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Title and Subtitle Review of Literature on Driving Performance Measures and Licence

Author (s) Dr Wendy Macdonald

Performing Organisation (Name and Address)
Road Traffic Authority
854 Glenferrie Road
Hawthorn, Victoria, 3122

Sponsor (Name and Address)
Federal Office of Road Safety
G.P.O. Box 594
CANBERRA A.C.T. 2601

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Abstract The purpose of this report was to review literature relating to car driver licence testing. Major objectives of testing systems were identified as establishing competence and setting a standard. The review brings together current knowledge relating to driver behaviour and to studies of 'unsafe' driver behaviour, against which licence tests might be evaluated. Studies of licence tests are discussed and recommendations made regarding tests, which should be considered for adoption in Australia.

Keywords (IRRD)

Driving test, car, driving licence, driving aptitude, accident rate, experience.

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DRIVING PERFORMANCE MEASURES AND LICENCE TESTS

A LITERATURE REVIEW

Prepared by
Wendy Macdonald
1987

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EXECUTIVE SUMMARY

This literature review forms the first part of a research project to assess the need for revision of Australian driver licence road tests, particularly the Victorian test.

The present report discusses the adequacy of driver licence testing systems in terms of their major objectives, which are to establish that drivers have attained an adequate level of competence and to set an appropriate standard of good driving behaviour. The degree to which a testing system achieves these objectives is difficult to assess, for several reasons. Most importantly, there is a need for more information about the nature of unsafe driving behaviour and the factors which produce it.

Driving behaviour is determined by the interactions of factors reflecting both driving skill (perception, cognition and vehicle control) and motivation (perceived costs and benefits). From a variety of information on the nature of "unsafe" driver behaviour, especially that of inexperienced drivers, it is evident that deficits in perceptual, cognitive and vehicle-control skills, possibly acting in conjunction with motivational factors, are typically associated with driving errors and "risky" behaviour.

Driving errors leading to accidents are fairly equally distributed over perceptual and response error categories. In terms of the observable aspects of perceptual behaviour, there is

evidence that "unsafe" drivers, typically the young and inexperienced, have a less efficient visual scanning strategy than other drivers, display longer fixations, do not look as far ahead, and make less use of peripheral vision. They make less use of the rear view mirror, and use it at less appropriate times.

They are more likely to miss seeing hazards, particularly the more distant ones, and tend to take longer to notice them. They pay attention to non-moving hazards, often at the expense of more important moving hazards associated with the changing traffic situation. They are less able to integrate various sources of hazard, or risk, into an overall assessment. They assess level of risk within a narrower range, presumably because they are less able to discriminate differences. Underlying these characteristics may be a tendency to process information less actively: displaying fewer changes in visual fixations, poorer ability to switch attention between different sources, and using less of the available information in reaching a decision.

In vehicle control skills, also, there is clear evidence of differences between drivers associated with different levels of driving experience. They may be differentiated by their different patterns of control activity and, more clearly, by the more accurate and faster performance by experienced drivers of slow-speed vehicle manoeuvres such as reversing and parking.

Experienced drivers with good accident records are generally smoother in their manoeuvring, with lower maximum values of longitudinal or lateral acceleration forces. They are able to

track along a line with smaller and less variable lateral error, and can bring their vehicle to rest at a designated line, or negotiate a path through narrow gaps, more accurately. In contrast, less experienced drivers or those with a poorer accident record have a fast and abrupt response style. They apparently reach decisions on the basis of less information and respond quickly and inaccurately.

There is conflicting evidence on the relationship between the development of perceptual skill, vehicle control skill, perceived risk and speed. Inexperienced drivers involved in accidents are more likely to have been travelling at excessive speed than more experienced, accident-involved drivers. However, it appears that vehicle control develops more quickly than perceptual aspects of driving skill. As drivers perceive their control skill increasing, their confidence increases and they increase their speed accordingly, without making due allowance for their relatively undeveloped perceptual and cognitive skills. Such drivers are most typically young males with relatively poor cognitive skills. They see speeding as less risky than do "better" drivers, and tend to over-estimate their own control skills. The highest risk-takers tend to be those who perceive the risk as least.

Thus, inexperienced drivers appear to be poor in perceptual and cognitive aspects of driving skill as well as displaying poor vehicle control. These characteristics probably result in such drivers frequently driving in a "risky" fashion independent of other contributory factors such as a possible tendency

deliberately to accept higher risk in some situations.

It is doubtful that drivers' perceptual and cognitive skills can be measured effectively by an on-road test, but such skills can, and it has been suggested should, be assessed by other means. It has been demonstrated that testing perceptual skills such as hazard perception by means of a series of slides or film can be a valid means of discriminating "good" from "bad" drivers. The development of such a test would require a substantial research investment. It is suggested that the development of such a test should proceed concurrently with the development of an associated training program. This approach would serve to increase safety directly, by improving perceptual skill, and indirectly by increasing inexperienced drivers' awareness of the importance of perceptual and cognitive skills and their own inadequacies in this area, leading to improvement of their decision-making performance. Ideally, such a training and testing program would be incorporated into a graduated licensing program at a stage when vehicle control skills had been largely mastered.

It is clear that no on-road licence test can hope to be valid in the sense that good performance during the test will predict good subsequent performance under normal driving conditions. On the other hand, it is clear that a good test can measure reasonably well a driver's vehicle control skills, and these are a necessary prerequisite for safe driving. That is, bad performance in the licence test due to inadequately developed vehicle control skill is associated with poor performance in "the real world".

Existing on-road tests for which some evaluative data was available were critically discussed, and the most potentially useful identified. These are the ADOPT, developed by McPherson and McKnight (1981), a test loosely based on the Michigan Driver Performance Measure developed by Engel et al (1979) and, surprisingly, a test developed by McGlade (1963) which is reported to be the most commonly used of "traditional" tests. All place considerable emphasis on both the perceptual and the response aspects of driving.

It is evident that a road test is a valid means of assessing vehicle control skills but not perceptual and cognitive skills. Nevertheless, the inclusion of all aspects of driving in a licence test is necessary to ensure content validity, as discussed in Section 2. All three of the above tests have been demonstrated to possess acceptable levels of reliability and criterion validity. It is therefore suggested that experimental work be conducted to evaluate and compare these three tests in terms of their suitability for adoption in Australia.

1. INTRODUCTION

The main purpose of this report is to review literature on driving performance measures which may be suitable for use in licence testing and to review available information on existing driver licence tests. First, the main objectives of licence testing are defined. These are: (1) to establish the competence of individual drivers, "screening out" those who present an unacceptably high accident risk, and (2) to set an appropriate standard of good driving behaviour and hence exert a beneficial influence on driver training programs.

The difficulties of assessing the validity of licence testing procedures in terms of these objectives are discussed. Attempting to relate licence test performance to subsequent accident record is not a satisfactory solution. The difficulties stem in large part from the complex nature of the determinants of driver behaviour, and the inadequately defined nature of unsafe driver behaviour.

The major determinants of driving behaviour - skill and motivation - are considered in detail, followed by a section in which the nature of unsafe driving behaviour is clarified by reviewing literature on the relationship between driver behaviour and accident occurrence. The literature is considered in three main sections: (a) evidence from accident studies, (b) evidence from studies of driver behaviour in non-accident situations, and (c) evidence from non-driving studies.

Finally, information on existing licence tests is described

and evaluated in terms of the criteria established in the preceding discussion.

2. LICENCE TEST OBJECTIVES AND TEST VALIDITY

The objectives of a licence test, as stated by various authors in past reviews, include determining the road worthiness of the applicant's vehicle (Lauer, 1960), revenue-raising (Waller, 1975) and satisfying those who feel that something should be measured (Belmont Conference on State Road Test Examinations, 1977, in Waller, Li, Hall and Stutts, 1978). However, the most generally agreed objective concerns the need to establish the competence of the applicant as a driver. For example, the Victorian Road Safety Act (1987) specifies four purposes of licensing, of which the first is "to ensure that people who drive motor vehicles on highways are competent drivers". Related to this, it is also usually accepted that an important function of a licence test is to motivate drivers to achieve some standard of driving performance, as defined by the content of the test. Hence, the licence test strongly influences the content and standard of driver training.

2.1 ESTABLISHING DRIVER COMPETENCE

In practice, the emphasis is usually on the first of these two major objectives: the licence test is primarily seen as a means of establishing that a driver attains a certain standard of competence before being permitted to drive without supervision. The test might then serve to screen out potentially "bad" drivers - those who, if licensed, would present an unacceptably high

accident risk. For a test to serve this purpose effectively, it must be assumed that (1) the test procedure identifies and appropriately penalises unsafe or "bad" driving behaviour; (2) such behaviour under test conditions is associated with an unacceptably high rate of accident involvement under non-test conditions. Unfortunately, evidence to support these assumptions is lacking, for two major reasons.

In relation to the first assumption, our knowledge of drivers and driving is inadequate to permit a clear and comprehensive description of the nature of safe or unsafe driving behaviour, independent of accidents. Thus, Shaoul (1975) pointed out that in the U.K. people are taught that the correct way to steer a car around a corner is to use a shuffling action of hands on steering wheel, avoiding crossing over the arms, and licence testing officers may penalise candidates who do not demonstrate what is considered to be a proper steering action, whereas in the U.S.A., received wisdom is to the contrary. In fact, there is no hard evidence that one technique is safer than the other. The same situation holds true in relation to many other driving techniques and procedures, regardless of their being dear to the hearts of driving instructors throughout the world.

The second assumption was that drivers who fail or, to a lesser extent, who obtain low test scores, are more likely to be involved in subsequent accidents. However, people who fail the test can continue to drive only under the direct supervision of a licensed driver, which is not comparable to the conditions under which people passing the test can then drive. Consequently, those drivers who would have been expected on the basis of their poor

test performance to be involved in the most accidents, are removed by the licence test from the sample of drivers whose subsequent accident record is investigated.

Another problem with the use of subsequent accident data to validate a licence test is that performance during the test can only reflect current level of ability. However, driving ability does not remain static, particularly during the first few years of experience when significant development of driving skill (taken to include perceptual and cognitive skill as well as that related to vehicle control) is occurring. Thus, even given a perfectly valid and reliable test, it cannot be expected that, for a particular sample of drivers, the ranking of their initial test scores would remain much the same if they were all re-tested six months or a year later.

Furthermore, reported crashes are comparatively rare, even for high-risk drivers, so a fairly long time period is required for the accumulation of patterns of crashes which are significantly different for "good" and "bad" drivers. This exacerbates the effects of changes in driving behaviour, making the likelihood of a significant relationship between test score and subsequent accident rate even lower. Only if accident involvement was primarily determined by individual driver characteristics which were both invariant over long time periods and measured by the licence test could it be expected that performance in the test would be significantly predictive of future accident rate.

Thus, it appears unreasonable to evaluate licence test

validity in terms of the relationship between test score and subsequent accident record. This is not to say that the test should not discriminate relatively safe driving from unsafe; indeed, safety is the criterion of "good" driving normally given most emphasis in the context of licence testing. Rather, it is argued that subsequent accident record is not a good index of the degree to which the test discriminates good or safe driving from bad or unsafe.

Empirical evidence on the relationship between test score and subsequent accident record is presented below; the studies reviewed are summarized in Table 1.

2.1.1 Licence Test Score and Accident Record.

Campbell (1958) compared a group of drivers involved in fatal accidents with a random sample. The accident group were found to have a lower average passing score on their original road tests than the random sample, but the groups did not differ significantly on most of the individual manoeuvres which constituted the total score.

Lauer (1960) concluded that a single manoeuvre, parallel parking with six feet clearance, is the best indicator of competence to drive as indicated by subsequent accident rate, with a secondary indication available from correct turning manoeuvres in which signals are given. He suggested that the actual driving test should be confined to these.

Goldstein (1961) found that for two groups of army drivers

TABLE 1

Studies of the association between licence test scores and accident record.

STUDY	DESCRIPTION	FINDING
Campbell, 1958	Fatalities compared to random sample	Fatalities had lower passing score
Lauer, 1970		Parallel parking best indicator
Goldstein, 1961	Army drivers	Association not significant
Kaestner, 1964	Oregon licence test	Association not significant for males; positive association for females
McRae, 1968	North Carolina licence tests, 16-20 yr old drivers	Significant association but not strong
Wallace & Crancer, 1969	Washington	Association not significant
Waller & Goo, 1968	Californian road test	No significant association except for drivers aged 50 to 59
Harrington, 1972	Californian road test, 16-17 yr old drivers	Significant but not strong association found for males. No assoc. found for females
Jones, 1973	Californian test, teenage drivers	No significant association
Dreyer, 1976	Californian test	No significant or strong relationship
Coppin, 1977	Californian test	Backing/parking good indicator
Ratz, 1978	Californian test, increased difficulty	No significant association

Berthaid & Mackie, 1972	Advanced drive test, UK, Institute of Advanced Motorists	Pass drivers had fewer accidents
Sheppard, Henry & Mackie, 1973	UK, minor faults on test	No significant association

the correlations between road test ratings and accident record were not significant.

Kaestner (1964) investigated the relationship between performance on the Oregon licence test and subsequent accident record. Passing scores of males were not significantly related to accidents. For females, those with high passing scores were more likely to go five years without accident than females with low passing scores. There were no significant relationships for either sex between drive test failures or passing drive test scores and the percentage of drivers without accidents.

McRae (1968) related North Carolina driver licence test scores and subsequent accident and violation records. Drivers 16 to 20 years old were classified into three groups according to their record in the two years subsequent to licensing: clear record, minor violations only, and accident (two or more accidents, or one accident plus one major violation). Using weighted values for the various road test manoeuvres, he found significant differences in scoring pattern between the groups, the accident group being worse. Although significant, the relationships were not particularly strong.

Two different classes of skills seemed to contribute: first, a "physical handling of the automobile" class, including brake stop, turn about, stop and start, and clutch. The second class was an "interaction with traffic" class, including attention, keeping in lane, right of way, and first slow sign.

Wallace and Crancer (1969) found no significant relationship

between road test scores in the State of Washington and subsequent four-year driving record.

Waller and Goo (1968) found little relationship between accident rate and passing scores on the Californian road test. Among drivers aged 15-29 there were no significant differences in accident rate by test score. However, among drivers age 30-59, those with high and midrange scores had significantly lower accident rates than did low-scoring drivers. Thus, there was evidence of test validity for drivers over 30 but not for those under.

Harrington (1972) related passing scores of 16 and 17 year olds on the Californian drive test to accidents during their first four years of driving. For males, there was a statistically significant (but practically, insignificant) correlation of -.02; for females the correlation was not significant. Jones (1973) found no significant correlations between California road test score and subsequent six month and one year accident records of teenaged applicants.

Again in California, Dreyer (1976) found that relationships between drive test performance and subsequent driving record were of no practical significance. The correlations between total score and subsequent driving record ranged from .06 to -.03 with one being statistically significant. He suggested that the result might be partially explained by unpublished results from Burg showing that California drivers with higher mileage had both higher drive test scores and more accidents. These Californian studies are particularly interesting in the present context,

because the California drive test was basically the same as the present Victorian test.

Coppin, in his 1977 review, referred to unpublished Californian research which indicated that the backing/parking manoeuvre section of the test has the best relationship to future driving record.

Ratz (1978) evaluated the effects of making the California drive test more difficult. Two new versions of the test were developed: (1) the existing test with more penalty points deducted and parallel parking in place of usual skill tests; (2) using routes taking twice as long and with more high density and multi-lane traffic, plus a parallel parking test. Accident rates in the first post-licence year were slightly lower among both treatment groups but the difference did not approach significance.

On all three tests, females and older people scored lower. In all cases the direction of significant correlations indicated that people scoring higher on the test tended to have more accidents and convictions. The number of test items having significant correlations with subsequent accidents was no greater than expected by chance, and total scores were not significantly correlated with accidents. However, there were no exposure data.

In the U.K., Hoinville, Berthoud and Mackie (1972) found that a group of experienced drivers who had passed an "advanced" driving test associated with a course run by the Institute of Advanced Motorists (IAM) had fewer accidents in the following

three years than a group which had not done the course. However, the "self-selection" factor was not controlled.

In light of this finding, Fazakerley and Downing (1980) compared the IAM and normal licence tests. Comparison of IAM and licence test fault markings of the 45 experimental candidates who failed both tests showed that similar categories of driving performance were recorded as faults for most candidates on both tests. Control faults were given as a reason for failure in more cases by the IAM examiners than by the licence testers but the difference was not statistically significant. It was concluded likely that the licence test discriminated between groups of experienced drivers in a similar way to the IAM test, and it might therefore be expected to be predictive of accident record for such drivers. However, there is no evidence of the probability of either test distinguishing between groups of learner drivers in terms of their subsequent accident involvement.

Also in the U.K., Sheppard, Henry and Mackie (1973) studied the relationship between minor faults made by 1,123 drivers when passing the official test and their accident rate in the following year. They found that those with several kinds of faults were no more likely to be involved in an accident than those with few kinds of faults. There were no relationships between any of the 67 types of error and subsequent involvement in accidents.

In summary, the literature shows conflicting findings. Where significant relationships exist, their magnitude is small. This

situation is not surprising in light of the previous discussion on the value of accident record as an index of licence test validity. It was pointed out that accident record is of little practical value for the following reasons. First, people who fail the test, who on this basis would be expected to have the greatest number of subsequent accidents, are removed by their test result from the sample of drivers whose subsequent accident record is investigated. Second, it is unlikely that the ranking of the actual levels of driving skill for a group of newly licensed drivers would remain constant over the following year during which their accident records are established. Third, reported crashes are comparatively rare events, and are caused by many factors other than the driving skill of one of the involved drivers.

2.1.2 Licence Test Score and Driving Behaviour

If test validity cannot be judged on the basis of the relationship between test score and accident rate, how can validity be established?

One approach is to demonstrate that a poor score on the test is positively related to the incidence of unsafe driving behaviour in other situations. However, driving behaviour is affected both by level of driving skill and by motivational factors. To the extent that (a) motivation under licence test conditions is different from under most normal driving conditions, and (b) motivation affects the probability of occurrence of unsafe driving behaviour independently of driving skill, then test performance cannot be expected to predict the

occurrence of unsafe driving behaviour under normal driving conditions.

There is a paucity of empirical evidence concerning relationships between particular sorts of driving behaviour and accident probability. The evidence is discussed in a later section, as are the roles of driving skill and motivation (particularly risk-taking propensity), and their relationship to driver age and experience. These issues are all relevant to the feasibility of predicting driving behaviour under normal driving conditions, particularly the probability of unsafe behaviour, on the basis of performance in a licence test.

Another approach to establishing a valid licence test is to define "unsafe" behaviour operationally, as "behaviour characteristic of drivers with the highest accident rates". It is well established that accident rate decreases with increasing age and driving experience, at least during the first few years of driving; that is, safe driving skills are evidently accumulated over quite a long period. It appears reasonable, then, to assert that "The minimum condition for external validity is some degree of association with experience" (Shaoul, 1975). That is, drivers with very little experience have less skill and should therefore be more likely to score poorly and/or fail than drivers with greater experience, provided that the latter are not yet "old".

This approach is simpler than others in that it avoids the necessity to validate independently each item of the test. However, it is open to question on the grounds that at least some of the differences between experienced and inexperienced drivers

probably result from the need for those with little experience to allow greater margin for their own errors (due to their lower levels of driving skills), if they are to decrease their objective risk of accident to a similar level to that of experienced drivers. It is possible that part of the reason for the over-involvement in accidents of inexperienced drivers is their tendency to imitate experienced driver behaviour in aspects such as speed and overtaking frequency, without having commensurate perceptual and cognitive skills.

A parallel, although more extreme, case is that of pedestrian behaviour. Inexperienced pedestrians (i.e. children) have been observed to behave differently from more experienced pedestrians (adults) in many ways. Observations of behaviour in non-accident situations has shown that, according to normal road safety rules, children generally display safer road crossing behaviour than adults; they are more likely to stop at the kerb before crossing, and less likely to cross diagonally (see Firth, 1982). Macdonald (1985) commented: "In view of this, and their known physical and psychological deficiencies relative to adults, it appears that children tend normally to compensate for their lesser abilities by being more careful." Furthermore, it is recognised that children should be taught "safe" behaviour in terms of particular sorts of skills and procedures, rather than being encouraged to imitate adult behaviour which, while being relatively safe for highly skilled adults, would be impossibly difficult and therefore dangerous for them.

Therefore, in using the performance of experienced drivers as a criterion against which to judge the validity of a licence

test which is generally administered to inexperienced drivers, account should be taken of the modifying effects of varying levels of skill on the acceptability of the particular behaviours being evaluated in the test.

For example, it is known that experienced drivers normally focus further ahead down the road than inexperienced drivers, and spend less time looking directly at things in the periphery of their visual field (Mourant and Rockwell, 1972). On this basis, it has been suggested that inexperienced drivers should be taught to do the same, and that procedures might be developed which test such behaviour as part of the licensing process (Waller et al. 1978). However, since drivers' visual behaviour is closely inter-related to the performance of their whole task and is based on a very complex set of perceptual skills, expectancies and decision processes, it would seem unwise to attempt to modify this single, quite superficial aspect of observable behaviour in isolation from its context. It is known that experienced drivers are more efficient in their information processing, and make more use of information from peripheral vision. This ability is dependent on the prior establishment of a large "databank" of driving-related information and experiences. To attempt to establish the visual behaviour in isolation would probably not succeed; in the unlikely event that it did, accident risk would almost certainly be increased rather than decreased.

This argument would not necessarily apply to all observed behavioural differences between experienced and inexperienced drivers. However, some knowledge of the nature of driving skill would be needed to determine the probable basis for observed

differences, and hence their suitability for use in licence testing.

A more defensible approach might be to use as the criterion the behaviour of drivers of approximately the same level of inexperience as most licence test candidates, who were also known to have a low accident rate during the period of perhaps 6 to 12 months following the test. However, such an approach would be subject to the sorts of problems dicussed earlier in the section on using accident data to validate licence tests. Clearly, there is no simple solution!

In summary, there are major difficulties in attempting to validate a licence test on the basis of a relationship between low test scores and unsafe driver behaviour. In the first place, test performance cannot be expected to be a good predictor of unsafe driving behaviour because of the differential effects of motivation on behaviour under normal versus test conditions. Second, there is a lack of empirical evidence defining the nature of "safe" and "unsafe" behaviour.

Safe behaviour may be defined operationally as behaviour characteristic of drivers with low accident rates, for example older and more experienced drivers. However, in using the performance of experienced, highly skilled drivers as a criterion, account must be taken of the modifying effects of skill on the safety of particular types of behaviour. To do this requires considerable knowledge of the nature of driving skill, as a basis for determining the causes of observed behavioural differences between experienced and inexperienced drivers and

hence judging their suitability for use in licence testing.

2.2 SETTING A STANDARD

Thus far, this discussion has been concerned with the first of the two major objectives of licence testing: the measurement of performance so that drivers who are not sufficiently competent, and who are therefore likely to present an unacceptably high accident risk, can be "screened out". The second major function of licence testing was identified as setting a standard which influences the content of driver training programs. Because of this, the test should have good content validity - that is, it should require adequate performance of all major components of safe driving behaviour.

A test may have poor content validity while still having good validity as a screening instrument, provided that test score and the probability of accident involvement (based on an external criterion) are closely related. For example, if a strong empirical relationship were found between accident-free driving in traffic and the speed and degree of smoothness with which drivers could perform three-point turns on steep gradients, it might be decided to adopt performance on this manoeuvre alone as the licence test. Indeed, a similar suggestion was made by Lauer (1960) on the basis of an extensive review of evidence on the validity of licence testing. Such a test would be almost totally lacking in content validity, but whether this mattered would be dependent on the degree of interaction between the process by which people learned to drive and the nature of the licence test. If there were no interaction the lack of content validity would

be immaterial. However, if people directed their learning purely to master performance of the test manoeuvre, such a test might be expected to have unfortunate consequences.

In fact, there is little doubt that the content of the licence test influences the content of driver training programs, at least in Australia, so content validity of the test is important. Therefore, although it is not practicable to test all relevant aspects of driving ability, those which are tested should be relevant to safe driving practices, and those penalised should be associated with increased risk of accident, given that the ultimate purpose of driver training and licensing is to maximise safety.

2.3 SUMMARY

The primary objectives of licence testing are to establish that drivers have attained an adequate level of competence, and to set an appropriate standard of good driving behaviour. The degree to which a testing system attains these objectives is difficult to assess, for several reasons. The relationships between licence test score and subsequent accident record and between test score and "safe" or "unsafe" driving behaviour are both considered as the basis for validating a licence test, and major problems identified.

It is apparent that if testing procedures are to be properly evaluated and improved, there is a need for more information about the nature of unsafe driving behaviour and the factors which produce it. This is a difficult problem to investigate

because driving behaviour is determined by motivational factors as well as by driving ability, so performance under test conditions does not necessarily reflect that under normal conditions.

There are few studies which address this problem directly; most are primarily concerned with, for example, investigating differences between different groups of drivers, or evaluating proposed new test procedures or training courses, or investigating accidents. Consequently, there is a large and varied literature but most of it is of marginal relevance, making the process of reviewing it a difficult one.

3. DETERMINANTS OF DRIVER BEHAVIOUR

In the complex area of research into driver behaviour there is clear consensus on one thing: there is an urgent need for far more comprehensive information on the nature of driving skill and of the interactions between skill and other determinants of behaviour such as motivation.

Even when driving is considered purely as a psychomotor skill, leaving aside motivational determinants, the situation is not clear. Waller (1983) stated the problem clearly:
"...it is well known that in the acquisition of any complex skill many more errors will be made in the initial stages than in later ones. This basic principle of learning has been acknowledged in skills training in the air force, the space program, industry, and sports, and extensive research has been conducted to analyze carefully the kinds of behaviors involved and how they might best be modified. However, no such analysis has ever been conducted for the driving task, where the potential payoff may be greater than in all the other areas combined."

Many researchers have tackled the problem in an empirical fashion (e.g. McRae, 1968; McKnight and Adams, 1970; Quenault, 1967, 1968; McPherson and McKnight, 1981; Biehl et al. 1975). McRae distinguished various categories of drivers on the basis of patterns of scores on driver skill tests. Two different classes of skills were identified: a "physical handling of the automobile" class, including brake stop, turn about, stop and start, and clutch and an "interaction with traffic" class,

including attention, keeping in lane, right of way, and first slow sign.

Quenault and his co-workers (Quenault, 1967; Quenault, 1968a, 1968b; Quenault et al, 1968) initially observed a wide variety of driver actions from which they selected three main types as the basis for categorizing drivers into four "styles" of driving: safe, injudicious, dissociated active and dissociated passive. The three types of behaviour from which these styles were identified were: (1) near accidents, risks, and "unnecessary" manoeuvres, (2) use of rear-view mirrors in relation to manoeuvres, and (3) speed relative to other traffic.

Bristow, Kirwan and Taylor (1982) re-analysed some of Quenault's data and suggested that the four styles could be explained in terms of two dimensions: affective and cognitive. The active/passive distinction (closely related to drivers' speed in relation to that of other traffic) was described as the affective dimension, while they classified the dissociative aspect of behaviour (closely related to level of mirror use) as one of cognition.

According to McKnight (1983) "good driving requires superimposing the strategies of safety and efficiency upon the motor skill of vehicle handling". Discussing the development of driving skill, McKnight observed that until the basic motor skills of vehicle handling are completely mastered, there is insufficient spare mental capacity for the learner driver to worry about maintaining a safe following distance, anticipating traffic conditions 12 seconds ahead, monitoring overtaking

traffic in the rear mirror, and maintaining a steady, fuel-efficient speed - all at the same time.

In fact, McKnight's implied distinction between "skill" and "strategy" is not a clear one. Driving skill includes vehicle control skill but also has important perceptual and cognitive aspects. Drivers develop skill in "reading the traffic"; they learn which are the most relevant aspects of their visual environment to attend to in all the varying circumstances of driving; they build up a complex pattern of expectancies which, as they come to rely on its accuracy, decreases their need to pay attention to all incoming information. Thus, the development of greater skill is characterized by the progressive automation of sub-skills, permitting the driver to re-allocate attention in such a way that skill continues to develop until the maximum or optimum level of automation is attained.

A quite different approach was taken by Schlesinger and Safren (1964). Based on the work of Gibson and Crooks (1937) they defined the driver's task as being essentially that of maintaining a field of safe travel greater than the minimum stopping zone. Skill in driving is reflected by the accuracy with which drivers perceive the field of safe travel and the minimum stopping zone, and in the ratio of the field to the zone they maintain over time. Skill could also be measured by drivers' output to the vehicle, since this reflects their perception of the two fields and the field-zone ratio.

Rather than attempt to investigate the perceptual processes directly, they argued that a driver who accurately processes

incoming information has less occasion for abrupt speed and direction changes due to unexpected contingencies. A skilful driver would therefore tend to be a smooth driver. Specifically, they tested and found support for the hypothesis that more skilled drivers would have fewer accelerator actions, brake actions, total speed changes, and steering wheel reversals.

In an extension of this work Safren, Cohen and Schlesinger (1970) drew from basic research on the nature of skill the notion that "anticipation of what is coming next" explains the "smoothness" of performance which is the hallmark of a high level of skill (Bartlett, 1958). Thus, they selected "smoothness" or consistency of driving, as measured by speed changes over time and direction changes over time as their main experimental measures of driving skill.

However, Risk (1981) pointed out that we know very little of the perceptual circumstances that signal the need for control adjustment. These may perhaps appear obvious enough for steering control, being related to the curvature of the road ahead and the actual and anticipated blockages it contains. Further, the consequences of inaccurate steering are clearly apparent to the driver. But the hazardous significance of slight or even large variations in the speed with which manoeuvres are performed is not equally evident.

In recent years there has been a growing awareness of the need to investigate the driver's perceptual processes directly. For example, an OECD report (1980) concluded on the basis of the literature related to accident causation that most accidents are

caused by lapses in the perceptual components of driving behaviour rather than by poor vehicle-control capabilities. On this basis the report argued that greater emphasis should be given to the driver's perceptual tasks.

However, Hatterick and Bathurst (1976) concluded from analysis of accident situations in which there was a paucity of emergency responses other than braking, that lack of response availability may be a major factor in collisions. A report by Bathurst (1980) on accident avoidance skill training suggested that lack of appropriate response in an emergency situation could be due to any of the following - failure to detect the conflict, failure to correctly classify the conflict, lack of availability of the correct response, failure to select the correct response. Thus, perceptual, decision and response factors were all acknowledged as being potentially significant.

Perception may be defined as the encoding of stimuli into meaningful patterns. Skilful drivers are distinguished by the accuracy and efficiency with which they select and encode that information which is relevant to their task. There is now a considerable body of evidence on this aspect of driving skill, which is discussed in a later section.

In deciding on a response to perceived information, drivers are affected not only by their expectation of the likely effects of possible actions on vehicle speed and position but by wider motives and expectations concerning the various costs and benefits of particular actions. Indeed, motivation is seen by many to be the major determinant of driver behaviour.

The best known and most extreme theory concerning the importance of motivation is that based on utility theory (Fishburn, 1968; Wilde, 1976; Summers and Harris, 1978). Hodgdon, Bragg and Finn (1981) used this theory as the basis for their review of the research literature on risk-taking, particularly as it relates to young drivers. "Risk" is defined as "the product of the probability of the negative outcome and the cost (severity) of that outcome".

According to this theory, when a driver decides on a particular action the expected utility of engaging in that action is weighed, consciously or subconsciously, against its perceived risk. It is postulated that a driver usually chooses to take the action whenever the expected utility exceeds the perceived risk.

Thus, a high risk-taking tendency among a particular group of drivers (such as young drivers, or Quenault's "dissociated active" drivers) might be explained in any of the following ways:

- they may perceive the risks associated with a given behavior to be lower, and/or
- they may assign a higher expected utility to a hazardous driving practice, and/or
- they may weigh utility and risk equally, while older drivers may be risk avoiders, particularly for violation behaviours.

The first explanation focuses on risk perception, the second on risk utility, and the third on risk choice. The explanation in terms of risk perception is more related to skill than to

motivation; that is, it is a "cognitive" rather than an "affective" factor. Related to this, Shaoul (1975) wrote that: "It has generally been assumed that the safe driver is the conformist, or the cautious person. In understanding the part played by risk and hazard it may be that the safe driver ... is not necessarily conformist or cautious but one with a realism of judgement."

Good judgement is based on drivers' accurate perception of both the environment and their own driving skills. Thus, Brown (1982) found that inexperienced drivers tend to create accident opportunities for themselves, because they often misperceive the hazardous nature of forthcoming events in the traffic environment, or completely overlook a demand for action until it is too late to respond safely. The problem is exacerbated, particularly in the case of young males, by a tendency to overestimate their ability to manoeuvre the vehicle and to recover from error. Since driving is largely self-paced, this over-confidence may cause relatively naive drivers to place demands upon themselves (e.g. by driving excessively fast) which are inappropriately high for their level of experience.

In addition to cognitive or skill factors, there are undoubtedly affective or motivation factors. Thus, Sivak (1981), in a very large scale and well-controlled data analysis, found that fatality rates as a function of age, from road and nonroad accidents, were significantly related, which suggested general risk-taking as a significant factor in accident causation. According to Wilde, one of the main proponents of utility theory, only those factors affecting risk tolerance will have any

tangible effect on accident reduction; perceptual, decisional, and control factors will have no effect. Indeed, Wilde (1982) maintained that according to the theory, seat belts, crash helmets and highway modifications will have at best only a temporary effect, an argument which has since been comprehensively refuted (see Evans, 1985).

McKenna (1982) suggested a more useful approach to the problem. His approach avoids claims that all other approaches to improving road safety will fail when many of them have been shown to work. Also, it avoids the paradoxical position of positing the critical importance of accident risk in the face of evidence that road users are generally very inaccurate in their perception of this risk.

McKenna suggested that what drivers experience is variation in their level of control, and that they act in a way which attempts to maintain this at an acceptable level. A high level of control would be experienced if there were little difference between the predicted road situation and the actual road situation or if it were judged that differences which might occur could be coped with adequately. A low level of control would be experienced if there were large differences between the predicted road situation and the actual road situation or if it were judged that differences could not be coped with.

He pointed out that it is possible for accidents to occur even when high levels of control are experienced. For example, a high level of control might be experienced by a driver who has few and vague expectations due to inexperience or to abilities

being diminished for some reason, and who is unaware of this inadequacy. Presumably many of the young, inexperienced male drivers referred to by Brown (1982) as being over-confident would fall into this category. Because few predictions are being made such drivers have to respond as things happen and are therefore more vulnerable than those who have anticipated the situation and have a set of responses prepared.

3.1 SUMMARY

No comprehensive analysis of the processes and stages involved in the acquisition of driving skill has ever been conducted, which means there is no solid basis for licence testing or driver training programs. However, many researchers have studied driver behaviour, categorizing it in a variety of ways, and in general terms it is clear that behaviour is determined by the complex interactions between both "skill" and "motivational" factors.

Skill is a major factor in the perceptual processes of selecting and encoding information from the environment, but motivational factors are also influential. Similarly, the processes by which perceived information is classified and used in the process of response selection and execution entail both skill and motivation.

Acquisition of driving skill entails the establishment of an accurate "database" from which the probabilities of particular outcomes, given particular configurations of external events and possible responses to them, are judged. Perception by drivers of

their own response capabilities is an important factor in this process. The acquisition of driving skill also entails learning to perform a wide range of possible responses and selecting the most appropriate response in particular circumstances. Motivation may be seen as affecting these processes via the individual pattern of perceived costs and benefits, which interact with perceived probabilities in determining the way individuals "weight" various possible responses and expected outcomes.

It has not been the purpose of this section to reach conclusions but to present the main concepts relevent to studying driver behaviour. Johnston and Perry (1980) observed that, "Unfortunately, the now vast literature is a morass of relatively disconnected elements, compounded by the fact that behavioural scientists of all persuasions continue to join the fray with piece-meal approaches." It is therefore exceedingly difficult to establish a coherent framework within which literature can easily be reviewed. Bearing this difficulty in mind, the preceding discussion on the determinants of driver behaviour may serve as a context within which the following section on Unsafe Driver Behaviour can be better understood.

4. UNSAFE DRIVER BEHAVIOUR

The problems of categorising particular examples of driver behaviour as "safe" or "unsafe" were discussed in Section 2 above, in the context of assessing test validity. Evidence relevant to the definition of unsafe behaviour is considered below in three main sections: (1) evidence from accident studies, (2) evidence from studies of driver behaviour in non-accident situations, and (3) evidence from non-driving studies.

4.1 ACCIDENT STUDIES

Research on the nature of drivers' behaviour immediately prior to their being involved in an accident is of obvious relevance to the definition of unsafe behaviour. Unfortunately, such research is rare. It is reviewed below, with particular emphasis on the role of driver inexperience. This emphasis is adopted for two, inter-related reasons. First, the licence test is generally passed at a relatively early stage in the development of driving skill (there is evidence, e.g. OECD, 1975, that level of driving skill takes some seven to eight years to asymptote). Second, any difference in accident patterns related to driver inexperience is likely to be indicative of those aspects of driving skill which are slow to develop and which are therefore important "target behaviours" for licence testers.

Clayton (1972) obtained data from accident-site investigations and follow-up interviews from which was developed a classification of road-user errors. The criterion used for

determining error was the Ministry of Transport Highway Code, representing the officially accepted standard of good driver behavior in the U.K. Any contravention of the Code was deemed an error. These were classified on the basis of a simple three-stage human decision-making model: perception, decision, and implementation (Welford, 1960).

Errors were further divided as follows:

1. failure to look (failed to receive all relevant sensory information available)
2. misperception (scanned relevant parts of situation but failed to perceive the hazard within it correctly)
3. excessive speed (approached hazard at such a speed that unable to negotiate it safely).

For the following three errors, it must have been established that the road user perceived the hazard correctly:

4. panic reaction (over-reacted with excessive use of controls)
5. other known error of decision (incorrect decision)
6. error of implementation (used a control other than the intended one).

Two errors accounted for over half the recorded errors: failure to look (28.5%) and excessive speed (25.3%). There were basic differences in what appeared to be the causal factors associated with the various types of errors. For errors of failure to look, the prime causal factor was distraction of the road user at the critical moment. For errors of misperception, adoption of an incorrect set or perceptual expectancy appeared to be more prevalent than a visual defect, and there were several cases of alcohol and fatigue.

Excessive speed was shown to be associated with youth and inexperience. Errors tended to be related to restrictions of available sight distance, usually at bends or crests, and to vehicle defects such as inadequate brakes or steering.

Panic reaction was mainly caused by one vehicle suddenly infringing or threatening to infringe on the intended path of another. Mean ages and levels of driving experience of the excessive speed and panic reaction groups were significantly less than the means of the nonerror groups. In the case of panic reaction there was evidence that, possibly due to the inexperience of these drivers, they could not process all available perceptual information well enough, so instead of responding correctly they simply tried to stop as quickly as possible, and in so doing lost control.

Barry, Roper and Pitts (1974) analysed critical manoeuvres in crashes of drivers aged 16-18 years and compared them with those for drivers aged 35-44 years. They found no evidence for differences between groups of drivers in their ability to handle emergency situations. Both groups of crashes contained the same proportion attributable to emergency situations, although there were no data on exposure to emergency situations.

However, there was evidence that younger drivers were more prone to accidents when pulling in front of oncoming traffic and they also had a disproportionate number of rear-end collisions. The authors suggested that this may be due to their inexperience in judging gap clearance and closure speeds.

Council, Sadof, Roper and Desper (1975) referred to unpublished work by Griffin and Leggett showing that 35.7% of fatal accidents in North Carolina in 1973 were caused by a chain of manoeuvres that started with one vehicle running off the road. They commented that drivers aged 16 were more likely to be involved in run-off-road accidents than those aged 26 or older, and very young drivers running off the road were reported to have had a mean and median speed almost 10 mph higher than that reported for drivers over age 25 involved in such accidents.

Lohman, Leggett, Stewart and Campbell (1976) analysed accident data to identify a set of unsafe driving actions (UDA's) and determine their relative frequencies in accidents. Through field observations at accident locations, frequencies of occurrence were estimated and subsequently used to calculate relative risk factors for a selected group of six UDA's.

Turning in front of oncoming traffic was found to be the highest risk behaviour, three times that of pulling in front of oncoming traffic (which ranked second). Following too closely ranked third and failing to comply with a traffic control sign or signal was fourth. Speeding was the least risky behaviour. Young drivers were over-represented in two of the six UDA's: failing to keep to own side of road, and speeding.

Probably the most comprehensive investigation into the relationship of driver factors and accident causation was that by Treat et al. (1977). According to their analysis, errors associated with driver "performance", the category most sensitive

to vehicle control skills, accounted for only 7% of the accidents investigated. The leading causes of accidents were lapses in the use of safe driving practices, most noticeably those associated with visual search.

Shinar, McDonald and Treat (1978) developed an analytical methodology to study the relationships between driver behaviours causing and immediately preceding an accident and causal impairments in drivers' predisposing mental and physical states. For the cases when driver inexperience was judged to be a predisposing state, inadequate directional control was significantly overrepresented as a direct causal factor, "indicating a lack of knowledge of appropriate steering maneuvers by drivers whose inexperience was judged to cause an accident."

According to a report by Bathurst (1980), lack of appropriate response in an emergency situation could be due to any of the following - failure to detect the conflict, failure to correctly classify the conflict, lack of availability of the correct response, failure to select the correct response. They pointed to the lack of responses other than braking found in an analysis of accident situations and responses by Hatterick and Bathurst (1976) as evidence that lack of response availability may be a major factor.

On the other hand, an OECD report (1980) outlining guidelines for driver instruction concluded from studies based on post-hoc accident reconstructions and clinical evaluations of drivers involved in accidents that there was a predominance of perception/attention errors over response errors. The report

concluded that most accidents are caused by lapses in the information processing task, rather than by poor vehicle-control capabilities.

Consistent with this emphasis, Quimby, Maycock, Carter, Dixon and Wall (1984) studied the visual and perceptual abilities of 370 accident involved drivers in relation to their accident experience. Accidents were classified in terms of contributory factors in great detail. Those possibly involving a visual or perceptual factor were identified. Accidents in which the driver was considered to have been to blame for the accident were analysed separately from the rest.

Results of tests on the drivers of static and dynamic visual ability, performance in a driving simulator and various aspects of cognitive performance, age, experience, sex, average distance travelled per year and self-reported accident histories were analysed. This produced a predictive model of accident frequency as a function of age, exposure and some of the "higher order" test results. Once age and exposure had been allowed for, no correlations between accidents and "simple" visual or performance tests could be detected. In general, there was little evidence for links between a particular visual or perceptual ability and specific factors identified in the accident.

Young and inexperienced drivers (at least in extreme cases) appeared to be much more likely to have been judged to blame for the accident in which they were involved than drivers in the sample as a whole. There were significant differences in blameworthiness for those at the extremes of the visual acuity

distributions, but they were not in the direction that would be expected if good visual acuity were important to safe driving. Such results may be explained by the fact that those with good visual acuity tend to be young and inexperienced, and these are also the drivers to whom blame was most often attributed.

When comparisons were made between those drivers who had not reported any other accidents in the previous 3 years and those who reported at least 2, it was found that visual performance of the two groups differed significantly with both static and moving targets. Subjects performing well in tests requiring fast responses had the poorer accident history. Again, this was thought to be explicable in terms of age effects - young people are more likely both to respond fast and to be involved in more accidents.

Allen and Weir (1984) wrote that "Young drivers involved in accidents are commonly found to have been driving too fast, following too close, and to have been drinking, while the older driver is more likely to have acted carelessly in yielding, observing signs, maneuvering, etc." Their reference for this statement was an unpublished NHTSA Research Note by Smith, M.F. (1983) entitled "Older Driver Retraining", so the research basis cannot be readily verified. Nevertheless, the mention of excessive speed in young driver accidents is consistent with other work reviewed.

In summary, then, it appears that errors in driver behaviour leading to accidents are fairly equally distributed over perceptual and response error categories. However, when drivers

are young and inexperienced, response errors (particularly excessive speed) are more likely than perceptual errors to be implicated. The only study in which perceptual errors were associated with young drivers was that of Barry et al. (1974), which was exclusively concerned with young driver accidents.

4.2 DRIVER BEHAVIOUR IN NON-ACCIDENT SITUATIONS

There is a wide variety of studies in this category. They include those in which observations were made from within the vehicles of individual drivers by observers or by vehicle instrumentation systems, observation of individual drivers from a following vehicle, measurement of behaviour at particular sites, measurements of behaviour on a driving range and in a simulator. In some studies the approach was purely observational, but in most cases the observed driver behaviour was related to factors such as the nature of the driving environment or to known driver characteristics such as age, driving experience and accident record.

The latter type of study will be emphasised in this report. In particular, the types of unsafe behaviour which are presumably associated with the poorer accident record of young, inexperienced drivers will be clarified by an examination of evidence concerning behavioural differences between different groups. Comparisons will be made between drivers with good and bad accident records, and between inexperienced (usually young) and experienced (usually older) drivers. As mentioned earlier, young drivers form the majority of licence test candidates and their behaviour is therefore of primary interest.

In the preceding section on evidence from accident studies it was found that when young and inexperienced drivers are involved in accidents, response errors (particularly excessive speed) are most likely to be implicated. Therefore, the present

section will begin by considering evidence related to vehicle control skills.

Greenshields and Platt (1967) used a system of vehicle instrumentation called a drivometer to record driver control actions, vehicle motions and traffic events. The measures were able to discriminate approximately two thirds of drivers tested in terms of the following driver categories: high accident, low accident, high violator and inexperienced.

Inexperienced drivers and those with a poor record (accidents, violations) generally made more reversals of the controls, which was attributed by the authors to overcorrection and indecision. The four discriminating variables were: trip time, accelerator reversals, gross steering wheel reversals, fine steering wheel reversals.

Safren, Cohen and Schlesinger (1970) also used the drivometer. They had two groups each of six male subjects: one group of drivers were inexperienced, having driven less than 300 miles in their lifetime, and the others had driven at least 10,000 miles per year for each of the previous three years. Each subject drove for two trials (16 laps per trial) on a test track, one trial at 30 mph and one at 45 mph.

There were no significant differences between groups for any single measure. However, intercorrelations between measures showed differences between the groups: there was a moderate positive correlation between steering wheel reversal rates and speed changes for the experienced group, and a moderate negative

relationship for the inexperienced. The authors suggested on this basis that separate aspects of the driving task were "fused" differently for the experienced and the inexperienced. In view of the extreme inexperience of the inexperienced group, it seems more likely that the negative correlation in their case simply reflected their lack of spare mental capacity, such that they were unable to attend simultaneously to steering and speed control: the two subtasks were not fused, or co-ordinated, at all.

Council and Allen (1972) investigated the potential usefulness of instrumented cars in helping the licence examiner differentiate between a "good" and a "bad" driver. Six variables were recorded in their cars, but the only ones consistently important in differentiating subjects into groups were steering-related variables, ie. fine and coarse reversals. However, they pointed out that comparison of different studies of steering variables showed confusing results.

Macdonald (1979) and Macdonald and Hoffmann (1980) discussed such problems in the interpretation of steering movements and proposed an explanatory model. In view of the complex nature of the determinants they postulated it is unlikely that any measure based on steering reversals would be useful in licence testing. A further problem noted by Council and Allen was the occurrence of significant differences in results depending on which particular car was being driven, and over which particular route.

Notwithstanding these results, Attwood (1979) described an experiment whose purpose was to develop a method of predicting

driver ability using instrumented vehicles, with a view to possible use in driver licensing. There were fifteen subjects: seven novice drivers (less than 2,000 miles experience) and eight experienced (5+ years experience), who drove an instrumented vehicle (including a more sophisticated version of the drivometer) in a variety of traffic conditions. On some sections, subjects were instructed to maintain certain speeds or lanes, during which periods data were collected on vehicle velocity, lane position, steering wheel position, and accelerator pedal position.

On each task, the centreline tracking performance of the novice group was typically more variable than that of the experienced group, and on average the novice drivers placed their vehicle further from the centreline. Although some variant of lateral position dominated all analyses, other summary variables also contributed to group discrimination. The report suggested that in future it could be possible to employ on-line monitoring devices to determine whether a driver is capable of a minimum level of driving performance. However, this appears to be most unlikely in the foreseeable future.

Further evidence of the superiority of more experienced drivers in vehicle control skills is provided in a report from Bathurst (1980), concerned with a method of training accident avoidance skills. Initial differences were noted between students who were newly licensed teenagers and adults with more than five years of driving experience in their respective abilities to avoid crashes on a driving range, and the rate of improvement with training was greater initially for groups with more prior

driving experience. Before leaving the program, however, drivers of each age and experience subgroup had become significantly better and about equal in their ability both in strategy selection and strategy implementation (in manoeuvering cars to avoid collisions). All students retested nine months after training not only had retained the crash avoidance skills developed but had improved them.

McPherson and McKnight (1981) evaluated a number of measures of different aspects of vehicle control skill in terms of their ability to discriminate novice from experienced drivers. The measures were related to the following aspects of behaviour: acceleration, braking, speed on curves, braking on curves, stopping at a designated point, parallel parking and angle parking. Results were as follows.

Acceleration. No significant difference.

Braking. A negative acceleration of 0.3g discriminated the groups; only novices recorded higher values.

Speed on curves. A lateral acceleration of 0.4g discriminated the groups; only novices recorded higher values.

Braking in curves. Application of brakes at the point of maximum lateral acceleration appeared to discriminate the groups; experienced drivers rarely applied the brake during maximum lateral acceleration.

Stopping at designated point. Experienced drivers stopped much closer to the line than the novices.

(The authors interpreted the results for both braking on curves and stopping at a designated point as suggestive of the novice drivers' deficiency in judgment accompanied by added caution.)

Parallel parking. Novices were worse than the experienced drivers in terms of number of direction changes, number of cones knocked, time taken, and distance of parked position from the kerb.

Angle parking. There was little difference between the groups.

McPherson and McKnight also found that experienced drivers were more likely to give proper signals. The authors commented that this result is consistent with other research showing that when drivers know what they are supposed to do and are motivated under test conditions to do it, those who are most proficient in vehicle handling skills will exhibit superior performance in safe operating practices. That is, the incidence of safe operating practices may serve as indirect measures of vehicle handling skills.

Shaoul (1975) also found that signalling behaviour was better among the older, more experienced drivers within a subject group of 17-21 year olds. They also performed better in reversing through an S-shape, in parking, and in driving through narrow gaps.

Jones (1978) reported on the development of a driver performance test in which observers rated drivers of varying age and experience on aspects of behaviour such as observation, speed, path, gap acceptance, mirror use, etc. during certain specific manoeuvres such as left turn, through, right turn, and lane change. Scores were grouped into subscores for Observation, Car Control, Judgment and Other.

On the Car Control subscore drivers in the 17-21 and 25-35 age groups (the former with 2+ years experience, the latter with 10+ years) were best, then drivers aged 60-69 years (20+ years experience) then those over 70 years old (20+ years experience), with the worst being students aged 15-16 years who had just completed a driver education course. On the Observation subscore those with 10+ years of experience were the best, followed by those with 2+ years, then the students, then the second oldest and last, the oldest drivers. Thus, in Car Control the worst group was the least experienced but there was no difference between those with two years experience and those with over ten years, whereas in Observation those with more than 10 years experience were significantly better than those with two years, suggesting that vehicle control develops more quickly than perceptual aspects of driving skill.

The relationship between drivers' self-perceived and actual skill was investigated in studies by Cohen and Hansel (1956, 1958) and Erikson (see Shaoul, 1975), using a gap estimation and negotiation task. In Cohen and Hansel's work, two groups of bus drivers differing in experience (training as bus drivers) first stated the number of times out of five hypothetical attempts they thought they could succeed at driving through a series of narrow gaps between two posts; actual performance was then measured. The superiority of the more experienced group showed itself in better performance in steering and manipulating the vehicle rather than in better judgement of their own driving capacity.

Erikson compared groups of drivers who had had accidents with matched control groups. Following the same procedure and

method of analysis as Cohen and Hansel, he found that the gaps at which non-accident groups invariably succeeded were in each case narrower than the gaps at which the accident group always succeeded, and the gaps at which the non-accident groups believed they would succeed were larger than the corresponding gaps of the accident groups. Clearly, the relationship between what drivers think they can do and what they can actually do is an important aspect of driving skill.

The above results provide ample evidence of the measurable differences between drivers in vehicle control skills associated with different levels of driving experience. They may be differentiated by their different patterns of control activity and, more clearly, by the more accurate and faster performance by experienced drivers of slow-speed vehicle manoeuvres such as reversing and parking. These drivers are generally smoother in their manoeuvering, with lower maximum values of longitudinal or lateral acceleration forces. They are able to track along a line with smaller and less variable lateral error, and can bring their vehicle to rest at a designated line, or negotiate a path through narrow gaps, more accurately.

Next to be discussed is a major factor associated with poor vehicle control skill in young drivers' unsafe behaviour: that is, excessive speed and its possible determinants such as a tendency to accept high risks or poorly developed perceptual and cognitive skills.

Parker (1973) compared the behaviour of 80 drivers at the beginning and end of the three year period after they passed the

standard British licence test (the DOE test). There was no significant change in the number who had no dangerous or serious errors; the total number of errors in these categories committed by the group as a whole was almost identical in both drives. However, errors associated with driving at speed were more frequent and average speeds had increased after three years.

A relationship between speed and experience was also found by Shaoul (1975), who recorded the performance of 17-21 year olds on the DOE test, various slow speed manoeuvres, estimating gap size, and driving through narrow gaps. People passing the DOE test were older, had been driving for longer, had driven twice the mileage, took less time on the practice drive, less time for the slow manoeuvres, more time on the test drive and were more successful at the narrowest gap than those who failed. The two slow speed manoeuvres investigated were parking and reversing through sets of posts in an S shape. The correlations involving time taken for the various procedures highlight the importance of speed control. People passing the test (the older, more experienced drivers) took less time on the practice drive and for the slow manoeuvres, but more time on the test drive, suggesting the combined effects of greater skill and high motivation to pass the test.

Quenault and Parker (1973) found significant differences in behaviour among groups of drivers with 1, 13, 26, 39 and 52 weeks of experience after passing the official driving test. Specifically, average speeds both in 30 mph and de-restricted speed zones increased with time after the test while the frequency of instances of poor car control decreased. These

results, together with those of Shaoul (1975) and Parker (1973) discussed above, are evidence of a complex relationship between the development of vehicle control skills, speed and motivation. It appears that as drivers gain more experience and they perceive their skill increasing, their confidence increases and they increase their speed accordingly.

Knapper (1983) observed that studies of driver behaviour in natural settings have shown that young male drivers are more likely to exhibit "risky" behaviour such as speeding or driving close to the vehicle in front (Evans and Wasielewski, 1983; Konecni, Ebbeson and Konecni, 1976). Hodgdon, Bragg and Finn (1981), in a review of literature on young drivers' risk-taking, questioned the extent to which such behaviour is a function of young drivers' failure to perceive their driving as more hazardous, and the extent to which it arises from the particular satisfactions derived from risk-taking associated with the motivational pattern characteristic of young males.

For example, it is a common belief that unsafe young drivers are particularly affected by motives such as frustration, expediency, competitiveness, aggression, exhibitionism, and thrill-seeking, and there is some evidence from the literature to support this assumption. However, Sivak (1981) carried out a large-scale analysis of U.S. accident data, including a large number of independent variables in a multiple regression with road accident rate as the dependent variable. He found that the proportion of young drivers was a significant factor even when general risk-taking levels were controlled, and suggested on this basis that lack of driving experience per se was likely to be a

contributing factor independent of risk-taking factors. However, there is conflicting evidence on the relationship between driving experience, perceptual skill, perceived risk and speed.

Basic to perceptual skill is the process by which drivers acquire information, which for the most part is visual. Mourant and Rockwell (1972) found differences between novice and experienced drivers in their patterns of visual scanning and fixations. Novice drivers apparently cannot use the information from peripheral vision, so must look at the side of the road for lane guidance, whereas experienced drivers look well ahead, engage in more scanning behaviour and show briefer durations of fixation.

McPherson and McKnight (1981) assessed drivers' visual search patterns in terms of their observation of other vehicles, looking in the mirror and over the shoulder during lane change and merging manoeuvres, and looking from side to side at intersections. The novices were observed to search for other vehicles significantly more often than the experienced drivers, a result which surprised McPherson and McKnight. Their suggested explanation was that experienced drivers may be less familiar with defensive driving practices than the novices, the latter having just completed their driver education.

However, they appear not to have considered the probability that experienced drivers were making far greater use of peripheral vision than were the novices (see Mourant and Rockwell, 1972). This seems particularly likely to be the underlying factor in view of the fact that experienced drivers

used their mirrors more often than novices: it was only in failing to look from side to side and in failing to look over their shoulder "properly" that their score fell down. In these cases their use of peripheral vision would not have been evident. There is, after all, no evidence that drivers who display visual search behaviour like that recorded for the novices in this experiment are in any way safer drivers; indeed, the prima facie evidence from this result is to the contrary.

Mourant and Donohue (1974) also reported significant differences in mirror usage between very experienced drivers and those with both moderate and small amounts of experience. Novices not only did not look at their mirrors as often but spent almost as much time monitoring during the non-critical period preceding a manoeuvre as they did during the critical 5 secs preceding the manoeuvre. Shaoul (1975) and Jones (1978) also found that mirror use improved with increased experience.

Brown (1982) reported that less experienced drivers were relatively poor at identifying a variety of distant hazards, although they did not differ from experienced police drivers in the detection of near hazards, which is not surprising in view of evidence that experienced drivers' visual fixations and scanning patterns are generally located further ahead of the vehicle than those of inexperienced drivers. In addition, Brown concluded that inexperienced drivers, especially males, appeared to be overconfident of their vehicle control skills, particularly in terms of their ability to recover from error.

On the basis of such results, Brown proposed a model

describing the effects of age and experience on accident probability in terms of the differential rates of acquisition of vehicle control and cognitive aspects of driving skill. Inexperienced drivers, particularly young males, apparently fail to understand the nature and importance of cognitive skills, do not appreciate their own lack of them, and consequently are overconfident and drive at inappropriately high speeds.

Bragg and Finn (1982) investigated one such cognitive skill when they compared young, inexperienced males with older, experienced males in terms of their rating of the riskiness of a variety of driving situations. Ratings were made as a driver, as a passenger, and from photographs and videotape. They found that the inexperienced drivers considered speeding to be less risky, but driving on snow-covered roads to be more risky, than did the experienced drivers. As the young drivers became more familiar with a particular location such as an intersection, they reduced their rating of the risk associated with negotiating it, whereas experienced drivers did not. The fact that inexperienced drivers rated speeding as less risky than did older drivers seems to suggest a cognitive rather than an affective or motivational ("risk-taking") explanation for the difference in actual driving speed.

A study by Quenault et al.(1968) produced suggestive evidence of a relationship between perceptual deficits in young drivers and excessive speed. They found that a group of very young drivers drove faster than an older group, and noted that, of the "dissociated" drivers, all the young ones were "active" while all the older ones were "passive". There were no

differences in the speeds of the "safe" drivers in either group. This led Bristow et al. (1982) to suggest that "the change in speed (perhaps in level of affect) with age may only apply to drivers whose cognitive skills are poor; young drivers with good cognitive skills are not the ones who drive faster".

Bristow et al. (1982) also noted the work of Hagen (1975), who found an interesting interaction between age, sex and speed. It was found that males tended to drive faster than females, and that young males and young females differed far more in this respect than did older males and females. Bristow et al. related this to some data of their own concerning drivers' verbal responses to film of various driving situations: men made more cognitive comments the more experienced they were, whereas women made more affective comments if they were less experienced. That is, men seemed to become less dissociated with experience, and women became less frightened. Combining this with the analysis of Quenault's data, it seems as if men drive too fast when they are young (especially if they are careless), and young women are more fearful and drive more slowly at first, gaining speed later.

Ganton and Wilde (1971) found a significant negative correlation between years of driving experience and average risk rating: inexperienced drivers perceived driving as being more hazardous than did experienced drivers. Also, Wilson and Anderson (1980) conducted two experiments, one on a test track and one on rural roads in normal traffic, to investigate the effects of varying task difficulty (tyre type) on driving speed and associated levels of perceived risk and risk-taking. In the test track experiment they found that a group of older, more

experienced drivers perceived the change in tyre type and varied their speed accordingly, whereas the young drivers did not perceive the changed difficulty of their driving task and did not vary their speed. This, then, was evidence of poorer perceptual skill associated with inexperience. The over-all level of perceived risk of the younger drivers was higher than that of the older drivers, and they had a lower mean speed, again suggesting the importance of differences in skill rather than motivation.

A more complex pattern of results was found in a laboratory simulation experiment reported by Colbourn (1978). Young drivers with less than one year of driving experience had high levels of perceived risk and were sensitive to changes in objective risk. A slightly older group with more driving experience showed no sensitivity to changes in objective risk, and rated it as uniformly very low. These results are of dubious validity because of the inadequacies of the task, as recognized by Colbourn. However, he commented that "These results do perhaps suggest that the initial nervousness of the novice driver gives way to overconfidence after a couple of years, which is in accord with the accident statistics." It must be further postulated that as level of skill increases further, occasions of very high task demand, or relatively high objective risk, become rarer and drivers regain their sensitivity to such occurrences.

One of the most carefully conducted and ambitious experiments in this field of recent years is that of Quimby and Watts (1981), which investigated the relative importance of a variety of human factor variables to driving performance, using a representative sample of 60 drivers, both on the road and in a

simulator. Special attention was given to identifying any factors that vary with age that might help explain the known relationship between age and accident rate. Factors considered included: visual and perceptual abilities, risk taking, reaction time measures, biographical, attitudinal and personality variables and physiological measures of stress. Driving performance was assessed by obtaining accident and exposure histories for the previous three years and also by considering the number of driving errors committed on a test drive.

Results indicated that the variable measuring risk-taking (derived from the drivers' speeds at potentially hazardous locations on a test route) was most highly correlated with driving performance. It was not clear whether drivers set inappropriate speeds because they failed to recognise the potential danger or because they were prepared to take "calculated" risks while driving, or a combination of these factors. However, it was suggested that those drivers whose speeds resulted in the greatest risk taking tended to consider the risk to be low.

Also, there were significant inverse correlations between number of hazards reported by drivers on the test drive and both observed driving errors and previous accidents. A variety of factors changed significantly with age. For example, the youngest and oldest age groups were on average slower to respond to potential hazards in the simulator and also adopted a lower safety index while driving on the road. The latter result was attributed mainly to the larger average response time to hazards of the older drivers and the faster speeds selected by the

younger drivers. In the simulator, the younger drivers appeared to be least sensitive to changes in risk.

Benda and Hoyos (1983) conducted a study to determine the major variables influencing drivers' estimates of hazard. They found that the most important single variable was information load; situations in which information input is fairly low and unchanging, and in which relatively little control action was required, were regarded by all drivers as low in hazard. However, the effects of driving experience were significant. The more experienced drivers were much more likely to be able to integrate various aspects of situations into a single "hazard" attribute, regardless of whether the hazard arose from fixed environmental features such as intersections or from other moving vehicles.

Less experienced drivers were more likely to base their estimates on specific aspects, particularly poor environmental conditions such as bad weather and unfavorable road conditions including intersections, narrowing roads, etc. The latter result is consistent with the conclusion of Soliday and Allen (1972) that the failure of less experienced drivers to recognise hazards often results from their excessive concentration on non-moving objects.

To summarize the perceptual and cognitive characteristics of "unsafe" drivers (typically the young and inexperienced), it appears that such drivers have a less efficient visual scanning strategy, display longer fixations than better drivers, do not look as far ahead and make less use of peripheral vision. They make less use of the rear view mirror, and use it at less

appropriate times.

They are more likely to miss seeing hazards, particularly the more distant ones, and tend to take longer to notice them. They pay attention to non-moving hazards (such as associated with various road features), often at the expense of more important (in the judgement of more experienced drivers) moving hazards associated with the changing traffic situation. They are less able to integrate various sources of hazard into an overall assessment. Some drivers (most typically young males with relatively poor cognitive skills) see speeding as less risky than do "better" drivers, and tend to over-estimate their own vehicle control skills. The highest risk-takers tend to be those who perceive the risk as least.

Thus, inexperienced drivers appear to be poor in perceptual and cognitive aspects of driving skill as well as displaying poor vehicle control. These characteristics probably result in such drivers frequently driving in a "risky" fashion independent of other possible contributory factors such as a tendency deliberately to accept higher risk for the sake of impressing their peers.

4.3 NON-DRIVING STUDIES

Evidence on the nature of unsafe driving behaviour and possible means of predicting those individuals most likely to drive unsafely is also available from experimental studies of non-driving behaviour. In those few cases where an experiment also included driving behaviour so that it was included in the previous section, the experiment is described again in the present section for the sake of completeness within each section.

Early tests concentrated on the measurement of simple abilities such as response time and visual acuity. However, drivers usually have little difficulty in compensating for deficiencies in such abilities. Quimby et al. (1981, 1983, 1984) measured a wide range of driver abilities and concluded that performance in tests of the higher order cognitive skills, such as the ability to correctly interpret the driving environment and perceive hazards (or "read the road"), are more relevant to safe driving than tests of basic abilities such as eye sight and reaction time. Similarly, an OECD (1980) report commented that safe driving attitudes appear to be connected with the way in which people perceive and assess the potential risks of becoming involved in an accident.

Quimby and Watts (1981) conducted an experiment with sixty drivers in which they measured a wide variety of driver abilities on the road and in the laboratory. In the laboratory the measures included static visual acuity, field dependence (using the

embedded figures test), risk assessment and hazard perception (also measured when driving), simple and 4-choice reaction time, and physiological measures of stress (heart rate increase and galvanic skin response). Measures of driving behaviour were the number of errors recorded by an observer on a test drive and the speed-related "safety index" adopted by the driver at a number of road locations with restricted forward visibility (defined as visibility distance minus calculated stopping distance). Biographical information, including mileage and accident involvement during the previous two and three year periods, was also collected.

It was found that risk assessment and hazard perception skills, as well as actual risk-taking behaviour (average safety index) were significantly correlated with past accident rate in the expected directions.

The most important age-related result was that the youngest and oldest groups of drivers set the smallest average safety index when driving and took longer to respond to hazards in the laboratory than the intermediate age groups. Reaction times increased with age, but not enough to explain the increase in response time to hazards. Variability of risk assessment was lowest for the youngest group and greatest for 45-54 year olds, a finding which is probably related to the fact that the youngest and oldest groups exhibited the smallest increase in heart rate while performing this task.

Quimby (1983), describing the same experiment, reported that reaction time to perceive hazards and the number of hazards

responded to (in the laboratory) were significantly related to number of driving errors recorded during the test drive. He concluded that the hazard perception test offers an objective measure of perceptual skills important in driving, although the level of its predictive power requires improvement.

Quimby, Maycock, Carter, Dixon and Wall (1984) analysed the visual and perceptual abilities of 370 accident involved drivers in relation to their accident experience. The accidents were classified in terms of contributory factors in great detail, and those possibly involving a visual or perceptual factor were identified, as were those in which the driver was judged as having been to blame. Abilities measured included some of the most promising from previous studies, together with additional tests of vision in difficult conditions, psychological tests of basic cognitive processing abilities and the hazard perception test (Quimby and Watts, 1981).

People who perceived and responded to hazards quickly, and those with a high variability of perceived risk (the most discriminating) had better accident records. However, there was little evidence for links between a particular visual or perceptual ability and specific factors identified in the accident.

Ability to correctly detect the direction of travel of targets as they approached or receded was measured by a "movement in depth" test, and this ability was strongly related to accident record. It combines visual ability, reaction time and willingness to risk an error. Subjects taking longer to decide which way the

target was moving were those with lower accident rates.

Visual performance with both static and moving targets differed significantly according to whether drivers had not reported any accidents in the previous three years or had reported at least two. People who reacted quickly in tests requiring fast responses had the poorer accident history. Since age is related both to reaction time and to accident rate, the causal factors underlying these results are no doubt complex.

Thus, variables having an element of reaction time, or speed of responding, appeared to be the most highly correlated with accident history. When risk of error could be traded for faster responses, the results suggested that perhaps the people who in the laboratory were more inclined to respond fast and accept the increased risk of error may tend to behave similarly when driving.

There are several earlier studies whose findings parallel and support the above findings concerning the perception and style of response to hazards. Spicer (1974) devised a film showing several brief segments representing a variety of traffic situations; after each segment, subjects selected from a checklist whatever features they had noticed that were of importance to them. Drivers aged 15-17 years who had been involved in accidents were less accurate in perceiving the essential features than were accident-free drivers.

Using a model car simulation with accident repeaters and non-repeaters matched on age and mileage, Currie (1969) measured

subjects' speed in perceiving potential collisions, measured by quickness in braking. The two groups did not differ in response time but the accident non-repeaters perceived the danger sooner.

Hakkinen (1958) studied the performance of 44 Helsinki tram drivers and 52 bus drivers classified by accident experience. In one test the subject turned a wheel to keep a pointer on a "road" on a moving belt, while simultaneously responding by hand and foot levers to erratic signals. In another test the subject watched a kind of moving highway map and was told to respond whenever two highways actually joined but not when they nearly joined or simply bridged one another.

In a large factor analysis the highest accident loading appeared on a factor which Hakkinen called "attention", determined primarily by correct responses and absence of errors on the two tests above, indicating "correct motor responding within a specified time to a suddenly occurring signal". Next highest accident loading was on a factor of "involuntary control of motor functions", with poor control indicative of "hastiness, susceptibility to disturbances and motor restlessness".

Adams (1968) took a different approach to studying the perception of hazard, using a stimulus accretion technique with static targets. Starting from a partially visible coloured photo of a traffic situation, more of the photo was gradually revealed until the subjects said they had sufficient. It was found that low accident rate subjects accumulated more information before identifying the hazard. In contrast with Spicer's finding there was no correlation between accident record and number of hazards

correctly identified.

Supporting Adam's finding, is one reported by Rackoff (1974; in Jones, 1978) in which the information-seeking behaviour of young drivers was compared with that of older ones, using a vision-occlusion device which subjects manipulated to view the road ahead only when they felt it necessary. It was found that older subjects had slower search times and also longer "open" times than younger ones.

Pelz and Krupat (1974) related what they termed the "caution profile" of young drivers to their accident record. Subjects watched a movie film and continuously adjusted a handle to register their level of safety/danger as it varied over time; specifically, they were asked to show "How safe or unsafe you feel as the driver".

Non-accident drivers retained the highest level of caution during baseline periods between hazards, and responded early to each hazard. Level of caution both rose and declined gradually. They remained "on guard" the longest. Those with one or more accidents but no violations were intermediate in their baseline level of caution, and somewhat slow in responding to a hazard. Once they noticed it, they responded sharply, then relaxed quickly. Drivers with violations, some of whom also had accidents, were most relaxed during baseline conditions but responded sharply on appearance of a hazard. Their maximum level was lower and it fell quickly when the hazard had passed.

It is evident from the above experiments that "unsafe"

drivers are characterized by two factors: late detection of hazard, and abrupt response. A result reported by Engel, Paskaruk and Green (1979) is in a similar vein. In performance of a self-paced laboratory tracking task, there was a tendency for young drivers to perform the task at high speed with very fast reactions and poor precision. Older, more experienced drivers took longer, with slower reactions and better precision, while professional drivers of similar age were similar in general performance speed but had faster reactions (only slightly slower than the young drivers) and the greatest precision.

These findings might be described as relating to style of response. Perceptual style, referring especially to the way in which people distinguish relevant from irrelevant stimuli, has also been shown to be related to accident risk. People who have most difficulty in extracting the salient information from a complex background, for example detecting a figure embedded in a camouflaging background, are referred to as field dependent. Field dependence has been found to be correlated with accident involvement (e.g.Harano, 1970; Mihal and Barrett, 1976). According to Barrett and Thornton (1968) there is evidence that field independence increases with age up to about 21 years, and that alcohol decreases it. Both these trends are consistent with trends in accident data.

McKenna (1982) suggested two alternative hypotheses to explain the relationship between field dependence and accidents. The ability to extract information from a complex background might be correlated with accidents in a fairly direct way. Loo (1978), for example, found that field dependent people (as

measured by the Embedded Figures Test) take longer to respond to traffic signs viewed in their natural setting. Alternatively, Goodenough (1976) has characterized field-dependents as processing information in a passive way while field-independents process it more actively. Possibly the active processors use information which the more passive do not. Field independents might thus anticipate the road situation to a greater degree, and prepare to respond accordingly.

Olson (1974) found results consistent with the latter hypothesis in an experimental investigation of platoon car-following behaviour. A three car platoon was used with the lead car accelerating and decelerating and the subject in the third car. The lead car was either visible to the subject or screened off. Field dependent drivers appeared to take little advantage of the presence of the lead car and responded little differently whether it was visible or not. It seemed that this group was less actively involved in using the available information to predict what was going to happen.

Further supportive evidence was cited by McKenna (Quimby, personal communication) to the effect that field-independent drivers detected more road hazards than field dependents, suggesting a more active involvement by the former in predicting the road situation. Also consistent with the view of field-independents as being more perceptually active is evidence from Boersma, Muir, Wilton and Barham (1969) concerning the eye movements of field-dependent and field-independent subjects. Eye movements were recorded as they searched for figures embedded in camouflaging backgrounds (a test for field dependency).

Field-independent subjects made more shifts between target and alternatives than did field dependent subjects.

Evidence of the relationship between perceptual style and accident risk is not confined to visual perception. Gopher and Kahneman (1971) found that performance on a complex selective attention task was correlated with pilots' training performance and discriminated between those flying slow transport aircraft and those flying high-performance jets. Later Kahneman et al (1973) found that performance on the task was also correlated with the road accident involvement of bus drivers. Mihal and Barrett (1976) found that measures of selective auditory attention and of complex reaction time were significantly related to accident involvement for 75 commercial drivers. Attentional selectivity appears to be the general factor of importance in all these studies, and perhaps also the speed at which people switch attention between stimuli.

Jones (1978) developed a laboratory task as a possible means of predicting drivers' perceptual skills. Two colour slides of driving scenes were presented simultaneously, one directly in front of the subject and one behind, the latter visible by means of a standard rear vision mirror set at an angle of 40 degrees, necessitating a shift in fixation. The task was to say whether the two views matched, in the sense that they represented the same road, location, and conditions. There were 50 pairs, 25 of which matched and 25 which did not. Each pair was shown for 1 sec with a 4 sec interval for a verbal "same/different" response. The scoring method made use of signal detection theory: d' (a measure of discrimination) and beta (related to criterion level or

motivation). There were significant differences between the drivers of varying age and experience. Order from best to worst was experienced drivers, novice drivers, non-drivers.

Most of the results described in this section can be summarized in terms of the perceptual and response characteristics of "unsafe" drivers.

Such drivers typically take longer to identify salient information such as a possible hazard within its context; they more often miss seeing a hazard at all, and assess level of risk within a narrower range, presumably because they are less able to discriminate differences. Underlying these characteristics may be a tendency to process information less actively: displaying fewer changes in visual fixations, poorer ability to switch attention between different sources, and using less of the available information in reaching a decision.

The response style of such drivers is fast and abrupt. They apparently reach decisions on the basis of less information and respond quickly and inaccurately.

4.4 SUMMARY

Overall, available evidence suggests that errors in driver behaviour leading to accidents are fairly equally distributed over perceptual and response error categories. In terms of the observable aspects of perceptual behaviour, there is evidence that "unsafe" drivers, typically the young and inexperienced, have a less efficient visual scanning strategy than other drivers, display longer fixations, do not look as far ahead, and make less use of peripheral vision. They make less use of the rear view mirror, and use it at less appropriate times.

They are more likely to miss seeing hazards, particularly the more distant ones, and tend to take longer to notice them. They pay attention to non-moving hazards, often at the expense of more important moving hazards associated with the changing traffic situation. They are less able to integrate various sources of hazard, or risk, into an overall assessment. They assess level of risk within a narrower range, presumably because they are less able to discriminate differences. Underlying these characteristics may be a tendency to process information less actively: displaying fewer changes in visual fixations, poorer ability to switch attention between different sources, and using less of the available information in reaching a decision.

In vehicle control skills, also, there is clear evidence of differences between drivers associated with different levels of driving experience. They may be differentiated by their different patterns of control activity and, more clearly, by the more

accurate and faster performance by experienced drivers of slow-speed vehicle manoeuvres such as reversing and parking

Experienced drivers with good accident records are generally smoother in their manoeuvring, with lower maximum values of longitudinal or lateral acceleration forces. They are able to track along a line with smaller and less variable lateral error, and can bring their vehicle to rest at a designated line, or negotiate a path through narrow gaps, more accurately. In contrast, less experienced drivers or those with a poorer accident record have a fast and abrupt response style. They apparently reach decisions on the basis of less information and respond quickly and inaccurately.

There is conflicting evidence on the relationship between the development of perceptual skill, vehicle control skill, perceived risk and speed. Inexperienced drivers involved in accidents are more likely to have been travelling at excessive speed than more experienced, accident-involved drivers. However, it appears that vehicle control develops more quickly than perceptual aspects of driving skill. As drivers perceive their control skill increasing, their confidence increases and they increase their speed accordingly, without making due allowance for their relatively undeveloped perceptual and cognitive skills. Such drivers are most typically young males with relatively poor cognitive skills. They see speeding as less risky than do "better" drivers, and tend to over-estimate their own control skills. The highest risk-takers tend to be those who perceive the risk as least.

Thus, inexperienced drivers appear to be poor in perceptual and cognitive aspects of driving skill as well as displaying poor vehicle control. These characteristics probably result in such drivers frequently driving in a "risky" fashion independent of other contributory factors such as a possible tendency deliberately to accept higher risk in some situations.

5. LICENCE TESTS

An OECD report (1976) compared existing driver training and licence testing systems for 14 countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Japan, the Netherlands, Portugal, Spain, Sweden, the United Kingdom and the United States. All countries required an on-road driving test, for a period ranging from 10 to 40 minutes. The test always required demonstration of adequate skill in car control and the performance of basic manoeuvres, as well as knowledge of road rules. Belgium, Japan and Spain always included off-road testing of vehicle control skills, and in Germany and the U.S. off-road tests "sometimes" occurred. Itemised score sheets were relatively little used.

From a postal questionnaire survey conducted as part of the present research, it appears that since 1976 there has been an increase in the number of jurisdictions using itemised score sheets. Certainly this is the case in Australia. However, as the original OECD report pointed out, use of a score sheet does not necessarily imply that an objective procedure has been adopted. Often it is just a means of recording subjective impressions during the drive, rather than a marking system based on an experimentally-based scale of values. The report noted "huge variation" in the scoring systems being used and this situation has not changed.

As part of the process of developing a new licence test Vanosdall et al. (1977) investigated the decision-making

processes of licence testers using the existing system in which drivers' behaviour is subjectively rated as either a pass or a fail. For some testers, the basis for the decision to fail an applicant seemed intuitive and difficult to verbalize. The decision seemed to be based on a "gut-feeling" associated with the perceived risk. Sometimes this appeared to be strongly influenced by vehicle-handling skill. Other testers were more influenced by "risky" actions that made them afraid of an accident. In contrast to these intuitive examiners, others used a legalistic framework. To them, behavior at stop signs, yield signs, etc., was important, and minor right of way violations, observance of speed limits, turning from the wrong lane, straddling lane lines, etc., were noted. All testers expressed the strong opinion that vehicle-handling skill should be specifically tested.

5.1 "NEW-GENERATION" TESTS

The new test developed by Vanosdall et al. (1977) was based on the Michigan Driver Performance Measure (Forbes et al. 1975), a test which is intended to measure drivers' perceptual and cognitive behaviour and the way in which they interact with traffic, rather than their vehicle control skill. It is typical of recently developed tests in that it requires the use of a carefully pre-planned route. At various locations along the route particular aspects of driver behaviour (search, speed and direction) are assessed according to detailed criteria specific to that location. Each "behaviour pattern" has to be assessed by the tester as being suitable or unsuitable, the judgement of "suitability" being based on estimated effects of the behaviour

on probability of accident occurrence and/or impedance of other vehicles. Given appropriate training of testing officers such a test produces reliable results: that is, similar driving behaviour tends to be rated by different testers in a similar way.

The concentration of the Michigan test on perceptual and cognitive aspects of driver behaviour at the expense of vehicle control skill is based on the assumption that such "higher order" skills are more relevant to the avoidance of hazard. Thus, Forbes et al. reported that during the test's development "It was soon very clear that when and where braking and speed changes were used in relation to traffic conditions was more important than "smooth braking", "smooth steering" or other behaviors often used in check lists."

However, literature reviewed in the present report, while confirming the importance of perceptual and cognitive skills, gives no support to the view that vehicle control skills are less important, particularly in the case of inexperienced drivers who constitute the majority of licence test applicants. Furthermore, data from four separate studies carried out during development of the Michigan test were subjected to six analyses of variance with amount of prior driving experience of the subjects as a factor. The effects of experience were significant in only one of these analyses, and then the result was that inexperienced drivers scored better than experienced. Clearly there is reason to doubt the test's validity as a measure of safe driving ability.

Engel, Paskaruk and Green (1979), also developed a test

based on the Michigan Driver Performance Measure. It consisted of a check list of 41 manoeuvres including various kinds of turns at intersections, cruising under varying conditions, lane changes, merging, passing, starting, stopping, reversing, parking on a hill, parallel parking and three-point turn. Each time a particular manoeuvre occurred it was scored as satisfactory or unsatisfactory relative to the three dimensions of search, speed and direction, as defined in the Michigan test. Routes were designed to include a representative assortment of manoeuvres, but unlike the test developed by Vanosdall et al., scoring criteria were not specific to particular sites. Also different was the inclusion of several "vehicle-control" manoeuvres.

To evaluate the test in a field experiment, two groups of drivers, professional and novice, were used. Professionals were defined as those whose daily fulltime job was driving in normal traffic under the discipline and supervision of a safety conscious fleet management.

Score on the test was the sum of the number of manoeuvres marked satisfactory on "Speed", the number of manoeuvres marked satisfactory on "Search" plus one third of the number of manoeuvres marked satisfactory for "Direction". (The Direction score was divided by three because a regression analysis showed that the weights for these scores were consistently about a third of those for Search and Speed. Since there were 41 manoeuvres for each route, the maximum score was 96. Average score for the professionals was 79 and average for the students was 73. Agreement between two examiners scoring the same driver was 0.74. Performance on all types of manoeuvres contributed about equally

to the discrimination between students and professionals. Students were much more variable in their scores than the professionals, especially on search and speed scores.

Engel et al. concluded that "Overall the test has satisfactory criterion validity for a test that depends essentially on observer ratings of a complex performance task. It also has good content validity in the sense that it seems to measure specific behaviors that are relevant to safe driving." These conclusions appear to be justified.

Another test of driver performance to measure the effectiveness of a driver education program was developed by Jones (1978). Hazard detection was seen as central to safety and the driver's visual scanning behaviour was seen as critical to this process, so it was decided to use a "coder", sitting in the back seat, as well as a tester, since it is difficult to observe the driver's visual scanning from the front seat.

The observers rated drivers on aspects of their behaviour such as observation, speed, path (these three being similar to those used in the Michigan test), gap acceptance, mirror use, following, backing, etc. Particular performance variables were rated at specified locations along the route. According to Jones, "Most of the performance variables refer to awareness of hazards, searching for hazards, or response to hazards. It is assumed that car control skills can be tested more adequately on a range than on the public streets, however the minimal level of skill will be tested by such performance variables as path and speed on turns." A certain number of each type of variable were assigned to

specific locations, but provision was made for additional ones to be added to bring the total number of observations to more than 100. Scores on individual variables were grouped to give subscores for categories labelled Car Control, Observing, Judgement and Other.

In an initial experiment the test was administered to five groups of drivers:

novices, aged 15-16 years, who had just finished the driver education course

drivers with 2+ years of experience, 17-21 years old

drivers with 10+ years of experience, 25-35 years old

drivers with 20+ years of experience, 60-69 years old

drivers with 20+ years of experience, 70+ years old.

A second experiment was conducted using only two groups of drivers: novices with either a learner's permit or a newly-acquired licence who had completed a driver education course, and experienced drivers aged between 25 and 45 years with 5+ years and 50,000 miles experience.

In the second experiment average total score was 61% for the novices and 63% for the experienced drivers, in contrast with the first experiment in which the two comparable groups of experienced drivers (aged 17-21 years and 25-35 years) each averaged 73% while a group of novices averaged 65%. In the second experiment Car Control skills were rated equally for the two groups, whereas in the first experiment the novices were much worse and the corresponding experienced drivers were much better. In both experiments the novices were better than experienced

drivers in Judgement and Other categories of behaviour. The most valid of the test's categories appears to be Observation, in which the experienced (but not elderly) drivers were substantially better than the novices in both experiments. However, overall the test's validity is evidently inadequate.

The most thoroughly evaluated of the "new generation" performance tests is that of McPherson and McKnight (1981): the Automobile Driver On-road Performance Test (ADOPT). Like other recent tests it assesses specific behaviours at designated locations, each being scored as either satisfactory or not. The total score is calculated by dividing the number of satisfactory scores by the total number of behaviours scored. Behaviours are grouped into two basic categories: skills (vehicle control, vehicle manoeuvring, interaction with highway traffic hazards) and practices (driver/vehicle readiness, interacting with environment). In fact, when the actual behaviours within each of these categories are inspected, it appears that the distinction is somewhat arbitrary. For example, gap selection and keeping within the lane are included as "skills", whereas following distance and maintaining an appropriate speed are termed "practices".

The ADOPT is unique among licence tests in that its validity was evaluated both in terms of the capacity of individual behavioural measures to discriminate drivers belonging to criterion groups (experienced and novice drivers) and in terms of the correlation between test behaviour and behaviour under "real world" driving conditions when drivers were unaware of being observed (they were filmed by an observer in a following vehicle

when they left the testing station).

The validity of each of an initially selected set of behavioural measures was first experimentally determined in term of its capacity to discriminate experienced and novice drivers. Results of this experiment were described in Section 4.2 above. In view both of the results of the experiment and literature on the nature of safety-related driver behaviours, decisions were made to eliminate some of the measures from the test battery.

The remaining set of measures, forming the ADOPT, was pilot tested to assess its reliability and validity in terms of real world behaviour. It was then modified, and the revised version field tested again, together with some additional off-road measures of vehicle-control skills. Field testing was carried ou using real licence test applicants as subjects, so it was possible to compare performance on the ADOPT with that on the then standard Oklahoma licence test which was administered concurrently by normal licence testers. The field testing result are described below.

Results of the pilot field test showed significant correlations between test behaviours in the Skill category and both skill and practice behaviour in real-world driving. This supported the view that people drive in a test in a similar way to normal, and that test measures are predictors of skill-mediated driving behavior. However, the ADOPT measures of safe driving practice (as opposed to skill) were not related to any aspect of real world driving behavior, supporting the hypothesis that use of safe driving practices in a test situatio

is not representative of normal driving behavior.

Thus, it was concluded from the pilot study that the skill component of the ADOPT appeared to have some validity in predicting real world performance. Measures of safe driving practice, although reliable, did not appear related to any aspect of real world driving performance.

The test was revised in the light of the pilot study results and field tested again. The following off-street skill tests were added: serpentine, T-exercise, head-in parking, barricade manoeuvre, back-in parking, and backing out. Some people were also given the standard Oklahoma test.

There were moderately strong correlations between ADOPT scores and scores on the off-road skill tests. The Oklahoma test, on the other hand, was unrelated to the off-road test. These results indicated that the ADOPT reflected drivers' level of vehicle-control skill but the standard Oklahoma test did not.

The Practices subtest of ADOPT correlated with the off-road skills test almost as strongly as did the Skills subtest. This lends some support to the view expressed earlier that the distinction between Skills and Practices is rather arbitrary. McPherson and McKnight (1981) appear to have underestimated the importance of perceptual and/or cognitive skills in behaviour such as "following distance" or "intersection speed", both of which are categorized as practices rather than skills.

Neither the ADOPT nor Oklahoma test measures were correlated

with real world performance, which is consistent with the view that use of safe operating practices by licence applicants when they are being tested simply bears no relation to their normal behavior. However, the ADOPT provided a valid measure of driving skill as measured both during the initial selection of component measures and independently through an off-street test of automobile driving skill.

Both the skills and practices components of the ADOPT contributed to its validity. Among behaviors in the Skill category such as smoothness of brake application or ability to keep the vehicle within a lane, it is primarily perceptual and manipulative skill that determines how well the behavior is performed. For some of the behaviors in the Practices category the relationship is less direct. Why should drivers who more often signal turns or use their mirrors be more skilful than drivers who don't? The most probable explanation is that drivers who lack skill have all their attention occupied with handling the vehicle, so that they have insufficient spare capacity to employ the safe operating practices that they know are required. More skilful drivers have more attention free to allot to these higher order components of driving skill.

The ADOPT is also highly reliable. Mean scores attained by applicants from different examiners and across different routes were virtually identical. The intercorrelation of scores across examiners exceeded 0.80 and across routes exceeded 0.70. The total measurement reliability, as indicated by the correlation of scores across examiners and routes, exceeded 0.70. A typical State road test, as represented by the Oklahoma licence test,

showed the same high reliability as the ADOPT. However, results on the standard licence test were unrelated to performance on an independent measure of vehicle control skill.

5.2 "NEW-GENERATION" VERSUS "TRADITIONAL" TESTS

What, then, can be concluded concerning the value of recent tests which have been developed to overcome the large element of subjectivity which has been seen as a major flaw in the traditional form of licence test. Tests considered are the Michigan DPM (Forbes et al, 1975), the Michigan licence test (Vanosdall et al. 1977), a Canadian test loosely based on the DPM (Engel et al. 1979), a test developed by Jones (1978) and the ADOPT (McPherson and McKnight, 1981). These tests have in common the use of carefully planned routes along which, at specified locations, particular aspects of behaviour are scored. They all achieve reasonably high reliability. They differ markedly, however, in terms of validity; in fact, only two of the five can justifiably claim to have acceptable validity. These are the Canadian test and the ADOPT.

What advantages might be gained by electing to use one of these two tests instead of a "traditional" test such as those currently in use in Australia and in most other jurisdictions throughout the world?

The present Victorian test, for example, was developed in California and is basically the same as that evaluated by Dreyer (1976). Unfortunately, the evaluation was only in terms of the test's predictive validity. No significant relationship was found

between licence test score and accident/violation record during the subsequent 12 months, but it was argued in the first section of the present report that such a finding is not necessarily a poor reflection on the test. Also unfortunately, the test's reliability was assessed only in terms of correlations between different test items. As Dreyer commented, "If the test is made up of items of differing nature, then this method does not give a true estimate of reliability. ...Test-retest and dual rater coefficients would both give better estimates of reliability of the drive test."

A very much earlier test was that reported by McGlade (1963). According to Jones (1978) McGlade's test is the most widely used. It was initially constructed on the basis of information from a survey of the testing systems used by 46 U.S. States. Information on test items and item weightings was then analysed and rated by a "jury of experts". This process determined the following aspects of the test: selection of items, weight values of items, types of road test areas, minimum length of test and minimum time allotted for test. Analysis of various licence testers' manuals and driver education manuals were the basis for detailed definition of test items and method of scoring. Items were eliminated if they could not be defined precisely and unambiguously.

The test was administered to five groups of drivers:
a. 30 licensed high school students, 17 years old, with classroom driver education but no on-road driving instruction
b. same as (a) but with on-road driving instruction also.
c. 25 accident and violation-free adult drivers, all with more

than 7,500 miles per year for each of last 5 years
d. same as (c) but less than 3 years holding licence and total mileage less than 10,000 miles
e. 18 problem drivers (accidents and violations) whose remedial training had not yet begun.

All drivers (except group e) were aged 17 to 25 years, had no accidents or violations, and 20% of each group were females.

The significance of mean score differences between the subject groups was determined for each of the test items individually, and both total test validity and specific item validity calculated in terms of their capacity to discriminate the effects of on-road driving instruction, driving experience, and accident/violation record. Both inter-rater and test-retest reliability coefficients were determined.

On the basis of the individual item analysis, seven of the original 35 test items were removed from the final form of the test. The mean performance score of group b was higher than that of group a, and that of group c was higher than those of both d and e. The test-retest correlation (tested for group b only) was significant (0.77), and inter-tester correlations, based on the results of two testers simultaneously rating the same subject, were 0.93 and 0.88 for groups b and c respectively. Scores of groups a, b, c and d, singly and in combination, approximated very closely to a normal curve, thus establishing a sound basis for the selection of tentative minimum passing scores.

McGlade concluded, with apparent justification, that the

test provides a satisfactory measure of driving ability. Jones (1978) referred to an unpublished study of her own on the McGlade test in which she found that inter-tester comparisons "showed very pronounced instructor bias". She also criticised the lack of adequate rating criteria, the relatively small number of items rated, and stated that "The validity of this test has not been established." Such a statement is at odds with the evidence discussed above.

What conclusions can be drawn from a comparison of the McGlade test, the current Victorian test (as reported by Dreyer, 1976) the test developed in Canada by Engel et al. (1979) and the ADOPT (McPherson and McKnight, 1981)? The absence of any worthwhile data concerning either the validity or the reliability of the Victorian test must eliminate it from serious consideration at the moment. Still, it is interesting to compare the score sheet of the Victorian test with that of the McGlade test. Superficially they are similar in that neither requires particular aspects of behaviour to be scored at particular locations, and the behavioural items listed for assessment are basically the same ones. However, the scoring systems are very different.

Directions for scoring the McGlade test limit the number of points which can be deducted for any item to the number specified in the "Bad" column; repetition of the same driving error does not result in further points being deducted. The Victorian test, on the other hand, permits an unlimited number of points to be deducted on any item, which gives much greater scope for the expression of tester bias related to the relative importance of

the various types of error.

Item weightings in the McGlade test were arrived at on the basis of detailed investigation and discussion by "experts" concerning the relative importance to road safety of the various test items. In itself this is no guarantee of validity but it does make the achievement of reliability more likely. The Victorian test items are also weighted, although the basis for the weightings is unknown. Ideally, they should be related to the associated accident risks. In any case, it seems unwarranted to nullify such a weighting system by permitting individual testers to score particular items as many times as they wish. It is difficult to imagine that such an open-ended scoring system could produce satisfactory levels of either reliability or validity.

What are the relative merits of the remaining three tests (described by McGlade, 1963; Engel et al., 1979, and McPherson and McKnight, 1981), all of which have reasonable grounds for claiming both reliability and validity? Detailed comparison of them is not possible because of the very different ways in which they were developed and evaluated. In spite of the differences in scoring methods the behaviours being scored are much the same in all three, indicating a similar degree of content validity. All place considerable emphasis on both the perceptual and the response aspects of driving behaviour. It could be argued that the ADOPT is the strongest contender purely on the basis of the thorough and extensive nature of its development and validation process. Or it might be argued that the McGlade test, given its apparent validity and reliability, should be chosen on the grounds of greater simplicity of implementation. However, if the

best decision is to be made all three should be evaluated experimentally in terms of the same criteria under comparable conditions.

5.3 DIRECTIONS FOR THE FUTURE

In the previous section on the nature of unsafe driving behaviour, it was established that response errors, particularly excessive speed, are characteristic of accidents involving young drivers (who form the majority of licence applicants). Furthermore, such inexperienced drivers display much less "smooth" vehicle control and are both slower and less accurate in low-speed manoeuvres such as parallel parking, driving through narrow gaps, and reversing along a curving path. The three tests which have emerged from the literature review as satisfactory all include the measurement of some such vehicle-handling manoeuvres, although evidence reviewed earlier suggests that the precise nature of the test items could probably be improved. Vehicle-control skill is the most straightforward aspect of driver behaviour to measure.

It is most unlikely, however, that drivers prone to excessive speed under some normal driving conditions would display such behaviour under test conditions. In the terminology of the ADOPT, speed itself is a "practice" rather than a "skill", and as such is unlikely to be predicted by test performance.

Evidence was also presented that less competent drivers are measurably different in terms of their perceptual and cognitive skills. They display a less efficient visual scanning strategy,

making less use of peripheral vision, take longer to notice possible hazards and are more likely to miss some altogether. They use their rear vision mirrors less, make less use of available information in general, and tend to reach decisions too quickly on the basis of insufficient information. Furthermore, the highest risk-takers tend to be those who perceive the risk as least.

It is difficult or impossible to measure such aspects of driving behaviour during an on-road licence test, although tests such as that developed by Vanosdall et al. (1977), Jones (1978) and Engel et al. (1979) attempted to do so. The only licence tests shown to have any validity are those incorporating a significant proportion of items measuring vehicle control skills, so the contribution of more "perceptual" items to a test's validity is doubtful. Nevertheless, in view of the importance of such skills to safe driving, and the role of the licence test in setting a performance standard which must inevitably influence the content of driver training programs, the inclusion of appropriate perceptual and cognitive items in the test is justified to ensure its content validity.

Consideration should be given, however, to the possibility of testing competence in these aspects of driving skill in the testing office rather than in a vehicle. Testing perceptual skills such as hazard perception under the more controlled conditions possible with a standard series of slides or film has been shown to be a valid means of discriminating "good" from "bad" drivers. Discussing road tests of driver performance, an OECD report (1980) acknowledged that, "for reasons of

standardization, test duration, accident risks, observational difficulties, etc., only a restricted set of relevant traffic situations and rather common and usually risk-free situations may be included in the test situation. Since this limits the capacity of the test to measure the full range of safety-related behaviours, such as perception of and response to various hazardous situations, some supplementary forms of test should be considered." The report suggested that slides or film segments of traffic situations might be used to assess hazard perception, knowledge of defensive driving techniques, etc.

From the literature reviewed previously it is clear that the development of such a test, or battery of tests, is feasible but would require a substantial research investment; it would be necessary to establish several parallel forms of test. The major benefit of such an innovation may well lie in increasing young drivers' awareness of the importance of perceptual and cognitive elements in driving skill, since there is some evidence that young males in particular tend to lack such awareness. The potential benefit would be much greater if training programs were to be developed in conjunction with the test. Saffron (1981) took a somewhat more conservative view, arguing that no such change in a licence test should be introduced without first having evidence of an effective training program which the new test element would serve to promote.

In this context it is relevant that "the driver training programs most likely to be effective are those which emphasize the perceptual and cognitive aspects of driving skill" (Macdonald, 1985). For example, Schuster (1978) compared

randomly-assigned experimental and control groups in terms of accident record for each of the three years following completion of a "cognitive accident-avoidance training program". In the first year of driving the controls were involved in four times as many accidents; in the subsequent two years there was no significant difference between the two groups. On this basis the training course was highly cost-effective.

One possibility would be to introduce such testing within a graduated licensing system. Graduated systems of varying degrees of complexity have frequently been proposed and are apparently gaining community acceptance as they are increasingly implemented. The introduction of additional testing at a later stage in the driver's learning process would encourage further driver training. Evidence of the potential value of such a process was presented by McKnight (1983).

In discussing the complex and hierarchical nature of driving skills, McKnight (1983) asserted that during the early stages of development of driving skill the driver's capacity is largely occupied in coping with the basic processes of vehicle control; there is little spare capacity available for the development of higher-order skills of less immediate urgency. In view of this, he suggested that the most appropriate time to teach "safe driving strategies" would be at a stage when control skills have been largely mastered. Training in more effective perception, particularly of hazards, might be classed as such a higher order "strategy". As indirect evidence in support of this approach, he reported as follows.

"We ran a three-hour course in fuel-efficient driving for experienced drivers of fleet vehicles in the State of Michigan. (Fuel efficient driving is easier to study than safety, because the ultimate criterion - miles per gallon - is so easily measured.) Two different groups on two separate occasions averaged about a 20% increase in mpg. Yet, when we taught the very same course to driver education students in three different high schools, there was no improvement in either mpg or in the driving behaviors intended to produce it. It wasn't hard to see why. Throughout training and testing, the students were obviously having too much difficulty trying to negotiate the route to be able to cope with the fuel-efficient driving practices we were attempting to teach them."

McKnight suggested that difficulty in motivating people to undergo post-licence instruction was probably the main reason why such an approach has not been applied to date. Incorporating further training into a graduated licensing system would overcome this problem. To warrant such a move the effectiveness of the additional training would have to be clearly established first. There is sufficient evidence to justify an attempt to do so.

6. CONCLUSIONS

The present review has discussed the adequacy of driver licence testing systems in terms of their major objectives, which are to establish that drivers have attained an adequate level of competence and to set an appropriate standard of good driving behaviour. The degree to which a testing system achieves these objectives is difficult to assess, for several reasons. Most importantly, there is a need for more information about the nature of unsafe driving behaviour and the factors which produce it.

In general terms, it is evident that behaviour is determined by the interactions of factors reflecting both driving skill (perception, cognition and vehicle control) and motivation (perceived costs and benefits). Unfortunately, no comprehensive analysis of the acquisition of driving skill has ever been conducted. Such an analysis would be particularly useful in developing and validating licence tests because such tests are normally applied to relatively inexperienced drivers whose skill is still developing. From a variety of evidence on the nature of "unsafe" driver behaviour, especially that of inexperienced drivers, it appears that deficits in perceptual, cognitive and vehicle-control skills, possibly acting in conjunction with motivational factors, are typically associated with "risky" behaviour.

It is clear from much of the research reviewed in Sections 2, 3 and 4 that no test can hope to be valid in the sense that

good performance during the test will predict good subsequent performance under normal driving conditions. Consistent with this, the work of McPherson and McKnight established that the ability of drivers to demonstrate safe operating practices bears no relationship to the probability of their doing so in "the real world". On the other hand, it is clear that a good licence test can measure reasonably well a driver's vehicle control skills, and these are a necessary prerequisite for safe driving. That is, bad performance in the licence test due to inadequately developed vehicle control skill is associated with poor performance in "the real world".

It is doubtful that drivers' perceptual and cognitive skills can be measured effectively by an on-road test, but such skills can and, it has been suggested, should be assessed by other means. It has been demonstrated that testing perceptual skills such as hazard perception by means of a series of slides or film can be a valid means of discriminating "good" from "bad" drivers. The development of such a test would require a substantial research investment, and should proceed concurrently with the development of an associated training program. This approach would serve to increase safety directly, by improving perceptual skill, and indirectly by increasing inexperienced drivers' awareness of the importance of perceptual and cognitive skills and their own inadequacies in this area, leading to improvement of their decision-making performance. Ideally, such a training and testing program would be incorporated into a graduated licensing program at a stage when vehicle control skills had been largely mastered.

Existing on-road tests for which some evaluative data was available were critically discussed, and the most potentially useful identified. These are the ADOPT, developed by McPherson and McKnight (1981), a test loosely based on the Michigan Driver Performance Measure developed by Engel et al (1979) and, surprisingly, a test developed by McGlade (1963) which is reported to be the most commonly used of "traditional" tests. All place considerable emphasis on both the perceptual and the response aspects of driving.

It is evident that a road test is a valid means of assessing vehicle control skills but not perceptual and cognitive skills. Nevertheless, the inclusion of all aspects of driving in a licence test is necessary to ensure content validity, as discussed in Section 2. All three of the above tests have been demonstrated to possess acceptable levels of reliability and criterion validity. It is therefore suggested that experimental work be conducted to evaluate and compare these three tests in terms of their suitability for adoption in Australia.

References

Adams, J. L. (1986). Measurement of hazard judgement by a stimulus accretion technique. Columbia University Teachers College, New York.

Allen, R.W., & Weir, D.H. (1984). Analysis of man-in-the-loop performance measurement technology for crash avoidance research. National Highway Traffic Safety Administration, Washington, D.C.

Attwood, D.A. (1979). "The effects of driving experience on objective measures of driving performance". 23rd Annual Meeting, The Human Factors Society, Boston.

Barrett, G.V., & Thornton, C.L. (1968). "Relationship between perceptual style and driver reaction to an emergency situation". Journal of Applied Psychology, 52, 2, 169-176.

Barry, P.F., Roper, R.B., & Pitts, L. (1974). An analysis of critical manoeuvres in the accidents of young drivers. Highway Safety Research Centre, University of North Carolina, Chapel Hill.

Bartlett, F.J. (1958). Thinking, an experimental and social study. Basic Books, Inc., New York.

Bathurst, J.R. (1980). Accident avoidance skill training. National Highway Traffic Safety Administration, Washington, D.C.

Benda, H.V., & Hoyos, C.G. (1983). "Estimating hazards in traffic situations". Accid. Anal. and Prev., 15, 1, 1-9.

Bichl, B., Fischer, G.H., Hacker, H., Klebelsberg, D., & Seydel, V. (1975). "A comparison of the factor loading matrices of two driver behaviour investigations". Accid. Anal. and Prev., 7, 161-178.

Boersma, F.J., Muir, W., Wilton, K., & Barham, R. (1969). "Eye movements during embedded figure tasks". Perceptual and Motor Skills, 28, 271-174.

Bragg, B.W.E., & Finn, P. (1982). Young driver risk-taking research: technical report of experimental study. ABT Associates, Inc., Cambridge, Massachusetts.

Bristow, J., Kirwan, B., & Taylor, D.H. (1982). "Cognition and affect in measures of driving style". Ergonomics, 25, 10, 935-940.

Brown, I.D., (1982). "Exposure and experience are a confounded nuisance in research on driver behaviour". Accid. Anal. and Prev., 14, 5, 345-352.

Campbell, B. (1958). "A comparison of the driving records of 1,100 operators involved in fatal accidents and 1,100 operators selected at random". Traffic Safety Research Review, 2, 2-7.

Clayton, A.B. (1972). "An accident-based analysis of road-user errors". Journal of Safety Research, 4, 2, 69-74.

Colbourn, C.J. (1978). "Perceived risk as a determinant of driver behaviour". Accid. Anal. & Prev., 10, 131-141.

Coppin, R.S. (1977). Driver licence and driver improvement programs, a national review. Australian Dept. of Transport.

Council, F.M., & Allen, J.A., Jr. (1972). Driver licence road testing - final report. Highway Safety Research Centre, University of North Carolina, Chapel Hill.

Currie, L. (1969). "The perception of danger in a simulated driving task." Ergonomics, 12, 841-849.

Dreyer, D.R. (1976). An evaluation of California's drivers licensing examination. California Department of Motor Vehicles, Research Report 51.

Engel, R., Paskaruk, S., & Green, N. (1979). Driver education evaluation tests. Department of Transport, Ottawa.

Evans, L. (1985). Risk homeostasis theory and traffic accident data. General Motors Research Laboratories, Warren, Michigan.

Evans, L., & Wasielewski, P,. (1983). "Risky driving related to driver and vehicle characteristics". Accid. Anal. and Prev., 15, 121-136.

Fazakerley, J.A., & Downing, A.J. (1980). A comparison of two methods of driver testing. TRRL Report LR931, Crowthorne, U.K.

Firth, D.E. (1982). "Pedestrian behaviour" in Chapman, A.J., Wade, F.M., and Foot, H.C. (ed.). Pedestrian Behaviour (John Wiley and Sons Ltd).

Fishburn, P.C. (1968). "Utility theory". Management Science, 14, 335-378.

Forbes, T.W., Nolan, R.O., Shmidt, F.L., & Vanosdall, F.E. (1975). "Driver performance measurement based on dynamic driver behaviour patterns in rural, urban, suburban and freeway traffic". Accid. Anal. & Prev., 7, 257-280.

Ganton, N., & Wilde, G.J.S. (1971). Verbal ratings of estimated danger by drivers and passengers as a function of driving experience. In "Studies of Safety in Transport". Queens University, Kingston, Ontario.

Gibson, J.J., & Crooks, L.E. (1938). "A theoretical field - analysis of automobile driving". Am. Jour. Psychol., 2,3.

Goldstein, L. (1961). Research on human variables in safe motor vehicle operation: a correlational summary of predictor variables and criterion measures. George Washington University, Washington, D.C.

Goodenough, D.R. (1976). "The role of individual differences in field dependence as a factor in learning and memory". Psychol. Bulletin, 83, 675-694.

Gopher, D., & Kahneman, D. (1971). "Individual differences in attention and the prediction of flight criteria". Perceptual and Motor Skills, 33, 1335-1342.

Greenshields, B.D., & Platt, F.N. (1967). "Development of a method of predicting high-accident and high-violation drivers". J. Appl. Psych., 51, 3, 205-210.

Hagen, R.E. (1975). "Sex differences in driving performance". Human Factors, 17, 2, 165-171.

Hakkinen, S. (1958). Traffic accidents and driver characteristics. Finland's Institute of Technology, Scientific Researches No. 13, Helsinki.

Harans, R.M. (1970). "Relationship of field dependence and motor-vehicle-accident involvement". Perceptual and Motor Skills, 31, 272-274.

Harrington, D. (1972). "The young driver follow-up study". Accid. Anal. and Prev., 4, 191-240.

Hodgdon, J.D., Bragg, B.W.E., & Finn, P. (1981). Young driver risk-taking research: the state of the art. National Highway Traffic Safety Administration, Washington, D.C.

Hoinville, G., Berthoud, R., & Mackie, A.M. (1972). A study of accident rates amongst motorists who passed or failed an advanced driving test. TRRL Report LR 499, Crowthorne, U.K.

Johnston, I.R., & Perry, D.R. (1980). Driver behaviour research - needs and priorities. Aust. Rd. Res. Bd. Res. Report ARR 108.

Jones, M.H. (1973). California driver training evaluation study - final report. University of California, Los Angeles.

Jones, M.H., (1978). Driver performance measures for the safe performance curriculum. National Highway Traffic Safety Administration, Washington, D.C.

Kaestner, N. (1964). A study of licensed drivers in Oregon: Part II - analysis of traffic involvement records. Oregon Department of Motor Vehicles, Salem.

Kahneman, D., Ben-ishai, R., & Lotan, M. (1973). "Relation of a test of attention to road accidents". Jour. of Applied Psychol., 58, 1, 113-115.

Knapper, C.K. (1983). Explaining young adults' involvement in road accidents: an overview of research. In young driver accidents: in search of solutions (Mayhew, D.R., et al., eds). Traffic Injury Research Foundation of Canada, 19-34.

Konecni, V.J., Ebbesen, E.B., & Konecni, D.K. (1976). "Decision processes and risk taking in traffic: driver response to the onset of yellow light". Journal of Appl. Psych., 61, 359-367.

Lauer, A.R. (1960). The psychology of driving. Thomas, Springfield.

Lohman, L.S., Leggett, E.C., Stewart, J.R., & Campbell, B.V. (1976). Identification of unsafe driving actions and related countermeasures. U.S. Department of Transportaton, Report No. DOT-HS-5-01259.

Loo, R. (1978). Individual differences and the perception of traffic signs. Human Factors 20, 65-74.

Macdonald, W.A. (1979). The measurement of driving task demand. Ph.D. Thesis, University of Melbourne.

Macdonald, W.A., & Hoffmann, E.R. (1980). "A review of the relationship between steering wheel reversal rate and driving task demand". Human Factors, 22, 6, 733-739.

McGlade, F. (1963). "Testing driving performance - developmental and validation techniques". Highway Research News, 5, 13-22.

McKenna, F.P. (1982). "The human factor in driving accidents: an overview of approaches and problems". Ergonomics, 25, 10, 867-877.

McKnight, A. J., & Adams, B.B. (1970). Driver education task analysis. Volume II: Task analysis methods. National Highway Traffic Safety Administration, Washington D.C.

McPherson, K., & McKnight, A.J. (1981). Automobile driver on-road performance test. Volume 1 - Final Report. National Highway Traffic Safety Administration, Washington, D.C.

McRae, D.J. (1968). The relation of licensing test scores to subsequent driver performance. The L.L. Thurstone Psychometric Laboratory, University of North Carolina.

Mihal, W.L, & Barnett, G.V. (1976). "Individual differences in perceptual information processing and their relation to automobile accident involvement". Journal of Applied Psychology, 61, 2, 229-233.

OECD (1975). Young driver accidents: a report prepared by an OECD research group, Paris.

OECD (1976). "Driver instruction". A report prepared by an OECD Road Research Group.

OECD (1980). Guidelines for driver instruction.

Olson, P.L., (1974). "Aspects of driving performance as a function of field dependence". Journal of Applied Psychology, 59, 2, 192-196.

Parker, P.M. (1973). Driving behaviour during the first three years after passing the driving test. TRRL Technical Note No. 750, Crowthorne, U.K.

Pelz, D.C. & Kupat, E. (1974). "Caution profile and driving record of undergraduate males". Accid. Anal. & Prev., 6, 1, 45-58.

Quenault, S.W. (1967). Driver behaviour - safe and unsafe drivers. RRL Report LR 70, Crowthorne, U.K.

Quenault, S.W. (1968b). Driver behaviour - safe and unsafe drivers - part II. RRL Report LR 146, Crowthorne, U.K.

Quenault, S.W. (1968a). Development of the method of systematic observation of driver behaviour. RRL Report LR 213, Crowthorne, U.K.

Quenault, S.W., & Parker, P.M. (1973). Driver behaviour - newly qualified drivers. TRRL Report LR 567, Crowthorne, U.K.

Quimby, A.R. (1983). Hazard perception in a laboratory test and driving performance on the road. TRRL Working Paper WP (HSF)2, Crowthorne, U.K.

Quimby, A.R., & Watts, G.R. (1981). Human factors and driving performance. TRRL Digest LR 1004, Crowthorne, U.K.

Quimby, A.R., Maycock, G., Carter, I.D., Dixon, R., & Wall, J.G. (1984). Perceptual abilities of accident involved drivers. TRRL Research Report 27, Crowthorne, U.K.

Ratz, M. (1978). "An evaluation of the California drive test in theme and variation". Volumes I and II. California Department of Motor Vehicles, Research Report 62.

Risk A. (1981). "A behavioural theory of driving and accident causation". Road Safety (Praeger Publishers), 219-225.

Saffron, D.G. (1981). Driver and rider education, training and licensing: a brief review. Traffic Authority of New South Wales, TARU Research Report 4/81.

Safren, M., Cohen, S., & Schlesinger, L. (1970). "The Drivometer as a measure of driving skill". Journal of Safety Research, 2, 1, 30-35.

Schlesinger, L.E., & Safren, M.A. (1964). "Perceptual analysis of the driving task". Highway Research Record, 84, 54-61.

Schuster, D.H. (1978). "Cognitive accident-avoidance training for beginning drivers". Journal of Applied Psychology, 63, 3, 377-379.

Shaoul, J. (1975). The use of driving tests as alternative criteria to accidents for evaluating driver education. Road Safety Research Unit, The University of Salford.

Sheppard, D., Henry, J.P., & Mackie, A.M. (1973). Faults in the driving test and their relationship with subsequent accidents. TRRL Technical Note TN 782, Crowthorne, U.K.

Shinar, D., McDonald, S.T., & Treat, J.R. (1978). "The interaction between driver mental and physical conditions and errors causing traffic accidents: an analytical approach". Journal of Safety Research, 10, 1, 16-23.

Sivak, M. (1981). Homicides, non-traffic accidents, and proportion of young drivers predict traffic fatalities. Highway Safety Research Institute, The University of Michigan, UM-HSRI-81-45.

Soliday, S.M., & Allen, J.A. (1972). Hazard perception in automobile drivers: age differences. Highway Safety Research Centre, University of North Carolina.

Spicer, R.A. (1964). Human factors in traffic accidents. United States Public Health Service, Research Grant No. AC-55.

Summers, L.G., & Harris, D.H. (1978). The general deterrence of driving while intoxicated. Volume I: system analysis and computer-based simulation. National Highway Traffic Safety Administration, Washington, D.C.

Treat, J.R., et al. (1977). Tri-level study of the causes of traffic accidents: final report. Institute for Research in Public Safety, Washington, D.C.

Vanosdall, F.E., et al (1977). Michigan road test evaluation study. Phase III. National Highway Traffic Safety Administration, Washington, D.C.

Wallace, J., & Crancer, A. (1969). Licensing examinations and their relation to subsequent driving record. Washington Department of Motor Vehicles, Olympia.

Waller, J.A. & Goo, J.T. (1968). "Accident and violation experience and driving test score". Highway Research Record, 225, 1-8.

Waller, P.F. (1975). "Education for driving: an exercise in self-delusion?" Driver Research, Colloquicum, Highway Safety Research Institute, The University of Michigan, Ann Arbor, June 4-5.

Waller, P.F., Li, L.K., Hall, R.G., & Stutts, J.C. (1978). Driver performance tests: their role and potential. National Highway Traffic Safety Administration, Washington, D.C.

Wilde, G.J.S. (1976). "Social interaction patterns in driver behaviour. An introductory review". Human Factors, 5, 477-492.

Wilson, W.T., & Anderson, J.M. (1980). "The effects of tyre type on driving speed and presumed risk taking". Ergonomics, 23, 2, 223-235.