards can be analyzed in detail. Moreover, subjects can be tested on a far greater range and severity of hazardous situations than it would be possible, or ethical, to expose them to on public roads.

There is empirical evidence to suggest that simulation in this context does reflect the same processes that are involved in on-the-road testing (Hughes and Cole, 1986; Watts and Quimby, 1979). Although on-the-road testing has considerable merits for many areas of driver performance the following difficulties occur in the case of hazard perception: (a) there is little control over the frequency and complexity of the hazards presented, (b) there are difficulties in determining the precise time that a hazard is detected, and (c) there are powerful ethical constraints on the range of hazards that may be presented. Overall, on-the-road testing is not ideally suited to the assessment of hazard perception.

Two major findings have emerged from previous work with laboratory tests of hazard perception. The first is that performance on the test correlates with accident involvement (Pelz and Krupat, 1974; Quimby and Watts, 1981; Quimby, Maycock, Carter, Dixon and Wall, 1986). The second major finding is that the time taken to respond to the presence of a road hazard decreases with increasing age and experience (until the age of about 55) (Quimby and Watts, 1981). It is thus possible that this relationship between hazard perception and age/experience might at least in part account for the well documented over-involvement of young drivers in accidents (Williams, 1985).

Our earlier work at Reading was concerned in the main with the development and validation of a portable test of drivers’ hazard perception (Crick and McKenna 1992; McKenna and Crick 1991). A test was developed that required minimal hardware - a TV monitor and video recorder linked to a Personal Computer via some simple electronics. The test requires subjects to react to the presence of road hazards while viewing driver’s-eye video recordings of a representative sample of hazardous traffic scenarios. Using Discriminant Function Analysis and other statistical techniques, it was possible to refine the content of the test. Two parallel forms of the test were then produced.

Initial attempts to validate the test revealed large significant differences between the performance of new drivers (up to three years driving experience) and expert (Police) drivers; expert drivers were far faster to react to the presence of hazards. The two groups of drivers differed on two important dimensions, either of which could account for the difference in performance. The expert group differed from new drivers in that they were both more experienced and had received post-licence training. To assess the relative merits of experience and training McKenna and Crick (1991) carried out a further study in which new drivers were compared both with an expert group and an experienced group. The experienced group and the expert group were matched in terms of driving experience so any difference that emerged would implicate training. It was found that all three groups differed from each other, with expert drivers faster to respond than experienced drivers, who were in turn faster to respond than new drivers.

The fact that expert drivers performed significantly better than experienced drivers of comparable age and experience was strongly suggestive of the influence of training on hazard perception. This suggestion was subsequently put to more direct empirical test in a before-and-after study of a group of drivers participating in an advanced driving course. Drivers taking the advanced training course were found to show significant improvements in hazard perception following training, whereas a matched control group showed no significant change in performance over time.

The results of the work undertaken to date indicate that the test is an appropriate and sensitive instrument for the measurement of hazard perception, and suggest that technically sophisticated and expensive simulators are unnecessary for the study of higher-order cognitive skills such as hazard perception.

It was also apparent that there is potential for the improvement of hazard perception skills through advanced driver training, if the course of training is appropriately designed. Given the consistently poor showing of new drivers on the hazard perception test, this suggests there is scope for gains in road safety through the deployment of appropriate training.

Hence the major concern of the next phase of our work on hazard perception, to be reported here, was driver training, more specifically, the development of training courses aimed at improving hazard perception. The first two experiments reported detail of our attempts first to develop such a course and subsequently to identify the critical components of the course. This is followed by two experiments which illustrate how the core experimental...
paradigm developed for testing hazard perception may be utilised to address other issues. Experiment 3 details our attempts to investigate the susceptibility of hazard perception to interference and disruption from secondary tasks, such as the use of mobile telephones. Here it is noted that driving is frequently assumed to be an automatic task. By this is meant that the task is neither interfered with by other tasks nor does it produce interference in other tasks. That assumption is investigated. Experiment 4 demonstrates how the basic paradigm can be used to assess other major facets of driving behaviour known to be important in accident causation. For example, driving is, in part, a self-paced task and the speed the driver adopts correlates with accident involvement (Wasielewski, 1984). The paradigm is then modified to assess the driver’s choice of speed.

2 Experiment I: The use of video technology in developing the hazard perception skills of novice drivers

2.1 Introduction
The purpose of the current study was to determine the effects of a purpose-built training programme that could be conducted in a relatively short period of time, and in a class room setting rather than on the road. The other major aim of the present study was to develop a training programme aimed at improving those drivers most at risk of an accident, namely the new drivers. The aim was to adapt the methodology constructed for testing hazard perception so that it may be used for training purposes. The objective is to bring about a contraction in the time it normally takes for the novice driver to reach the standard of performance of the experienced driver.

The training course was predicated on the idea that hazard perception might best be thought of as a cognitive process that entails the deployment of a mental model of how the traffic system and its elements interact. The use of a mental model enables experienced and expert drivers to make predictions about future events in that system. In simple terms, we propose that novice drivers have an under-developed mental model, tend not to anticipate future events and respond to those events more proximal in time. As a consequence the training programme concentrated on forcing the novices to develop a more sophisticated mental model by engaging them on anticipation tasks. This goal was achieved, in large part, by presenting sequences of road scenes and requiring novices to make predictions about what would happen next.

By employing two parallel hazard perception tests developed in earlier work, it was possible to assess the abilities of a group of novice drivers before and after receiving a course of in-house training of this kind.

2.2 Method
2.2.1 Subjects
Seven male and nine female novice drivers (drivers with no more than three years driving experience) were recruited from the student population at Reading to participate in the training course. The mean age of this group was 19.72 years (range 18.00 to 23.00); the mean number of years driving experience (number of years since passing the driving test) was 1.22 years (range 0.25 to 2.00); and the mean reported weekly mileage driven was 85.31 miles (range 0.00 to 400.00).

In order to provide a comparison control group, a further 14 novices, again from the student population, were recruited to take part in a pseudo-training course. The mean age of the control group was 20.14 years (range 19.00 to 25.00); the mean number of years driving experience was 1.59 years (range 0.33 to 3.00); the mean weekly mileage driven was 72.50 miles (range 0.00 to 500). There were 6 males and 8 females.

2.2.2 Hazard perception test
2.2.2.1 Simulator and paradigm
For a more detailed description of the test, the reader is referred to descriptions appearing in earlier work (McKenna and Crick, 1991). The simulator has some general similarities to that used by Watts and Quimby (1979), which itself derives from that of Pelz and Krupat (1974). However, there are some radical departures. In order to be portable, the simulator was necessarily simplified. In essence, the simulator consisted in a TV monitor and video recorder, interfaced with a computer and response button. The subject views a videotape of a sequence of various road and traffic situations, some of which are hazardous. The subject is instructed to respond with a button press immediately a hazard is detected. Also on the videotape are signals, of which the subject is unaware, which signal the onset of a pre-selected hazard. The signal from the videotape switches on the computer’s millisecond timer which is stopped when the subject, having spotted the hazard, presses the response button. If the subject fails to respond, the computer stops timing after 10 seconds, and a latency of 10 seconds is recorded for that hazard; latencies of 10 seconds thus denote a miss.

2.2.2.2 Video production
Information about commonly occurring road hazards was gathered by consultation with various expert groups such as police drivers and driving instructors. On the basis of this information, a number of hazardous scenarios were generated which were amenable to subsequent in-car videoing. Some of the scenarios were staged for videoing purposes, some occurred fortuitously while videoing. An approximate driver’s-eye view of the road was obtained by suitable mounting and adjustment of the camera. Scenarios selected for the final version of the test (Test One) were those revealed by earlier work to best discriminate between experts and novices while being least confounded with the effects of simple reaction time. A second parallel video (Test Two), designed to match the content of Test One, was produced by videoing the selected scenarios at different locations to those used previously and by employing different protagonists where possible.
2.2.3 Procedure

2.2.3.1 The training group

The training course proper was spread over a period of about three weeks; there was one group class room session, one session of group video watching, and one session of one-to-one tuition with video sequences. Care was taken to ensure that the content of these sequences did not duplicate that of the test material. In total, each subject received about four hours tuition. One-to-one tuition consisted largely in encouraging subjects to generate predictions about the likely outcomes of incipient road hazards. Other information derived from standard textbook sources and of our own creation was made available in order to assist the novices in their prediction making. Quite a large part of the course consisted in exhorting the trainees simply to look further ahead, an aspect of perceptual performance known to distinguish novice and experienced drivers (e.g. Mourant and Rockwell, 1972).

2.2.3.2 The control group

Subjects in the control group received as far as possible identical treatment as the training group, except in the content of training: they were given training on advanced control skills based on the Police Driving Manual ‘Roadcraft’ (Home Office, 1977) rather than hazard perception skills. The outline of this pseudo-training course in terms of pattern and duration of training sessions closely matched that of the trained group, along with the amount of exposure to video clips. In place of video sequences of incipient hazards, they received sequences of a commentary drive showing advanced control skills. They were led to believe that this was a genuine attempt to train advanced control skills. Care was taken to ensure that they were not actually being misinformed.

Subjects were tested before and after the training courses with the two parallel forms of the hazard perception test developed earlier. On each test session, subjects underwent a test of reaction time (VIDEORT) before undergoing the hazard perception test. This required subjects to detect the appearance of a football in a car park (see McKenna and Crick, 1994 for details). Following a five minute practice sequence, subjects received either Test One or Test Two. The order of presentation of the hazard perception tests was counterbalanced for each group. The same written instructions were read to the subject before and after the practice session. Test One was of approximately 15 minutes duration, and Test Two approximately 20 minutes duration. Latencies were recorded for 13 incidents in Test One, and 16 in Test Two. All other button-press responses made by the subject were also recorded.

2.3 Results

Overall mean hazard perception latencies were computed for each subject by averaging across latencies to individual scenarios (in the event of any missing values, group means for the particular scenario concerned were substituted). Reaction times taken were used as a covariate and partialled out of the overall hazard perception score for session 1 and session 2 (pre- and post-test) to provide a mean adjusted hazard perception time for the two groups, as shown in Table 1.

Table 1 Group means for overall hazard perception score in session 1 and session 2 adjusted for reaction time

| Overall hazard perception score in session 1 and session 2 adjusted for reaction time |
|---------------------------------|-----------------|-----------------|
|                                | Session one     | Session two     |
| Trained group (n=16)           | 4813.58         | 4324.21         |
| Control group (n=14)           | 4853.32         | 4785.96         |

Repeated measures analysis of covariance was conducted with these overall scores as the dependent variable, VIDEORT as covariate, and group and order of tape presentation as between-subjects factors, session as a within-subject factor. The analysis revealed a significant group by session interaction (F(1,26)=10.58, p<0.01), and significant main effects for session (F(1,26)=20.67, p<0.01) and group (F(1,25)=9.72, p<0.01).

In order to explore the interaction further, simple effects analysis was conducted. This revealed the presence of a significant group difference on session 2 (F(1,25)=26.50; p<0.01), that was absent on session 1 (F(1,25)=0.12; ns); and a significant effect of session for the trained group (F(1,14)=19.75; p<0.001), but no effect of session for the control group (F(1,12)=3.24; ns). Thus it seems reasonable to conclude that while the control group has shown no significant change over time, the training group’s latencies have become significantly faster following training.

2.4 Discussion

The results of the present study are remarkably similar to those of the earlier study of the effects of advanced training on experienced drivers (Crick and McKenna, 1992); the major difference is that the effects, if anything, are more clear cut. The response latencies of the novice group receiving training in hazard perception have improved overall by about 0.5 seconds. In fact, the trained novice group have improved their performance such that following training their performance approximately matches that of experienced drivers (using data from an earlier study by McKenna and Crick 1991 for comparison).

At present we can only speculate as to the time course of the training effect. Whether it is transient or enduring will have to be determined by future research. However, the results of the present study do suggest that it is at least feasible to train higher-order skills such as hazard perception without undertaking prolonged tuition on public roads. Currently, the job of equipping novice drivers with these skills is left largely to simple experience. The results of earlier work suggest that this can be a slow and inefficient process, one that can be measured in years rather than hours. It is also a training process with an unacceptably high drop-out rate, with some ‘trainees’ failing to reach the standard of experienced drivers before the intervention of death or injury through accident.
3 Experiment II: Determining the critical components of the hazard-perception training package for novice drivers

3.1 Introduction

It was unclear, a priori, exactly which elements of the training course developed in Experiment I were responsible for effecting the improvement in hazard perception skills shown by the experimental subjects. The course may be characterised as having broadly two elements: a theoretical element and a more practical element in which subjects were engaged in anticipation or prediction tasks. The question this experiment was largely designed to answer was whether one or other element is necessary or sufficient to produce the effect.

At the same time an attempt was made to bolster the theoretical element by drawing on the results of some qualitative research analyzing commentary drives of experienced and novice drivers. The results of this work suggested that experienced drivers pay far more attention to background features in the environment than do novices, and this finding was used to inform the content of this training element. There was also an attempt to delineate the links between these background features, error mechanisms or processes (such as loss of visibility) and potentially dangerous consequences. The impetus for this element of the course derived, in part, from work on the decision making of expert medical diagnosticians (e.g. Gilhooly, 1990). This work has shown that experts in medical diagnosis tend to employ stereotypical sequential schemes when trying to diagnose the cause of symptoms, rather than trying to reason from first principles. Their superior diagnostic skill appears to be highly dependent on their knowledge of the link between background, contextual information about the patient and presenting symptoms that they have gained largely through experience. It is possible that the way in which this knowledge is acquired and represented may be a model for the way in which knowledge about road hazards is acquired and represented. This possibility provided the design rationale for the theoretical training course.

The main contrast between the two training approaches taken, however, in practice, was the presence or absence of prediction-making on the part of the subject. Both approaches were compared, as in Experiment I, with a neutral, control condition. However, in contrast to Experiment I, the opportunity was taken in this experiment to test the possibility that mere passive exposure to the content of training materials might be sufficient to produce an effect. Hence, the control group in this study received the same exposure to the video material as other groups, rather than exposure to a pseudo-training course using different materials.

3.2 Method

3.2.1 Subjects

Three groups of novice drivers (less than four years driving experience) were recruited from the local population of students at Reading via advertisements. Overall, a low drop-out rate was maintained, most likely as a result of the simple expedient of paying subjects only on completion of all parts of the experiment.

3.2.1.1 Training group One

Sixteen subjects were available for pre- and post-testing in this group; the mean age was 18.8 years (range 18.0 -21.0); the mean driving experience (number of years since passing the driving test) was 0.85 years (range 0.25 to 1.5); and the mean reported weekly mileage driven was 46.75 miles (range 0.0 to 300.0). There were 6 males and 10 females.

3.2.1.2 Training group Two

Fourteen subjects were available for pre- and post-testing in this group; the mean age was 20.61 years (range 18.0 -30.0); the mean driving experience (number of years since passing the driving test) was 1.8 years (range 0.5 to 4.0); and the mean reported weekly mileage driven was 60.29 miles (range 0.0 to 200.0). There were 9 males and 5 females.

3.2.1.3 Control group

Sixteen subjects were available for pre- and post-testing in this group; the mean age was 20.4 years (range 18.0 -30.0); the mean driving experience (number of years since passing the driving test) was 1.94 years (range 1.0 to 4.0); and the mean reported weekly mileage driven was 58.38 miles (range 0.0 to 240.0). There were 6 males and 10 females.

3.2.2 Procedure - Training

Those aspects of procedure common to all groups were as follows: the video materials, the number of testing and training sessions, the time scale of the course and the time elapsed between sessions (approximately). As in Experiment I, care was taken to ensure that the content of video sequences employed in training subjects did not duplicate that used in testing. The audiovisual media employed consisted in overheads with summary points and video sequences. (The control group was not presented with any overheads). Testing and training took place over a one month period on a one-to-one basis. Approximately one week after initial testing, the first training session took place, lasting approximately 1 hour. One week later, session two took place, lasting approximately 1 to 2 hours. One week later, final testing of subjects took place.

3.2.2.1 Training group One - predictions task

First session - concerned largely with demonstrating the value of active visual search strategies (where and how to look). (Drawing in part on suggestions in early work by Smith and Cummings, 1956). Strategies and their benefits where possible were illustrated with video sequences.
Second session - subjects were invited to make predictions while viewing video sequences. These were freeze-framed at appropriate points (usually before onset of the hazard) and the question posed ‘what might be about to happen?’ rather than ‘what is happening?’ Feedback was given on accuracy and appropriateness of responses; prompts were given where necessary; salient features in the scene were described if not delineated by the subject.

3.2.2.2 Training group Two - non-predictions task
First session - identical to Group 1, largely visual-search strategies, illustrated with video sequences.
Second session - best characterised as an attempt to enlarge and structure the knowledge base of subjects. Subjects were presented with a structured classification of road and traffic features leading to loss of visibility, and unpredictability, processes cast as key mechanisms in the genesis of road hazards. Further practical guidance was given by providing a ready means of analyzing and conceptualising situations eg. asking the question can you be seen, as well as can you see; the conceptualisation of other drivers as ‘lurkers’ or ‘lemmings’. Examples were drawn of links between apparently innocuous background features of the road environment and potentially dangerous situations. Video sequences were described in terms of these links between antecedent conditions and dangerous events. Sequences were presented as exemplars of a causal chain between background features, the mechanism of loss of visibility or unpredictability, and the resultant hazard. In contrast to Training Group 1 predictions were not solicited from subjects.

3.2.2.3 Control group
Subjects were simply invited to watch the same video sequences used for Training Groups 1 and 2. Subjects were instructed to attend closely, with the understanding that they were to be questioned about the material at the end of the sessions. Two questions were presented to subjects which assessed their recall of two incidents occurring in the video sequences.
First session - same video material presented as that used for illustration of visual search strategies in Training Groups.
Second session - same material presented as that used for predictions task and other training.

3.2.3 Procedure - Testing
Subjects were tested before and after the training courses with the two parallel forms of the hazard perception test developed earlier (for details of the content of the hazard perception test, see Experiment I). On each test session, subjects underwent a test of reaction time (VIDEORT) before undergoing the hazard perception test. Following a five minute practice sequence, subjects received either Test One or Test Two. The order of presentation of the hazard perception tests was counterbalanced for each group. The same written instructions were read to the subject before and after the practice session. Test One was of approximately 15 minutes duration, and Test Two approximately 20 minutes duration. Latencies were recorded for 13 incidents in Test One, and 16 in Test Two. All other button-press responses made by the subject were also recorded.

3.3 Results
Overall mean hazard perception latencies were computed for each subject by averaging across latencies to individual scenarios (in the event of any missing values, group means for the particular scenario concerned were substituted). As for Experiment 1, reaction times were used as a covariate and partialled out of the overall hazard perception score for sessions 1 and 2 (pre- and post-test) to provide a mean adjusted hazard perception time for the two groups, as shown in Table 2.

Table 2  Group means for overall hazard perception score in session 1 and session 2 adjusted for reaction time

<table>
<thead>
<tr>
<th>Overall hazard perception score (ms)</th>
<th>Session one</th>
<th>Session two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained group (n=16)</td>
<td>4790.18</td>
<td>4509.74</td>
</tr>
<tr>
<td>Non-prediction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained group (n=14)</td>
<td>4808.41</td>
<td>4806.82</td>
</tr>
<tr>
<td>Control group (n=16)</td>
<td>4833.89</td>
<td>4953.21</td>
</tr>
</tbody>
</table>

Repeated measures analysis of covariance was conducted with these overall scores as the dependent variable, VIDEORT as covariate, and group and order of tape presentation as between-subjects factors, session as a within-subject factor. The overall analysis revealed a significant group by session interaction (F(2,40)=7.82, p<0.001), and a significant main effect for group (F(2,40)=6.62, p<0.01). In order to explore the overall interaction further, simple effects analysis was conducted. This revealed the presence of significant group differences on session 2 (F(2,39)=16.60; p<0.001), that were absent on session 1 (F(2,39)=0.12; p>0.05); and a significant effect of session for the predictions-trained group (F(1,14)=11.36; p<0.01), and for the control group (F(1,14)=5.76; p<0.05), but no effect of session for the non-prediction-trained group (F(1,12)=0.00; p>0.05). Post-hoc analysis (Duncan’s Multiple Range test) of the group differences shown on session 2, revealed that there was a significant difference at the 0.05 level between the prediction-trained and control groups. No other comparisons were significant.

Thus it seems reasonable to conclude that it is only the predictions-trained group that has shown any significant improvement in hazard perception during the course of training; the control group’s performance has if anything deteriorated over time, while the theory-trained group has shown virtually no change.

3.4 Discussion
The experiment has replicated the results of the previous study by demonstrating that it is possible to bring about significant improvements in the hazard perception abilities
of novice drivers through short-term training using video presentations.

It is also apparent that the key ingredient of the training programmes devised thus far is the engendering of predictions about the likely outcome of traffic situations. Clearly, exhorting novice drivers simply to look further ahead is not sufficient to bring about a quicker anticipatory response to hazards. The current study does not allow us to determine whether the generation of predictions alone is enough to produce a beneficial effect, but we can say that training in mere perceptual or visual strategies is not enough. It also appears that delineating links between background features or antecedent conditions and potential hazards is not an effective training strategy in the absence of prediction generation.

The apparent insignificance of the training in looking ahead is perhaps surprising given Mourant and Rockwell’s (1972) finding that experienced and novice drivers differ significantly in this respect, as measured by eye fixation patterns. It is quite possible that the training methods developed here are failing to have much impact on that aspect of hazard perception, but that other approaches may be more successful, such as direct training of oculomotor skills (e.g. Shapiro and Raymond, 1989). While looking ahead is a necessary requirement for effective hazard perception it does not provide a sufficient account for the significant improvements in hazard perception which were obtained with training. The results of the current study suggest that perhaps comprehension of the road scene is a more important, overriding factor.

It should not be overlooked, however, that the effectiveness of the predictions task might lie with its intrinsically engaging nature compared with the other elements of training tested here - subjects are more involved in training when forced to participate actively as when generating predictions. The other elements of the course require only passive involvement, and may be ineffective as a result.

With the control group showing no improvement in performance on the hazard perception test, the experiment has also demonstrated that the positive effects of training shown in Experiment I and in the prediction-trained group of the current study can not be the result of mere exposure to video sequences used in training. As in the previous experiment, it is impossible to say how durable the training effect on hazard perception shown here is. This question can only be answered by future work.

4 Experiment III: Dual-task performance and hazard perception

4.1 Introduction
At a theoretical level driving is frequently described as the prototypical automatic task. What is meant by automaticity, as Kahneman and Treisman (1984) have noted, is that “An automatic process does not draw on general resources, is not subject to interference from attended activities, and does not interfere with such activities”. What follows from this is that if driving is an automatic process then it is possible to carry out other tasks at the same time. For example, Wickens (1989) has argued that “People are often called upon to do more than one thing at a time ... while controlling your car along the crowded freeway, you are able to tune the radio dial to your favourite music, while planning what you will say in the forthcoming job interview.” The assumption of those who hold that driving is an automatic process is that there will be no decrement in performance. So one of the theoretical points that needs to be addressed is whether driving is an automatic task.

A second theoretical issue concerns hazard perception, and more specifically whether hazard perception should be construed as a simple memory retrieval system or alternatively as a capacity demanding ability. Logan (1988) has argued that automaticity is memory retrieval: “Performance is automatic when it is based on a single-step direct access retrieval of past solutions from memory.” So one conception of hazard perception is that it is in effect a memory retrieval system. Drivers process the scene and directly access the answer that this is or is not a hazard. The point is that this mechanism would require no computation, it would require no resources, and as a consequence would not interfere, or be interfered with by other tasks.

An alternative conception, and one that we have offered in the past is that hazard perception is more akin to running a simulation. In other words drivers are actively involved in constructing and running a predictive model. The point about this conception is that it does require computational power, and would be interfered with by other tasks. So by finding out whether other tasks interfere with hazard perception we may be finding out about the nature of hazard perception itself.

Of course, this issue of whether other tasks produce interference is not only of theoretical importance. It is of practical importance because drivers are frequently engaged in other tasks while driving. For example, drivers are frequently engaged in conversation with passengers. They are increasingly on the telephone. Driving is often presented as a prototypical example of the ability to perform two or more tasks at once. Often, implicit in this is the assumption that driving is an automatic task, that as a much-practised skill its performance is unaffected by the performance of concurrent or dual tasks such as using a mobile telephone, or simply engaging in conversation with passengers.

Some awareness that this might be a dangerous assumption is indicated by a recent English legal trial in which a car driver was found guilty of causing death by dangerous driving after being found responsible for an accident caused whilst using a mobile phone. This outcome rested on the sensible assumption that if two tasks are dependent on the same output system then there is a clear opportunity for interference. In other words if the two tasks no longer share the same output system then one source of interference has been eliminated. It is, of course, possible that there is in addition a more central source of interference and it is to address this issue that the present experiment is designed. In other words even when the secondary task does not share an input or output system
with the driving task there remains the possibility that interference may occur. In the present experiment the domain of driving that will be assessed will be hazard perception. Here it might be noted that there may be some aspects of driving (perhaps some elements of perceptual motor skill) that remain relatively unaffected by many secondary tasks. One of the many practical consequences of this issue concerns the effect of mobile telephone use on driving performance.

With the increasing use of mobile phones, the literature on dual-tasks in driving has been concerned primarily with the issue of the safety of using telephones while driving. An early study by Brown, Tickner and Simmonds (1969) showed that use of the telephone while driving had little effect upon routine driving skills, but did impair the perception of gaps in traffic. A more recent study by Brookhuis, de Vries and de Waard (1991) found that placing mobile telephone calls reduced mirror checks in light traffic, slowed responses to headway changes, and increased the variance of steering wheel movements.

Few studies have looked at the effects of dual-task performance on hazard perception per se, although perceptual factors are known to be more important in road accidents than vehicle control factors (e.g. Sabey and Taylor, 1980). One exception is a recent study by McKnight and McKnight (1993), which examined the effects of telephone use on a task which must have involved some element of hazard perception. Subjects were required to make responses with the steering and brake controls of a simulator while viewing a video simulation of road scenes. It was found that the overall number of responses to events on the video decreased significantly while using the telephone in intense conversation.

Our earlier work on hazard perception (McKenna and Crick, 1994) placed us in an ideal position to look at the effects of dual-tasks on hazard perception directly. One problem lay, however, with the choice of a secondary task. In designing a secondary task two criteria were considered important:

1. The task should be sufficiently different from the primary task to implicate a central processor rather than some more peripheral competition. Clearly there are some forms of interference that are trivially obvious, e.g. the hands cannot simultaneously be in two places at once.

Consequently, a purpose-built task was developed, analogous to using a telephone. Drivers had to listen to a continuous sequence of speech and to make appropriate responses. Peripheral competition was avoided in the following way. The hazard perception test involves visual input and manual output. The secondary task that was designed involved auditory input and vocal output.

It was decided to examine the performance of new drivers since their performance might be expected to be most readily disrupted by interference from secondary tasks, given that their performance on the primary task would be less practised than that of experienced drivers.

4.2 Method

4.2.1 Subjects

In all, 80 new drivers, i.e. drivers with less than three years driving experience, were recruited from the student population at Reading.

There was a strong tendency for subjects to disregard instructions and prioritise tasks in the course of the experiment to the detriment of their performance on the secondary, letter-identification task. In order to ensure that only those subjects that could truly be regarded as having performed both tasks concurrently were included for analysis, those subjects who made more than 10% errors on the secondary task were excluded from analysis. On this basis, 40 subjects, 10 in each experimental cell, were included in the analysis. The mean age was 19.75 years (range 18-24); the mean driving experience (number of years since passing the driving test) was 1.84 years (range 0.66-4.00); and the mean reported weekly mileage driven was 42.58 miles (range 0-400). There were 21 males and 19 females.

4.2.2 Procedure

Each subject acted as his or her own control in a repeated measures design; both test version and task order were counterbalanced.

4.2.2.1 Primary task

Hazard Perception Test (for details of the content of the hazard perception test, see Experiment I)

4.2.2.2 Secondary task

Subjects were required to listen to a random series of letters presented on audiotape at a rate of 1 per second, and to respond to each letter presentation verbally by determining whether or not it was the target letter; in this case, the letter K. Target letters constituted 31% of the total number of letters employed, distributed in random fashion.

Each subject was tested, using parallel versions of the hazard perception test, under single and dual-task conditions; the order of experimental conditions was counterbalanced, such that half the subjects received the single task first, followed by the dual task condition, while the other half of the subjects received the dual-task first, followed by the single task. The order of test versions used in each condition was similarly counterbalanced.

Subjects were given the opportunity to practise both the primary and secondary tasks prior to testing. Subjects practised the letter-identification task for approximately one minute. Subjects undertook the five minute practice sequence of the hazard perception test described in Experiment I. Subjects were instructed to give equal priority to both tasks.

Subjects also received a measure of simple reaction time in which they were required to press a response key upon the presentation of a stimulus upon a screen. In addition all subjects completed a questionnaire relating to basic
demographics and driving history. Version One of the hazard perception test is approximately 15 minutes long; version Two is of approximately 20 minutes duration. Latencies are recorded for 13 incidents in version One of the test, and for 16 in version Two of the test. An overall hazard perception score is derived for each subject by averaging across latencies to individual incidents. In the event of missed incidents, group means are substituted for that particular incident.

4.3 Results

The means for overall hazard perception scores in the single and dual-task conditions are shown in Table 3.

Table 3 Means for overall hazard perception score in single and dual-task conditions

<table>
<thead>
<tr>
<th>Overall hazard perception score (ms)</th>
<th>Single-task</th>
<th>Dual-task</th>
</tr>
</thead>
<tbody>
<tr>
<td>4754.56</td>
<td>4947.46</td>
<td></td>
</tr>
</tbody>
</table>

Repeated measures analysis of variance revealed a significant effect only for the within subject factor of condition (i.e. single versus dual task)(F(1,36)=13.79; p<0.001). The effects of task order and test order, together with their interactions with effect of condition were all non-significant.

The change in performance shown across conditions within subjects suggests that the secondary task is interfering with the performance of the primary task, that of hazard perception; the drivers’ reactions to hazardous situations are slower when having to deal with the demands of a secondary task, than when not. At least part of this effect is due to an effect on simple reaction time, as there were significant differences also between single and dual-task conditions on our measure of simple reaction time (F(1,36)=49.75; p<0.001).

4.4 Discussion

The results of the present study clearly indicate that the process of responding quickly to road hazards is not an automatic one for novice drivers. Given that driving requires the continuous assessment of hazards it is reasonable to conclude that the driving task as a whole is not immune to disruption by the performance of other tasks. Although there is evidence that some basic control skills are relatively unaffected by secondary tasks (Brown et al., 1969), higher order functions, such as the anticipation of hazardous events, would appear to be hampered by concurrent performance of other cognitive tasks, for novice drivers at least. However on the basis of this result alone it would be premature to claim that hazard perception is not automatic at all levels of driving experience. Due to the relatively low levels of driving experience of novice drivers a possibility is that automaticity has still yet to develop in contrast with a group of drivers with higher levels of driving experience. Subsequent work from our laboratory has examined whether the hazard perception performance of drivers with ten or more years driving experience is disrupted by the performance of a concurrent secondary task. It was found that with a concurrent secondary task the hazard perception performance of experienced drivers was significantly disrupted, being no better than the performance of a group of novice drivers when also performing a concurrent secondary task. This finding could not be accounted for in terms of differences in task prioritisation between the novice and experienced drivers however, as performance on the secondary task was similar for the two groups. The finding that experienced drivers performance is affected by a secondary task is further supported by a study by McKnight and McKnight (1993) which suggests that drivers aged over 50 show more dual-task interference than their youthful counterparts.

It is possible to argue that the effects of dual-task interference shown in this experiment could be ameliorated by drivers learning to switch attention when driving and conversing. In other words the efficiency with which drivers are able to prioritise their tasks may be an important factor. However, this factor needs to be weighed against the fact that it seems probable that subjects would find it easier to switch from the secondary task employed in this experiment than from, say, an intense conversation which would be of far greater personal significance.

Similarly, the secondary task employed here is probably a lot less demanding than some telephone conversations. The making of more elaborate decisions, of personal significance, over a telephone are likely to place greater demands on cognitive resources and could lead to greater decrements in performance.

From a practical point of view, the results of this experiment suggest that the assumption that the driving task is automatic, and hence will not suffer interference, should be viewed with caution. It does not of necessity follow that hazard perception performance will always suffer. It is theoretically possible that drivers will be able to prioritise their tasks and ignore the secondary task. Empirical evidence on drivers’ ability to prioritise is required. It does follow that if drivers do not or cannot prioritise then hazard perception performance will deteriorate. As demonstrated here, it is clear that if novice drivers are actively engaged in performing a secondary task their driving ability is adversely affected.

5 Experiment IV: Development of a measure of drivers’ choice of speed

5.1 Introduction

The role of speed in differential accident involvement has been documented through a number of methodologies including observational study (Evans and Wasieliewski 1983), instrumented vehicles (Wilson and Greensmith, 1983) and self-report (West, French, Kemp and Elander, 1991). Although the importance of drivers’ speed choice is generally accepted, providing an ideal measure of an individual’s speed choice is hampered by a number of factors. For example, the overall speed at which an individual travels will be a function of a number of factors including the density of the traffic, the capacity of the
vehicle and the individual’s choice. In observational studies the traffic conditions are uncontrolled and the capacity of the vehicle varies across individuals. In instrumented vehicle studies the capacity of the vehicle is generally controlled but the traffic conditions are not. In self-report studies the traffic conditions and the capacity of the vehicle are dependent on the driver’s imagination and therefore remain uncontrolled. The argument presented here is not that video simulation, if successful, would provide a perfect measure but rather that it would provide a complementary one.

Video simulation of traffic scenes provides an alternative method that does not rely on the imagination of the driver and provides an opportunity to control the traffic conditions. The main aim of the present study was to test the feasibility of using the core experimental paradigm used in the hazard perception test for the assessment of a driver’s choice of speed.

Observational studies of drivers’ observed speed show consistent differences in the speed choice of males and females (e.g. Hendrikx and Vlek, 1991; Noguchi, 1990); hence, we would expect the same sex differences to emerge on our test if it were to be regarded as a valid measure of speed choice.

The present experiment was conducted to test the ability of a newly constructed video test to discriminate between the speed preferences of groups of male and female drivers, matched in terms of age and driving experience.

5.2 Method

5.2.1 Subjects
Subjects were recruited from the student population of Reading University. Twenty-three males (mean age 20.87 years (range 18-27); mean years driving experience 1.7 years (range 0-6); mean weekly reported mileage 40.4 miles (range 0-200)) and 22 females took part (mean age 20.59 years (range 18-26); mean years driving experience 2.27 years (range 1-7); mean weekly reported mileage 61.6 miles (range 0-350)).

5.2.2 Procedure
A Choice of Speed Test was constructed along the lines of the hazard perception test developed earlier. A videotape was produced consisting of a number of sequences showing traffic scenes in which the speed of the car from which the drivers’ eye view is depicted varied, along with road type. For each of three road types (urban, rural, motorway), scenes were videotaped in which the speed shown was considered to be either fast, moderate or slow. The assessment of speed in these scenes was derived from information gathered from a pilot study. Care was taken during the production of the video to ensure each scene, as far as possible, gave the subject an open choice of speed, not constrained by interaction with other road users.

The drivers’ task is simply to estimate how much faster or slower they would normally prefer to travel for each scene (in mph). The precise instructions were as follows:

### Instructions to subjects

You are about to be shown a video of a driver’s eye view of various road and traffic situations. We want you to imagine that you are the driver of the car in which the video camera has been mounted. At certain points in the video a tone will sound, and I will stop the tape. On each occasion, we want you to estimate, as accurately as possible, how much faster or slower you feel that you would normally drive in that situation. Write your estimates for each point below in miles per hour. Use a minus sign to indicate slower, a plus sign to indicate faster and a zero for no difference. For example, if you would normally drive ten miles per hour faster for a particular sequence, write down +10. All your responses will be treated in the strictest confidence. We do not need to know your name.

Subjects were given a short practice sequence and then asked to write their responses on a pro forma response sheet.

#### Table 4

<table>
<thead>
<tr>
<th>Speed Preference (mph)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+1.63</td>
<td>-2.05</td>
</tr>
</tbody>
</table>

5.3 Results

Each subject’s responses for the various scenes were averaged to produce an overall measure of speed preference. Group means for males and females on this overall measure are shown in Table 4. An analysis of variance for this measure revealed a significant main effect for sex (F(1,44)=11.31; p<0.01), with males showing a preference for driving more quickly than females. Analysis of covariance for this overall measure with either years of driving experience or weekly mileage as covariates produced a significant main effect of sex in both cases, suggesting that the observed differences could not be ascribed to any differences in experience or exposure that may have existed between the groups.

5.4 Discussion

The findings of the present experiment are in accord with the results of previous research (Hendrikx and Vlek, 1991; Noguchi, 1990). The ability of the test to discriminate between males and females in their choice of speed clearly indicates the viability of the use of video simulation for this kind of assessment, and suggests that there may be other areas of application for the technology.

Some video sequences appeared to work better than others, and using Discriminant Function Analysis we were able to produce a shorter, more refined form of the test, which is now undergoing further trials in an ongoing large scale study of the relationship between speed choice and
accident involvement. The specific advantages of this methodology are that it is not dependent on drivers producing imaginary driving scenarios and precise control over the driving conditions is possible. One potential problem for this type of test is that drivers can readily manipulate the impression they wish to create. In contrast to the hazard perception test, the speed test is such that it is more vulnerable to the effects of faking, so its use might be restricted more to issues that do not invoke a high component of impression management.

6 General discussion

An examination of the cognitive abilities required to detect hazards on the road is attempted through visual simulation. As Gopher and Kimchi (1989) have noted, in the absence of formal principles for the construction of simulators the dominant design philosophy has been physical fidelity. In general, past work on driving simulation has aimed at providing a simulator which provides fidelity of the perceptual-motor components. Many of these simulators are extremely expensive and provide a very impoverished visual scene. The approach examined here, by contrast, is inexpensive and provides fidelity in the analysis of the visual scene. The results of previous work taking this approach showed that the hazard perception test developed was reliable and able to discriminate between drivers on the basis of experience and ability (McKenna and Crick 1991). It was then shown that hazard perception skills are not immutable. The role of training was highlighted when it was shown that the performance of experienced drivers could be improved through an advanced driving course (Crick and McKenna 1992).

6.1 Driver training

It should be noted that advanced driving courses tend to attract those with a reasonable amount of experience. The point at which interventions would have their most impact would be with new drivers who have the highest accident involvement and poorest hazard perception skills. The focus of the present work was therefore on those drivers most at risk, namely new drivers. One of the main issues was whether the hazard perception skills of new drivers could be improved. It was shown that the training programme designed for new drivers did produce a significant improvement in hazard perception. An attempt was then made to determine the particular components of the training programme that were responsible for the performance improvement. The role of anticipation was highlighted by the effectiveness of the training programme that emphasised predictions of future possibilities.

6.2 Automaticity

It seems clear that at least in the early years of driving there are good grounds for questioning the assumption that driving is automatic. This and subsequent work has shown that the performance of a secondary task does interfere with hazard perception. The practical implications of this result will be dependent on the extent to which drivers can and do prioritise. In other words if drivers cannot focus their attention on the driving task or do not choose to do so then hazard perception performance will deteriorate.

6.3 Speed

It is shown that video technology can be used to assess individual differences in speed choice. Self-report measures of speed suffer from the disadvantage that they rely on drivers’ imagination, and observational studies are unable to examine different drivers in standardised conditions. The video-based methodology may provide a useful complementary method.

7 Conclusions

The main findings of the present research programme are as follows:

1. The in-house training package is effective: the performance of novice drivers can be improved until it begins to approach that of the moderately experienced driver. This can be achieved in a matter of a few hours.

2. The key element in the training package appears to be prediction generation. Training given in terms of purely visual strategies appears to be ineffective, suggesting that an emphasis on more cognitive skills is desirable in the design of training courses.

3. The dual-task experiment and subsequent work suggests that the widely-held assumption that driving is a completely automated task is wrong and misleading. Higher-order skills such as hazard perception do not appear to be automated.

4. The experimental paradigm used to assess hazard perception can be extended to enable the assessment of other aspects of driver behaviour associated with risk-taking, for example speed choice. However, these measures are likely to be less robust as psychometric instruments for real-world settings than the measure of hazard perception, but show promise for exploitation in experimental studies.

8 References


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


Nouguchi K (1990) In search of ‘optimum’ speed: from the user’s viewpoint. IATSS Research, 14, 66-75.


Smith H L and Cummings J J (1956). Let’s teach drivers how to see! Traffic Digest and Review, March, 7-12.


Abstract

Previous research has indicated that in the first few years drivers are relatively poor at detecting hazards. The present report explores developments in research on hazard perception. In two experiments hazard perception training is developed and evaluated revealing that significant improvements can be achieved. A third experiment examines the prevalent assumption that driving is automatic. It is shown that hazard perception is not automatic and does suffer interference from other tasks. The fourth experiment demonstrates how the general methodology can be used to examine other important dimensions of driver behaviour such as speed choice.

Related publications

CR313  Hazard perception in drivers: a methodology for testing and training by F P McKenna and J L Crick. 1994 (price code H, £30)

PA2193/92  Behavioural research in road safety II. Proceedings of a Seminar at Manchester University, 17-18 September 1991, edited by G B Grayson (price code E, £20)

PA2038/91  Behavioural research in road safety. Proceedings of a Seminar at Nottingham University, 26-27 September 1990, edited by G B Grayson and J F Lester (price code F, £23)

RR27  Perceptual abilities of accident involved drivers by A R Quimby, G Maycock, I D Carter, R Dixon and J G Wall. 1986 (price code C, £15)

LR1004  Human factors and driving performance by A R Quimby and G R Watts. 1981 (price code AA, £10)

SR567  The known risks we run: the highway by B E Sabey and H Taylor. 1980 (price code AA, £10)

LR907  Design and validation of a driving simulator for use in perceptual studies by G R Watts and A R Quimby. 1979 (price code AA, £10)

Prices current at November 1997

For further details of these and all other TRL publications, telephone Publication Sales on 01344 770783 or 770784, or visit TRL on the Internet at http://www.trl.co.uk.