DRIVING REASSESSMENT FOLLOWING NEUROLOGICAL DAMAGE: AN INTEGRATED APPROACH

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Dedicated to the memory of
Grandad, with love.

ABSTRACT

The impetus for the present study was a lack of guidelines for evaluating neuropsychologically-impaired drivers, and the need for relevant exploratory research within a New Zealand context. The overall aim was to provide an integrated approach describing the driving performance and behaviour of neuropsychologically-impaired drivers. The researcher anticipated that social and neuropsychological factors could be identified which were related to various measures of practical driving ability, including current New Zealand driving test measures.

The present study involved a quasi-experimental analysis of four subject groups, each comprising ten subjects. Neuropsychologically-impaired subjects comprised two groups: (i) neuropsychologically-impaired presenters who were seeking driving reassessment; and (ii) neuropsychologically-impaired drivers who were driving again following a successful assessment outcome. The other two subject groups comprised: (i) control drivers who were similar for age, gender, and number of years driving experience to the neuropsychologically-impaired presenters, and (ii) professional drivers who provided a criterion for a high standard of driving.

All subjects underwent extensive neuropsychological and driver testing, as well as supplying background sociodemographic and driving-related questionnaire data. Seven neuropsychological tests (Mini Mental State Examination, Benton Visual Retention Test - Revised, Standardised Money Road Map Test, Southern California Figure Ground Test, Stroop Colour Word Test, Trail Making A and B Test, and reaction time) were included on the basis of several criteria. Practical driving measures included the New Road Test, which is the standard test for driver licensing in New Zealand, and the Advanced Driver Assessment, which is used in circumstances where an independent driving evaluation is required. These practical driving measures were complemented by an informal global driver instructor rating, as well as subject's own comparative driver self-ratings.

Questionnaire data gave some practical insight into the effects of neurological damage. Notably, all neuropsychologically-impaired subjects reported some reduction in driving frequency and a change in driving patterns. Post-injury driver self-report ratings for the two neuropsychologically-impaired groups indicated some important perceived differences relating to stages in return to driving. Both the neuropsychologically-impaired groups performed less well on the neuropsychological and practical driving

test measures. Across the neuropsychological tests, slowed response time and a difficulty with complex tasks were characteristic of many neuropsychologically-impaired subject's test performance. In particular, mean scores for the Mini Mental State Examination (Total Score), the Standardised Road Map Test of Direction Sense, and two of the reaction time conditions were significantly lower for neuropsychologically-impaired groups. For the practical driving test measures, type of driving errors made by the neuropsychologically-impaired subjects differed qualitatively from control and professional drivers. However, these differences were not necessarily reflected in overall driving test scores.

Multiple linear regression analyses were performed on composite groups of neuropsychologically-impaired versus neuropsychologically-intact subjects. Of the neuropsychological tests, the Standardised Road Map Test of Direction Sense, and some of the reaction time measures were related to both the practical driving tests. Interestingly, reaction time measures suggested an important differential relationship between neuropsychologically-impaired and neuropsychologically-intact subjects. Here, faster reaction times were associated with fewer driving errors in neuropsychologically-intact subjects. By contrast, slower reaction time for the combined neuropsychologically-impaired subjects was associated with better driving performance.

The present results demonstrated the importance of an integrated approach toward understanding the complexity of the driving process. An important theme to emerge from both qualitative and quantitative data was a relationship between subjects' perceived neurological deficit and the utilisation of compensatory driving strategies. Thus, the questionnaire data, and the driver self-rating scales suggested that the neuropsychologically-impaired subjects had some insight into their neurological deficit. Furthermore, the inverse relationship between some of the reaction time data and practical driving test outcome suggested the neuropsychologically-impaired subjects were compensating their driving, either by driving slower or by allowing a greater margin for error. The integrated approach also provided some insight into the process of return to driving through subject's reports of change, and comparison of retrospective and current driver self-ratings. Here, inclusion of the two neuropsychologically-impaired groups was an important feature of the research design, enabling further insight into different stages of this process.

Overall, the present study provided an entry point for further research, and has practical and safety implications for the reassessment of drivers following neurological damage.

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Chapter One

INTRODUCTION

The ability to drive a car rates highly on lists of everyday activities by most people, but particularly for individuals whose driving has been threatened by disability through acquired neurological damage (Cimolino & Balkovec, 1988; Golper, Rau & Marshall, 1988). For these individuals, driving is a means of maintaining independence and mobility, and has a significant effect on well-being and social adjustment (Legh-Smith, Wade & Hewer, 1986; Jellinek, Torkelson & Harvey, 1982). These issues are recognised in a rehabilitative context, and together with concerns for maintaining adequate levels of road safety, have prompted questions from professional spheres concerning how individuals with neuropsychological impairment should be assessed for driving again.

In practice, candidates for driving reassessment may be evaluated using a range of methods which are not necessarily appropriate (van Zomeren et al., 1987). Within this context, existing driving assessments are typically unstandardised, and may or may not include a practical driving component. Many of the practical driving tests being used were designed to measure skill acquisition in the new driver, and are largely based on simple operation of a motor vehicle. Consequently, some driving tests may be inappropriate for neuropsychologically-impaired drivers, where the focus is on ability to cope with complex interactions within a dynamic driving environment. Many existing assessment schemes also neglect to take account of other driving-related factors such as age, education, previous experience, motivation, and self perceptions of driving ability. These qualitative aspects may be potentially as important as quantitative scores on a driving test.

Within New Zealand there is a lack of guidelines for the assessment of drivers who have sustained neurological damage. Existing policy implies that drivers are effectively 'licenced for life' and no legal mechanism exists to ensure any form of driver reassessment following neurological damage (Jones, Giddons & Croft, 1983). Yet despite concern from a number of professions, there has been virtually no neuropsychologically-impaired driver research conducted within New Zealand. In this country, there are no standard assessment schemes. Clinicians involved in driver reassessment rely largely on overseas findings which may not necessarily be relevant for New Zealand conditions.

New Zealand based research on neuropsychologically-impaired drivers has several advantages within an assessment context. Notably, there is an appreciation for the local driving environment and the availability of resources, as well as an awareness of professional and legal issues in driver testing. In addition, the use of current driver tests set by the Land Transport licencing authority would provide a benchmark for judging a standard of driving which is currently considered appropriate for the wider community.

The impetus for the present research was to conduct an exploratory study that could pave the way for larger downstream driver research studies within New Zealand. It was hoped that such research could provide a valid theoretical and empirical base for the incorporation of specific measures into neuropsychologically-impaired driver assessments. This approach could then facilitate standardisation of current driving assessment practices.

Given the large variety of possible factors which can affect the driving process, the present study considered a wide range of sociodemographic and individual characteristics, together with neuropsychological measures and two driving tests currently utilised within New Zealand. The overall aim was to provide an integrated approach describing the driving performance and behaviour of neuropsychologically-impaired drivers. With this research design, the researcher hoped to identify social or neuropsychological factors which were correlated with practical driving ability, as measured by current New Zealand driving tests. Isolation of significant driver-related factors would provide an important insight, furthering our understanding into social and cognitive aspects of the driving task. Importantly, correlates of practical driving ability would have practical relevance as predictors of driving performance for use in neuropsychologically-impaired driver assessment.

The present research undertook detailed analyses of subjects with acquired neurological damage. These subjects were divided into two groups: those who were presenting for assessment for driving again; and those who had already been assessed and were given formal approval to resume driving again. For comparison, these neuropsychologically-impaired groups were compared with a group of control drivers who were similar for age, gender, and number of years driving experience, and a group of professional drivers who provided a criterion for a high standard of driving.

Several objectives were proposed which encompassed the overall research aim. Thus, the intention was to describe and compare the four driving groups using a range of sociodemographics, driving-related variables, practical driving and neuropsychological assessment measures. The researcher also sought to identify changes and adjustments as a consequence of subject's neurological damage, both through retrospective (pre-injury) and current (post-injury) reports, and comparison with the groups of neuropsychologically-intact subjects. Exploration of the relationships between selected subject variables and neuropsychological test measures to practical driving outcome completed the integrated approach taken by the present study. Finally, it was hoped that theoretical, methodological and practical implications could be drawn from relevant outcomes, thereby suggesting future avenues for neuropsychologically-impaired driver research within New Zealand.

OUTLINE OF THE PRESENT RESEARCH.

Chapters Two through to five provide a comprehensive review of the driver literature, with special reference to neuropsychologically-impaired drivers. **Chapter Two** presents a conceptual overview of existing driver models and theories. Here, the advantages of integrative over non-integrative driving models are described.

Chapters Three, Four and Five review the literature in the three research areas which underlie the integrative approach taken by the present study. **Chapter Three** covers measurement of driving within an assessment context. Here, driving simulation, accident data, practical driving assessment, and self reported measures are discussed. **Chapter Four** reviews the role of personal and driving-related variables in relation to driving performance and driving behaviour. **Chapter Five** reviews the neuropsychologically-impaired driver research in a clinical context. The relationship between neuropsychological assessment methods and driver ability is discussed.

Chapter Six sets the present study in the context of current research covered in the review Chapters. Here, the present integrative approach toward the assessment of neuropsychologically-impaired drivers is justified. **Chapter Seven** sets out the methodology employed in the present study, the driver samples and measures used, together with the analytical procedures applied to the research data.

Chapters Eight, Nine and Ten, present the results and discussion of analyses of the assessment variables compared across samples. **Chapter Eight** describes personal and driver-related variables, including relevant sociodemographics and the nature of subjects' driving experiences. **Chapter Nine** reports the outcome of the practical driving evaluations and the self report driving scales, including relationships between these measures. **Chapter Ten** summarises the neuropsychological assessment measures, namely, a record of time since injury, a symptom checklist, and the results from seven neuropsychological tests. **Chapter Eleven** presents the results and discussion of multiple regression analyses, where selected subject variables and neuropsychological test measures were examined for their ability to predict driving test outcome. **Chapter Twelve** presents an overview of the present findings in terms of the specific research objectives, including theoretical, methodological and practical implications. Suggestions are made for future neuropsychologically-impaired driver assessment research within a New Zealand context.

Chapter Two

DRIVING THEORY

An integrated driving model is central to the present study. Such a model emphasises the holistic nature of the driving process in which driving behaviour is explained by the complex interplay of social, cognitive, and driving-related factors. Consequently, an integrated research approach can incorporate traditional driving models together with qualitative descriptions of driver behaviour, and neuropsychological tests of cognitive function. These research designs are particularly relevant to describing the neuropsychologically-impaired driver, for whom impaired cognitive function may be an important assessment factor. This Chapter provides a conceptual framework for the integrative approach taken by the present study by reviewing existing traditional and integrated driving models. Consideration is then given to the practicalities surrounding the application of these theoretical frameworks to an applied assessment setting.

INTRODUCTION

Existing driving models can be separated into two major divisions. The first comprise traditional or non-integrative driving models which describe the driving task in terms of separate components such as operating procedures, error analysis, or independent driver, vehicle, and road characteristics. These driving models are defined according to Michon's (1985) matrix classification into the four distinct subgroups shown in Figure 2.1 (Michon, 1985). According to Michon's (1985) matrix classification, these non-integrative models are taxonomic or functional in structure, and are based on behavioural psychology principles (input-output) or on an analysis of psychological variables (internal state).

The second division of driving models are those which do not fit Michon's (1985) framework, but instead take an holistic or integrated approach to driving. Integrated driving theory can incorporate traditional driving models together in a unified and dynamic explanation of the driver, vehicle and environment. Historically, an integrated theoretical approach was not common. However, two current examples are the 'systems' model (Willumeit, Kramer & Neubert, 1981) and the 'cybernetic' model (Galski, Bruno & Ehle, 1992) discussed later in this Chapter.

	Taxonomic approaches to driving behaviour.	Functional approaches to driving behaviour.
Input-output (behavioural)	• Task analyses	• Mechanistic models • Adaptive control models -servo-control -information flow control
Internal state (psychological)	• Trait models	• Motivational models • Cognitive (process) models

Figure 2.1: Traditional or non-integrated driving models. Adapted from Michon, (1985, p.490).

The transition from driving model to measurement in a practical assessment context is complicated by problems with operationally defining model concepts. There are also other applied problems such as specifying criteria for an adequate standard of driving. Michon (1985) emphasises that, in applied analyses of driver models, it is necessary to differentiate levels of explanation in terms of rational (or intentional) and functional behaviours. Rational behaviour equates with an aggregate explanation of driving. This type of analysis falls short of reality by assuming that a driver will behave consistently at all times. Focus on functional behaviours involve analyses of actual functions and processes. This type of analysis emphasises the role of the individual in understanding group processes. In practice, the distinctions between functional and rational behaviours are often not made. An integrated approach to driving, however, emphasises the complementarity of these two levels of explanation.

TRADITIONAL OR NON-INTEGRATED DRIVING MODELS

A taxonomic analysis of driving

Many traditional driver behaviour models are classified as taxonomic, comprising what is "essentially an inventory of facts" (Michon, 1985, p 490). Taxonomic models incorporate either a task analytic or a trait approach, and they represent human factors in the driving scenario.

From a research perspective, the advantage of a taxonomy is that systematic and detailed description can be achieved. That is, one can identify and make assumptions about groups of variables, and the order of relationships between them. Results can be expressed in terms of proportions and probabilities, and it is also possible to build images which may form the basis of objective measurement criteria. A taxonomy therefore provides a useful database for research, allowing both examination of common patterns and themes across cases, and in the provision of 'rich' description at group and individual levels (Yin, 1985).

The negative side of a taxonomic structure is that relationships between defined tasks or traits are at best correlative. This complication questions the extent to which variables can be isolated and relied upon to form accurate predictions. Implications of many recorded observations are, therefore, not always clear nor particularly meaningful. Existing findings are complicated by a lack of consistency in the way some factors have been studied in the literature. This inconsistency is partly accounted for by the use of variable definitions and measurement criteria. With systematic investigation, however, the value of this level of description can be increased.

Task analysis of driving. Task analysis is essentially a taxonomic driving model approach which involves an input-output behavioural component (Forbes, 1972). Such models describe the performance and ability requirements for meeting a number of individual driving tasks (e.g. McKnight & Adams, 1970; van der Molen & Botticher, 1988). The main strength of a task analytic approach is an emphasis on operational definitions of task components. Therefore, most conventional driving tests are based on task analyses as quantification of a range of driving behaviours is possible. However, depending on what, and how, various behavioural units are defined, description of tasks can be general or can be so detailed and extensive that they become difficult to use. Consideration must be given to whether driving tasks are adequately represented, taking into account issues such as generalisation to a range of situations. In addition, there are problems with determining which specific driving features should be selected to permit a valid, reliable, and complete description of driving performance (Forbes, 1982).

Trait models of driving. Trait models, which are internal state, are a compilation of single or interrelated factors. These factors may contribute to, or be accountable for, driver behaviour. One example would be personality types and their relationship to driving. There are practical implications for describing drivers by certain traits, particularly for application to education and training for specific 'types' of drivers, who may be perceived to have special needs. The current literature identifies numerous individual factors which require further investigation for their potential role in driver trait models.

The use of trait typologies as driver 'reference populations' is criticised in the literature. There are difficulties with definition of various trait factors, and identifying their implicit relationship to the actual driving task. This is partly due to a lack of systematic investigation in research, complicated by the fact that most individual characteristics are also impossible to measure in the unsuspecting driver. Typologies which describe individuals as 'accident prone', 'anxious' or 'reckless' drivers (e.g. Mihal & Barrett, 1976; Shoham et al., 1984) are therefore controversial. Literature reviews suggest that trait differences do not show up in traffic significantly enough to make screening among normal drivers particularly useful (McKenna, 1982; Michon, 1985). Interpretation and any subsequent action as a result of driver typing or screening also raises potential ethical questions.

Functional analysis of driving

Models which take a functional approach emphasise the dynamic driving process as opposed to the more static nature of a taxonomy. Essentially these take the form of behaviourally based 'mechanistic' and 'adaptive control' models or as motivational and cognitive process models which reflect internal psychological states (refer Figure 2.1).

Mechanistic and adaptive control models. Mechanistic models attempt to describe the behaviour of cars in moving and following driving scenarios. These models have a role in the planning and engineering side of road transportation, but are not particularly relevant to driver research. They are limited by a lack of focus on human factors, and do not really fit a psychological frame of reference.

By contrast, adaptive control models do place more reference on the role of the driver. There are two types. First, servo-control or manual models consider driving as "a continuous or intermittent tracking task" (Michon, 1985, p.494) incorporating both driver and vehicle dynamics. These models form the basis of driver steering theory. However, because measurement outcome is expressed in precise mathematical terms, only a very narrow range of tasks can be represented (Reid, 1983). Criticism of servo-control models is also directed toward difficulties integrating driver perception with actual vehicle control (Michon, 1985).

The second type of adaptive control model deals with information flow and forms the reasoning behind most driving simulation. Current simulators are unable to represent the whole driving task due to the way they are data driven. Nevertheless, increasingly sophisticated programmes are becoming more interactive, and thus more useful in examining individual processing of information. A number of these, such as the Shell Training Video on laser disc, are currently used in a training context in New Zealand (P. Sheppard, personal communication, 21st June, 1992).

Motivational models. Motivational models comprise risk compensation, risk threshold and risk avoidance approaches in the theory of driver behaviour. These approaches emphasis the role of the driver in the control and maintenence of safety margins. Consequently, driving can be viewed partly as a self-paced task in which the driver is able to adjust, to some extent, the level of difficulty. In this sense, risk models are noteworthy for their progress toward a cognitive explanation of driving behaviour.

Risk models of driving beg the question 'how is risky driving identified and measured?' A major disadvantage, then, is a lack of definition for adequate performance criteria. Applied research has found that many risk model components are therefore unable to be operationalised. For instance, one landmark study which attempted to 'run' the three types of risk models on a relatively simple task description resulted in numerous assumptions being made about the definition of model concepts (van der Molen & Botticher, 1988). The role of many factors in determining individual risk and perceptions of risk also complicates interpretation of research results. For example. Spolander (1983) identified two risk generating mechanisms - experience and subjective driving skill - as important variables in any representation of an individual's risk in traffic. Whether or not there is an assumption that drivers always have sufficient insight or information about risk is also an important consideration, particularly in the case of neuropsychologically-impaired drivers.

Risk compensation driving models. Risk compensation works on the compensatory loop principle that drivers aim to balance what happens on the road with a personal level of acceptable subjective risk (e.g. Blomquist, 1986; Wilde, 1983). Hence, the larger the perceived risk, the slower the driver's speed. Examples of how a risk compensation approach can be utilised in an applied setting include the imposition of speed limits and the 'blackspot' approach to accident control. In other words, these techniques serve to increase individual perceptions of risk. Although these approaches are somewhat effective, critics of the risk compensation model consider them to be no more than a way of spreading accidents more uniformly within the system (Summala, 1985). Another point of contention concerns whether a risk compensation approach allows the benefits of road design and car technical improvements to be shown in terms of increased road safety.

Risk threshold driving models. Risk threshold models focus on the balance between drivers subjective perceived safety and objective, physically or statistically determined safety (e.g. Naatanen & Summala, 1974). Various influences such as cognitions, motivations, and physiological factors, may be seen to have an effect on this balance, or target level of risk, so that the situation of subjective safety equaling objective safety is not always achieved. According to this approach, individual weighting of cost and benefit (where one of the safety margins exceeds the other) are considered to be highly resistant to change through outside intervention, such as education programmes. For the individual driver who employs this model in their own driving, little or no change is brought about by technological improvement in vehicles and roads. Instead, the driver simply assimilates these into, and adjusts, his or her personal framework for risk.

Risk avoidance driving models. Threat or risk avoidance combines aspects of the two risk models and incorporates an avoidance learning approach as a way of dealing with the negative aspects of personal risk (e.g. Fuller, 1984). Consequently, the adverse nature of subjective risk implies that drivers will be motivated to escape from or avoid such experiences. In a practical setting, for example, a risk avoidance approach parallels the defensive driver concept as a scheme for dealing with apparent danger (Michon, 1985).

Cognitive models. To understand the complex behaviours inherent in driving, it is necessary to understand basic underlying principles at the cognitive level. In this regard, Michon (1985) states that a cognitive approach "constitutes a considerable step forward in the modelling of driver behaviour" (p.514). Further, Summala (1985) stresses that "the basis for any success in driving must be the memory representation of the traffic system hierarchically organised as schemata, programs, or internal models which govern both perceptual and motor sides of behaviour" (p.50). Although such psychological processes are fundamental to incorporating the driver as part of any traffic system, it is interesting that a cognitive explanation of driving is a fairly recent development in the literature. As yet, adoption from cognitive psychology of some of the more detailed computational models and production systems has not really occurred.

A range of general cognitive models can be used to explain driving processes, and are directly relevant to methods used in driver training and assessment. For example, an understanding of cognitive functions which govern the acquisition of driving skills can be gained through models of complex motor skill, such as Anderson's ACT Production System (1982). A conceptual understanding of attention and memory (e.g. Schneider & Shiffrin, 1977; Shallice, 1982) is also fundamental to cognition and has relevance to the processing of driving information. The neuropsychological implications of these and other cognitive model structures are emphasised in the empirical literature (e.g. Brooks, 1984; Lezak, 1978, 1979, 1994; Luria, 1966). Importantly, cognitive approaches offer a route to analyse the possible effects of neuropsychological impairment. At present, two cognitively-based applied models have been cited in the neuropsychologically-impaired driver literature. One is an hierachical representation of driver decision-making (Michon, 1981; van Zomeren et al., 1987). The other emphasises hypothetically important perceptual, cognitive and psychological factors in safe driving (Galski et al., 1992), and is discussed later in this Chapter.

There are many advantages in the use of cognitive models which include the flexibility offered by a dynamic representation of driving processes. That is, cognitive models are receptive to other individual and environmental variables which are encountered in a continually changing driving situation (Michon, 1981). Most other models of driver behaviour are therefore able to be interfaced with a cognitive approach, allowing for more systematic investigation of a range of variables. For example, the explicit description of task analyses enable an objective analysis of cognitive error patterns. Further, analysis of the driver is open to inclusion of a wide range of individual characteristics or internal states. Another distinct advantage is that a cognitive approach is appropriate for all levels of analysis as it "is essentially at the individual level as far as its performance is concerned, but it is general to the extent that it describes human cognitive competence" (Michon, 1985, p.515). These advantages highlight the utility of a cognitive approach for driving assessment.

An analysis of cognitive function, however, also presents a number of well documented methodological problems (Broadbent, 1984; Heinrichs, 1990; Kaufert, 1983; Lezak, 1982, 1995). Measurement is challenged by difficulties with operational definition and limited methods for the assessment of higher level functions. Attempts to impose measurement constraints on actual cognitive processes, as they occur in a real or practical setting, are particularly problematic. A few on-road driving tests, such as the Advanced Driver Assessment in New Zealand, exemplify a new focus on emergent patterns of behaviour over continuous driving. However, these tests are often limited by poor definition of the actual driving and cognitive processes measured, as well as a lack of validity and reliability data. Even in a general measurement context there are a lack of standardised methods for making objective or reliably replicable estimates of graduations of impairment in higher level functions, which is a limitation on the use of these methods for any form of comparison (Lezak, 1982).

<u>Cognitive models for the acquisition of a complex skill</u>. The process of acquiring a complex skill involves progression from conscious to automated control of a system. Thus, learning to drive follows a pattern of development from basic handling through

to the internal representation of knowledge or processes which enable successful control of a vehicle. Automated control can be illustrated in the way that an individual may drive from point A to point B without really being conscious of the exact actions involved in reaching the destination. Contrast this with the constant strain and concentrated effort required in basic mechanical and road manoeuvres when first learning to drive.

In the acquisition of a skill, instruction does not specify the exact procedure or information flow to be applied, but is presented as a series of facts, such as driving lessons. Nevertheless, an individual is generally able to emerge from this type of instruction with the ability to generate an interpreted behaviour Once a skill has been compiled into a task specific procedure, further learning occurs through improvement in the choice of method by which the task is performed.

One example of a model for skill acquisition is the ACT Production system (Anderson, 1982). This model asserts two major stages in skill development: "a declarative stage in which facts about the skill domain are interpreted, and a procedural stage in which the domain knowledge is directly embodied in procedures for performing the skill" (Anderson, 1982, p.369). The ACT Production system model is based on hierarchical sets of learning instructions which break up the overall skill to be acquired into discrete, manageable components (Anderson, 1982). Numerous subprocesses are involved before these individual components are combined as a continuous skill process. Once this occurs, practice and experience enable generalisation, discrimination and strengthening of the overall skill process, resulting in increased speed and accuracy.

The ACT Production system model is relevant not only to learning to drive but to the ongoing processes that occur as a function of driving. Knowledge and experience gained is constantly utilised and modified as ever changing driving scenarios are encountered by the driver. Anderson (1982) points out that interpretation of any scenario requires that declarative information is represented in working memory. This quantity of information places a heavy demand on short term memory capacity and retrieval from long term memory. Thus, the majority of a subject's driving errors and slowness in responding can be attributed to errors in working memory. Individual abilities, different response styles and problem solving techniques are all importanat facets.

Other cognitive models. Within psychology, a number of other cognitive processing theories can be applied to driving (Barsalou, 1992). Models of attention are one example which will be considered briefly here. Two well known models within this field include the Influential Model of Attention (Schneider & Shiffrin, 1977), and the Supervisory Attentional System (SAS) model (Shallice, 1982). The Influential Model of Attention proposes automatic (unconscious) and controlled (conscious) processing. Within this model, the individual's capacity for selective attention to discriminate between relevant and irrelevant stimuli may be adversely affected by both focused and divided attention errors.

The Supervisory Attentional System (SAS) model regulates the efficient use of attentional resources in a goal-directed manner. This model parallels the subgoaling procedure within the ACT Production system model (Anderson, 1982), and utilises generalisation, discrimination, and strengthening techniques for the ongoing processing of complex task information.

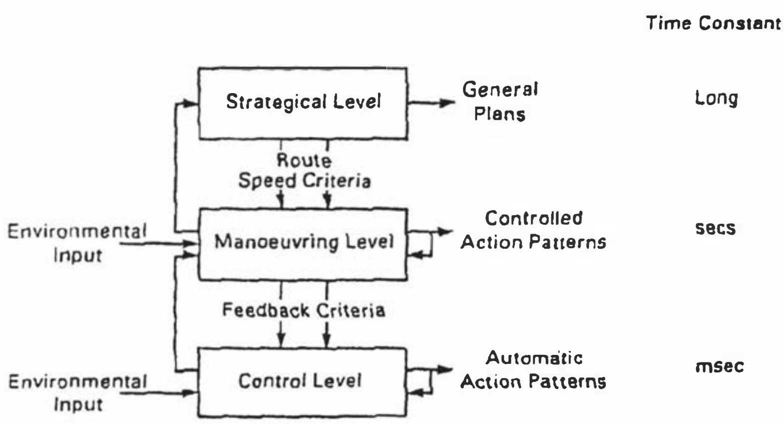

Figure 2.2. A hierarchical decision-making model for driving.

An hierarchical decision-making model for driving. Despite the relevance of a range of general cognitive models, the only well documented example specific to the driving literature is a cognitive representation of driving as a problem solving or decision-making hierachy (Michon, 1981; van Zomeren et al., 1987). This model is based on three "levels of skill and control" (Michon, 1981, p.489), and is hierarchical in the sense that decisions on a higher level determine the working load on lower levels (see Figure 2.2). The three levels comprise strategic (planning), tactical (manoeuvring) and operational (control) components of the "generalised problem solving task of the driver" (Michon, 1981, p.489).

(i) Strategic level. This constitutes the highest level. Emphasis is on decisions and planning ability prior to the commencement of driving, such as evaluating the general risks of traffic. Examples are a driver's decisions about choice of route, driving conditions, timing so as to avoid rush hours, and planning a sequence of trips or stops.

(ii) Tactical level. Here, behaviour and decisions in traffic are made, such as adapting speed to suit conditions, passing another car, using headlights and windscreen wipers.

(iii) Operational level. This is the lowest functional level and involves basic driving skills, such as controlling the vehicle, steering, perceiving and taking action.

The strategic and tactical levels are characteristic of higher order cognitive functions. The operational level reflects what become automatic processes in the experienced driver. Within this model framework, van Zomeren et al. (1987) emphasise the importance of a temporal component whereby time pressure increases over descending levels. Time pressure is therefore greatest at the operational level, where the driver has the least time available to respond to the demands of a situation.

In reality, use of this three-tiered model in a practical testing assessment generally fails to take the relative importance of each of the levels into account. Instead, as with other cognitive frameworks, it is the basic driving skills or operational level functions that are the focus of driver instruction and testing.

INTEGRATED DRIVING THEORIES

A second division of driving models are integrated approaches, which incorporate the traditional approaches discussed above. Such integrated theories interpret the driving process in a holistic sense through interactions between the driver, vehicle and environment. The need for research to combine existing areas of study is partly accountable for little development of integrated, testable theory. At present, there are few cited integrated models, particularly in the neuropsychologically-impaired driver literature.

An integrated approach is an important advance in the field because it enables scope for the development of driving models which more accurately describe driving. Integrative models have two major strengths. First, driving is viewed as a dynamic process in which higher level cognitive functions have an inherent role. Second, an integrated model emphasises the interactive relationships which exist between the driver, vehicle, and environment, but also accommodates individual variability within this framework. Consequently, an integrated approach can be meaningfully applied to the assessment of a diverse range of drivers, including those with neuropsychological impairment.

Current integrated frameworks reflect different degrees of integration and levels of explanation. Early work toward an integrated model of driving was carried out by Gibson & Crooks (1938). The model proposed was a field analytical approach whereby safe and efficient driving was seen as "a matter of living up to the psychological laws of locomotion in a spatial field" (Gibson & Crooks, 1938, p.471). Field of safe travel and steering components were identified and determined by various natural phenomena. Further, it was suggested that application of the model to road safety needed to adopt the driver's point of view, emphasising what he or she does during normal driving. While not explicit in cognitive terms, many aspects of this model are synonymous with the elements considered important by present day models. Unfortunately, no applied research relating to this model can be found in the available literature.

More recent integrative approaches include a systems model which is characterised by the driver's ability to receive information from the environment and to react by controlling the vehicle (Willumeit et al., 1981). This interactive model was developed in the context of research on alcohol, drugs and driving. Another example is the cybernetic model, an integrated approach to assessment of various cognitive factors in drivers with acquired neurological damage (Galski et al., 1992).

The systems model

The systems model supports an integrated approach toward driving (Willumeit et al., 1981). Here, the overall complexity of the driving process is divided into interconnected vehicle, driver and environment subsystems (see Figure 2.3). Interactions between vehicle, driver and environment subsystems are essentially characterised by cognitive processes or the "drivers ability to receive information from the environment and react upon it by activating the controls of the vehicle" (Kramer & Rhor, 1982: p. 891).

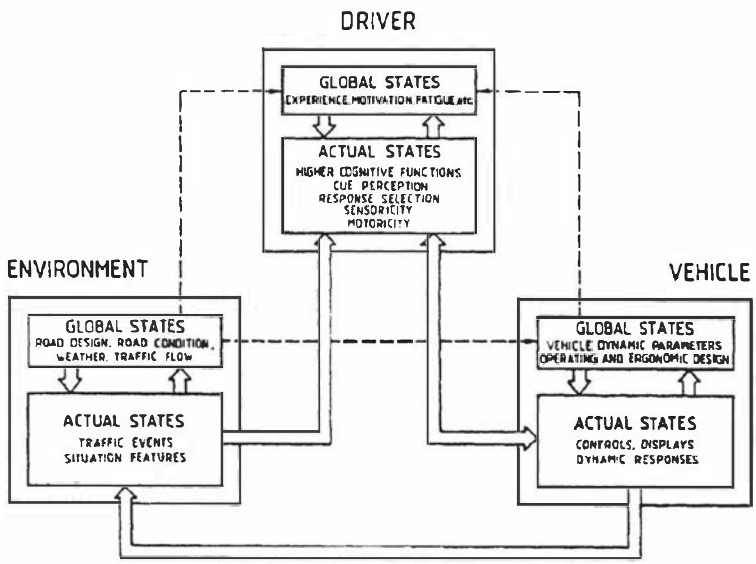

Figure 2.3. The systems model (Willumeit et al., 1981).

The variables within the proposed systems model are divided into global and actual states according to their temporal relationship (Willumeit et al, 1981; Kramer & Rhor, 1982). Those variables which are relatively independent on time are termed *global states*, and include driver experience, weather, and vehicle design. By contrast, variables which characterise instantaneous processes are represented by *actual states* such as driver steering movements, the course of the road, and momentary speed. Within this model, driver behaviour depends upon the global states of the environment and vehicle as well as the actual response states to which the driver reacts. Hence, this removes the emphasis from the parameters of the road or driving manoeuvre, for example, to focusing attention on the way these are cognitively processed by the driver.

Willumeit et al.'s (1981) systems model is unique in that it enables the interdependent nature of the vehicle, driver and environmental states to be seen (see Figure 2.3). For the individual, a shift in any one of the states will have some effect on all others. This may be accommodated or compensated for, or alternatively, it may weaken the systematic interactions which go on. Another important feature is that Willumeit et al. (1981) acknowledge both individual and group level explanations, which is a reflection of the cognitive functional approach taken by this model.

The cybernetic model

The cybernetic model also supports an integrative approach to driving in the sense that it is "an integrated system of component mechanisms designed to process information and perform behaviours pertinent to safe driving" (Galski et al., 1992, p.326). This model was developed in response to the "absence of a model for driving in which the salient elements of driving ability after a cerebral injury are identified and tested (Galski et al., 1990). The cybernetic model is designed to assess a range cognitive areas including aspects of sensory perception, scanning and attention, motor ability, information processing, and response feedback.

The fundamental components of the cybernetic model are shown in Figure 2.4. Sensory input, scanning, attention, calculation and construction co-processor components of the model are examined through tests of visual acuity and neuropsychological function. The general driving program component is aimed at the driver with residual driving memory, and examines an individual's capacity to build on driving experiences and apply learned information to familiar or new situations (Galski et al., 1992). This component encompasses tests of road knowledge and neuropsychological tests of memory. The 'residual diagnostic program' involves observation of executive functioning along with associated effects such as inattention, impulsiveness, distraction, confusion, slowness, and hostility. All model components are monitored against simulator, on-road closed and open driving measures.

A positive feature of the cybernetic model is attention to the definition of outcome measures, particularly with reference to criteria endorsed by professional driving instructors. Importantly, this criteria reflects skills and abilities which are relevant to practical driving measurement. An apparent lack of a feedback loop in the diagramatic representation (Figure 2.4), however, would appear to be an inherent weakness of the model in its current form.

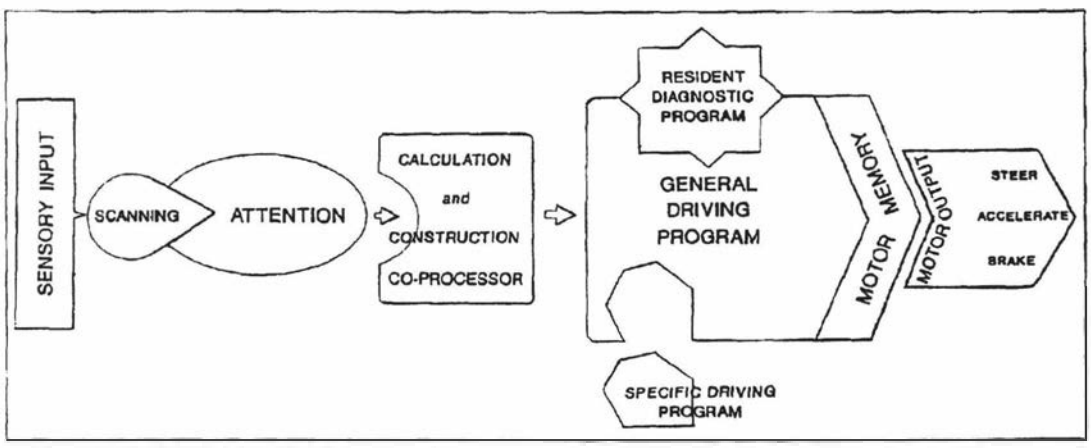

Figure 2.4. The cybernetic model (Galski et al., 1992).

FROM THEORY TO MEASUREMENT: METHODOLOGICAL ISSUES

Galski et al. (1992) emphasise that "current knowledge about driving has remained severely limited because the models have not been empirically tested nor developed beyond original conceptualizations" (p.325). Subsequently, a number of methodological issues are raised in the transition from driving models to measurement in a practical assessment context. Broadly, these issues relate to two domains: either problems with definition and interpretation of model concepts, or with a distinction between individual or group analyses represented by various models.

Definition and interpretation of model concepts

The contribution of different theoretical and research perspectives are accountable for some definitional issues surrounding the driver (Forbes, 1982). Problems are associated with adequate standard operational definitions of driver concepts. Thus, driving theories typically do not address questions concerning how driving ability is quantified and measured, what a driver does, and the practical implications of assessment. Unfortunately, no models actually delineate or quantify the minimum requirements a driver ought to have. These issues are all very relevant to measurement and undertaking research.

Making theory operational. The transition from driver behaviour model to applied research is problematical at the operational level. Difficulties are encountered in defining various model components, irrespective of whether models are taxonomy- or functionally-based. The two approaches are, however, characterised by slightly different measurement problems, and present an added challenge when an integrative model structure is employed.

Taxonomic models are more concrete than functional models, so the components of a taxonomy are more readily identified and quantified. Nevertheless, a lack of consistency in the research has created problems for comparison between studies. For example, a task analytic approach may involve numerous interpretations or standardised test measures of driving. Similarly, definition of driver traits in the research is varied both in terms of traits selected and measurement criteria used (Evans, 1991).

With a functional approach, model components need to be able to accommodate ongoing cognitive processes in their definition to be plausible (Kaufert, 1983; Ponsford & Kinsella, 1992). In operational terms this is difficult to achieve because artificial measurement constraints must be imposed on actual behaviour. Such working models are limited by a lack of explanation of underlying processing mechanisms and in the amount of flexibility required to enable continuous information exchange. These difficulties are exemplified in studies such as van der Molen & Botticher (1989) which attempted to quantify an hierarchical risk model for driving. Here behaviour alternatives, expressed in terms of subjective probability of events and outcomes, were devised to explicitly distinguish between risk and other judgements. These measures, however, categorised individual behaviours as mutually exclusive rather than part of a continuum.

Criterion for measurement. Most models for driving lack provision of any framework for identifying, instructing and promoting certain levels or standards of driving. The concept of driver ability is loosely applied and many components of driving lack operationally defined criteria. Separate concepts of driving performance and behaviour have been identified, but have not been incorporated as part of any theoretical model structure.

What defines a good, skillful or safe driver? The literature attempts to differentiate groups of drivers but presents a variety of nebulous and unhelpful terms such as 'good', 'skillful' and 'safe' drivers, which lack clear or consistent definition. In a commissioned report on driving skill, Michon & Fairbank (1969) state that "the literature does not provide a generally accepted procedure for determining whether or not a driver is skillful in the sense of being a good driver" (p.205). Recent literature continues to use these terms ambiguously. Construct validity appears not to have been established and each lack *a priori* criterion and clear operational definition (Cutler, Kravitz, Cohen & Schinas, 1993).

Most practical tests measure driving precision, which is only a component of good driving or driving skill (Evans, 1991; Michon & Fairbank, 1969). However, other criteria for good driving, such as accident rates, reference to type and amount of driving, correlation with social factors, are used arbitrarily in the literature. How a level of driving skill relates to what a driver actually does in traffic is also an issue. Naatanen & Summala (1974) maintain that evaluation of driving skill should account for the effect the driver's behaviour has on traffic in general. This view is supported by integrated driving models which stress that the skill of a driver cannot be measured adequately without consideration for interaction with the total traffic situation.

Reference to 'safe' drivers has been associated with risk models of driver behaviour. Here, the literature attempts to relate individual differences in risk perception to accident occurrence. A safe driver is defined by an absence of recorded accidents. Although such a definition has the advantage of being quantifiable, it does nothing to enlighten the qualities a safe driver may have.

Driver ability. Jones et al. (1983) define 'driver ability' as "prerequisite functions plus driving experience" (p.754). Prerequsite functions comprise sensory, perceptual motor, cognitive, and behavioural components, while driving experience encompasses practical knowledge learned or acquired through on road driving. An adequate level of ability in these two areas results in the "ability to drive competently and safely" (Jones et al., 1983, p.754). Standardised criteria exist for sensory, perceptual motor, cognitive, and behavioural functions through neuropsychological measures, however, it is noted that there is no comparable method for defining or directly measuring driving experience. Current literature suggests that driving experience is best represented by an integrated or composite measure, taking into account driver, vehicle and environmental variables (Evans, 1991).

Driving performance versus driving behaviour. Shinar (1978) makes the important theoretical distinction between concepts of 'driving performance' and 'driving behaviour'. Here, "driving performance is probably more indicative of the limits of our capabilities, while driving behaviour determines actual behaviour somewhere below these limits" (p.26). Shinar (1978) maintains that driving assessment situations tend to measure driving performance because the tests used emphasise perceptual motor abilities and also carry with them the expectation that candidates should perform well to pass. Therefore, conditions under which driving performance is relevant may be limited, raising questions concerning the predictive validity of assessment (Perkins, 1984). Driving behaviour, on the other hand, is more representative of everyday operation of a motor vehicle and the wide range of driver, vehicle and environmental variables which influence performance.

These terms have important implications for integrated theory and measurement of driving. It is important to point out that accepting driving behaviour as a more feasible indicator of individual driving does not, however, diminish the necessity for having reasonably clear assessment criteria and an acceptable standard as an ideal.

Levels of analysis

In the analysis of driver models for research, Michon (1989) emphasises the need to differentiate levels of explanation and claims that in practice distinctions are often not made. Michon (1989) uses the terms rational (or intentional) and functional levels to describe differences in individual versus collective driver behaviour, or normative and descriptive levels of analysis.

Rational or normative behaviour. Rational or normative behaviour represents an aggregate or group level explanation. Driver model typologies based on the analysis of group characteristics are an example. Such analysis does not adequately explain all, or variations in, individual behaviour. Instead, a basis for prediction of driving behaviour is made on the assumption of an average driver who will behave consistently with the same rational intentions. Models which accommodate only intentional (or rational) behaviour therefore fall short of a real world representation of driving as they do not represent 'actual' driving behaviour characteristic of an individual's driving routine.

Functional behaviour. Genuinely individual driver models are functional and describe behaviour in terms of process, or those operations performed on internally represented facts about the world. Rather than based on the assumption that the driver is behaving optimally or rationally "the focus of attention is on actual behaviour" (Michon, 1989, p.345). Advantageously, functional model structures are able to explain behaviours of individuals or groups of individuals because they emphasise the role of individual analysis toward understanding group processes. Analysis of behaviour is therefore based more heavily on description.

Michon (1989) argues that "distinctions that are useful to describe what appears to be going on in driving when we adopt the intentional point of view need not all correspond with relevant distinctions that need to be made at the functional level" (p.344). This is not necessarily a problem, but it does raise the question of what connection can be made between the two approaches. These theoretical issues have received little attention in the literature despite being fundamental to data collection and interpretation. In particular, the relationship between aggregate performance and individual processing models is important for an integrated frame of reference for driving. Here, rational and descriptive levels of analysis can be viewed as complementary. At the group level, this complementarity enables one to see how whole and coherent accounts of driving covary.

Chapter Three

DRIVING MEASUREMENT

This Chapter reviews driving measurement as it relates to driver assessment in the general population, and to neuropsychologically-impaired drivers. On-road retesting of neuropsychologically-impaired drivers encompasses both formal and informal practical tests, some of which are standard measures for general use. A broad range of other evaluative techniques, including the use of driving simulators and the analysis of driving accident data, are also employed in driver assessment studies. Recently, the use of self-report data has provided a new perspective on driving measurement which may have important implications within an assessment context.

INTRODUCTION

Driving is a dynamic complex process governed by the driver's ability to interact and respond to information from the environment. The measurement of this complex process should be fundamental to any assessment which attempts to define an acceptable standard of driving. Current standards rest on licensing test criteria for successful performance. Although these licencing or selection procedures have widespread use within the general population, they do not emphasise underlying cognitive functions which may be important criteria in the assessment of drivers with neuropsychological impairment.

Driving measurement may be at a broad or individual level, and may take either a non-integrated or an integrated approach. Driving measurement includes on-road testing, simulation, accident analyses, and recently, the use of driver self-ratings. Each of these approaches have different strengths and weaknesses relating to validity and reliability, and the use of different research designs. Many broad measurement approaches are unsuitable for individual driving assessments, but may be used to gather information on driver and vehicle behaviour in a planning or road safety context. Examples are frequency counts taken over 'blackspot' accident and speed areas, and other methods of driving observation such as photographic and aerial spotting. These measures are common in providing feedback on specific traffic situations. Efforts to monitor and modify driver behaviour through the use of compulsory vehicle checks, breath testing, and the recent introduction into New Zealand of laser speed measuring devices, can also be a source of measurement data (Teed & Lund, 1993; Wasielewski, 1984). Quasi-experimental designs have also been utilised to gain an insight into driver workload and driving behaviour across defined traffic situations (Hancock, Wulf, Thom and Fassnacht., 1990). Taken together, these studies can provide practical information on aspects of driving.

A number of validity and reliability issues surround the measurement of driving at all levels (Willumeit et al., 1981). For example, construct validity may be compromised if dynamic environmental and situational variables are overlooked in driving measurement. At present, practical on-road driving measures are generally limited to behaviours that are directly observable in traffic situations, while driving behaviours such as decision making, information acquisition, and visual orientation can only be evaluated by indirect techniques (Blanchard, 1979; McKnight & McKnight, 1994). Specifically how these indirect techniques, such as simulated task performance and psychometric testing, relate to actual driving performance is unclear (Aaronson & Eberhard, 1994; Michon & Fairbank, 1969). The obtrusive nature of most driving measures is a threat to construct validity. Formal driver assessment, for example, is more likely to measure optimum driving performance rather than actual driving behaviour (Shinar, 1978). Definition of an adequate standard of driving is also problematic, partly due to a range of available measurement criteria (Michon & Fairbank, 1969). Many existing measures lack adequate standardisation. Unfortunately, there has been little research on the concurrent and predictive validity of the various measurement approaches.

Historically, research designs for driving measurement have been limited In particular, most studies are cross-sectional rather than longitudinal and are, therefore, unable to focus on some of the more dynamic aspects of driving behaviour. Only a few available follow-up studies evaluate the effectiveness of assessment procedures (e.g. Hopewell & Price, 1985). Furthermore, research on new versus experienced drivers imply that a number of driving factors such as age, and driving history, could be more effectively evaluated over time, and through within-group designs (Spolander, 1985). Methodological limitations imposed by the choice of driving sample are also common. In particular, there are difficulties when elderly and neuropsychologically-impaired groups are being studied. Typically, sample size is small due to subject availability, and there is often a lack of subject description, and inadequate control groups (van Zomeren et al., 1987). Generalisations and inter-study comparisons are therefore not always possible. It appears that almost without exception, the literature focuses on normative analysis of results and lacks research to suggest behaviour patterns within individuals.

DRIVING SIMULATION

Background

Driving simulation continues to be a popular focus for applied driving research, especially in training and assessment. A wide range of simulators have been developed specifically for driver evaluation and these have become increasingly sophisticated, paralleling advances in modern technology (Aaronson, 1994). Many of the earlier models are now virtually obsolete.

In a comprehensive review, Forbes (1982) identified five approaches or modes of simulation, for all of which visual input is the predominant concern. First, there are static models which rely on a slide projector or a television camera as a fixed-base stimulus set. This type of model is limited by discrete measurement settings, and is intended for planning more than the measurement of dynamic interaction or simulation of specific tasks. Second, there are moving-base stimulus sets, characterised by a conveyer belt-type roadway which creates the illusion of forward movement within the system. Like the static model, these simulations are suitable for investigating a restricted range of driver abilities in a context where a visually impoverished environment is of little importance. More complex hybrid systems, combining the above models, are a third type of simulation, which involves a recorded image projected onto a static background (Blaauw, 1982). An important advance in this area was a model road system on a turntable base, which projected moving scenes across the driver's windscreen view (Professor G. Shouksmith, personal communication, 30 September, 1996). However, before the full potential could be realised, such methods have been overtaken by other types of computerised simulation.

The fourth type of approach is the pre-recorded visual display encompassing a scale model or actual road scene on film, videotape or videodisc, which depicts a non-repetitive simulated trip and roadscape. This type of simulation is more realistic than static and moving base models, as it allows interaction between the subject operator, vehicle and environment. Current versions are usually interfaced with a computer to record subject responses (Schiff, Arnone & Cross, 1994). Predetermined time and spatial constraints are the main limitations on this type of simulation. A fifth model comprises computer-generated visual stimulus-sets which responds to numerous aspects of driver-related skill (Gianutsos, Campbell & Mandriota, 1992; Gianutsos, 1994; McKnight & McKnight, 1994). More specific subject interaction is possible with both of these latter types of simulation, yet there are limitations in the responses recognised and processed by the simulator, and on the available size of the visual image and graphics.

While different simulations have their own features, there tends to be some common ground in the major advantages and disadvantages underlying all simulation methodology to date. Most models operate under the assumption that psychophysical changes brought about by certain loads, or situations created, correlate with changes in driver performance. However, as Forbes (1982) points out, 'whole-task simulation' is a fallacy as it has thus far been impossible to reproduce the living environment which drivers have to negotiate. It is difficult, therefore, to assess the ecological validity of these artificial settings. A more objective analysis might question how much realism is appropriate for the targeted goals of a specific simulator system (Aaronson, 1994). Cost and participant discomfort are also constraints on more complete or realistic simulation (Aaronson, 1994).

The value of any simulator must be dependent on its ability to elicit the same sort of behavioural response from the operator that would be made in a real situation. Many studies fall short of employing techniques for determining whether such a behavioural correspondence exists (van Zomeren et al., 1987). Furthermore, simulated systems contain deficiencies in information and are restricted by the fact that they are data driven. Nevertheless, when used in conjunction with practical driving assessment, there are advantages in isolating specific tasks and scenarios for analysis. Notably, simulation can imitate a dynamic parameter, such as hazard identification, in a way that it can be more readily and consistently measured. A situation is created in which the researcher is able to control extraneous variables or to separate factors that are confounded in nature (Aaronson, 1994). This establishes reproducibility and provides a basis for comparative studies.

Nevertheless, one area of concern is the physical correspondence between simulated and real situations. For a number of reasons, an individual may negotiate and perform quite differently in front of a simulator as he or she would perform in a moving vehicle. For example, absence of kinesthetic feedback is a very relevant factor, although some of the more sophisticated systems have the scope to develop these types of parameters (Blaauw, 1982). Obviously, a match of both behavioural and physical components of a simulation with the actual driving task is important. In addition, the artificiality of a driving simulation may evoke different demands on a task so that it is not representative of actual driving. For example, there is debate concerning the amount of positive transfer between aspects of actual driving and simulation of a task or skill factor. Conflicting evidence for age-related effects on adaptability to driving simulators provides a good example of limitations within an assessment context (Cimolino & Balkovec, 1988; McKnight & McKnight, 1994; Schiff et al., 1994).

A positive feature of driving simulators is the reduction of risk associated with on-road driver testing. Ethical concerns relating to the safety of subjects and other road users during the assessment process tend to be alleviated when the task is simulated. This can be particularly important where there is the question of a subject's fitness to drive (Katz et al., 1990). Gianutsos (1994) also notes that simulation can inspire confidence and insight as well as objective feedback of results which subjects can relate to as a phase of driving assessment. There is no doubt that today's simulation technology is a much more realistic and exciting prospect for evaluation of the driver. However, high costs involved, particularly with high fidelity simulation, remains a severely limiting factor for use in research and small scale assessment programmes (Aaronson & Eberhard, 1994).

Driving simulation and neuropsychologically-impaired driver studies

The question is frequently asked whether simulators can aid in assessment and/or predict driving quality in real traffic of persons with neuropsychological impairment. Neuropsychologically-impaired driver research has used simulations of varied complexity, both in terms of simulator type and skills or behaviours evaluated. It is, therefore, difficult to make comparisons between many studies. Further, different simulator systems take slightly different approaches toward demonstrating validity (Aaronson & Eberhard, 1994). Apparent face validity of driving simulators over other off-road assessment measures has been noted (Engum, Lambert & Scott, 1990), although the use of more sophisticated and standardised simulation is only a recent development in the assessment of brain-impaired drivers (Aronson, 1994; Aronson & Eberhard, 1994; Gianutsos, 1994; McKnight & McKnight, 1994; Schiff et al., 1994).

Reviews suggests that simulators are not a valid substitute for on-road driver testing of neuropsychologically-impaired drivers (van Zomeren et al., 1987), nor appropriate for use as an isolated psychometric tool in making final driving decisions (Hopewell & Price, 1985). However, the contribution of simulator research to assessment and training has more far-reaching implications for the measurement of driving-related cognitive abilities within a controlled setting (Barsalou, 1991; Gianutsos, 1994). In particular, recent research has found strong correlations between simulated driving-related tasks and computerised neuropsychological and clinical tests (Flemons, Remmers & Whitelaw, 1993; Kandra, Barrett & Doverspike, 1993; McKnight & McKnight, 1994).

Compared to use for evaluating physical disability (Shipp, 1986, 1987; Shore, Gurgold & Robbins, 1980) the unfamiliar and often confusing controls of a driving simulator have been considered, by some authors, as impractical for neuropsychologically-impaired subjects (Jones et al., 1983; Quigley & de Lisa, 1983). Studies involving experienced and learner drivers who are neuropsychologically-impaired suggest that the novel simulated task becomes more a measure of ability to adapt than any other driving-related component (Cimolino & Balkovec, 1988; Simms, 1989). Furthermore, it appears that simulation measures are less likely to predict on-road driving in all experienced drivers, for whom driving is an automated task (Barsalou, 1991). Gianutsos (1994) takes up this point and emphasises that "since driving is an overlearned skill, assessment should minimise learning and emphasise practical performance" (p.183). Due to the nature of the task, as well as the reaction time data involved, simulator research has also found subject age to be an important factor (Cimolino & Balkovec, 1988; Crook, West & Larrabee, 1993).

An advantage of some driving simulation measures is their sensitivity to executive level information processing deficits resulting from neurological damage. Thus, subjects who find it difficult to track many things simultaneously, or to modulate attention rapidly and flexibly, are identified by high error scores (Engum et al., 1990). These cognitive processes are critical in complex traffic situations (Hancock et al., 1990). Another advantage is the safety factor in using driving simulators for evaluation, particularly for screening prior to on-road driver testing. While mostly reliable, any question over the validity of a measure generally sees the short term risk of a driving test outweighing the long term risk of turning an unfit driver on the road (Nouri & Tinson, 1988).

In the last decade, neuropsychologically-impaired driver studies commonly report the use of two main types of driving simulator: the Doron system (Doron Precision Systems, Inc., PO Box 400, Binghamton, NY 13902, USA) and the Driver Performance Test (Advanced Driving Skills Institute, 4660 Brayton Terrace South, Palm Harbour, FL. 34685, USA). Other computer-based driving systems are popular in the most recent literature (Aaronson, 1994, Aaronson & Eberhard, 1994).

Doron Driving Simulator. The Doron Driving Simulator is essentially a static simulator operated in conjunction with a 60 minute cine film of a specific driving situation, although not directly linked. There is no interactive feedback loop so that subjects are unable to alter the driving task itself (Hopewell & Price, 1985). Driving controls are connected to a computerised panel which records steering, acceleration, signaling, and driving speed responses. While several models of the Doron system are available, few studies actually document the version they have used. Face validity of the Doron system is considered high by some authors (Gianutsos, 1991b) and low by others (Galski, Bruno & Ehle, 1992a). Compared with other simulators, the financial cost of the Doron system is high.

The Doron system has been used in the assessment of varied subject samples. Cimolino & Balkovec (1988) found that older drivers who suffered cerebral vascular accident (CVA) performed poorly compared to adolescents with mixed disability.

Adolescents significantly improved simulator performance with training, while the older CVA subjects did not. Adolescent subjects in this study were learner drivers. The advantage of the Doron simulator as a training tool for basic driving skills for the adolescents has also been supported by other studies (Simms, 1986, 1989). Other research with older subjects, however, has also not been particularly successful. For example, Quigley & de Lisa (1983) found that the Doron simulator was not considered a useful retraining tool, and drew a negative response from 50 older CVA subjects. These authors observed that subjects were able to benefit from the visual, auditory and vestibular cues which are inherent in a real car, but absent in simulated driving. No statistical data was given to indicate whether simulator performance predicted on-road driving in any of these studies.

The Doron (model L225) simulator has been used as a screening and training device before on-road driving assessment. In one study, Hopewell & Price, (1985) found significant group differences between Doron simulator scores and current driving and non-driving status. Here, a cut-off with very poor performance on the simulator was a predictor of non-driving status, indicating a possible floor effect. Combined with length of post traumatic amnesia and overall IQ scores, performance on the Doron simulator differentiated driving versus non-driving subjects. However, a proportionally high number of traffic violations (accessed through police files) was noted for the neuropsychologically-impaired subjects, suggesting a driving standard lower than the general population. Although no relationship between quality of driving and any of the off-road measures was noted in this study, an important feature was a longitudinal type design using driving status as a realistic measurement criterion.

Incorporation of the Doron L225 model simulator with other assessment measures in a multivariate research designs has found mixed results (Galski et al., 1992, 1993). For example, neuropsychologically-impaired subjects, comprising a wide age range, underwent a predriver psychological testing together with the Doron simulation (Galski et al., 1992). This study found higher order correlations for the simulator and neuropsychological test items, suggesting the simulator was tapping integrated abilities rather than separate skills. Although simulation scores were significant predictors of driving outcome, these scores enhanced the predictive ability of the predriver evaluation by only 6%. In a similar study involving neuropsychologically-impaired subjects, however, discriminant function analysis found that simulator measures predicted failures on the behind-the-wheel evaluation with 65% sensitivity and 80% specificity

(Galski et al., 1993). In this study, the predictive validity was increased when the simulator results were combined with an informal behavioural index.

Driver Performance Test. Two groups make reference to the Driver Performance Test which is similar in format to the Doron simulator (Hopewell & Price, 1985; Gouvier et al., 1989). The Driver Performance Test takes 45 minutes to administer and comprises a series of potentially dangerous driving situations presented on video, to which the subject must rapidly and safely respond with either acceleration, signal, steering, or brake responses (Gouvier et al., 1989). Gianutsos (1991) reported good face validity and the availability of normative data for this test.

Using the Driver Performance Test, Hopewell & Price (1985) found a highly significant difference between small numbers of neuropsychologically-impaired subjects and matched controls. A large proportion of the variance between groups was accounted for by errors in the 'acceleration' category, suggesting a reduced ability by the neuropsychologically-impaired subjects to anticipate and react to changing traffic demands. Overall, however, Driver Performance Test scores did not show a statistically significantly relationship to either a general driver screen (Baylor Institute for Rehabilitation Driver Screening Inventory), nor to a driving instructor rating (Hopewell & Price, 1985).

In another study, the Driver Performance Test was included in the assessment of small numbers of neuropsychologically-impaired, spinal cord-injured and able subject groups (Gouvier et al., 1989). Results taken across the three subject groups suggested 79% of the variance in practical driving test scores could be predicted by a combination of Driver Performance Test Scores, full-sized vehicle driving over a closed course, and the Oral Digit Symbol subtest of the WAIS. However, within the neuropsychologically-impaired subject group the Driver Performance Test Scores were not statistically significant in relation to the practical driving test criteria.

Static simulator measures. Rudimentary static simulators comprising a driver's seat, steering wheel, and foot pedals linked to a screen displaying light and auditory bleep cues have been documented in some neuropsychologically-impaired driver studies (Engum, Lambert, Womac & Pendergrass, 1988; Katz et al., 1990; Nouri &

Tinson. 1988). These simulator devices are essentially measures of complex reaction time. averaged over a number of trials.

Some studies of driver performance rely on simulators of this kind as a precursor to on-road driver testing. For example, Katz et al. (1990) stipulated that failure to pass the simulator test precluded real driving assessment in their study of neuropsychologically-impaired subjects. However, this type of constraint appears premature in light of the questionable predictive value of static simulators. Nouri & Tinson (1988), for example, compared simulator scores with the standard British School of Motoring Road Test across a sample of subjects with CVA. Here, there was little relationship between the simulator and driving test measures on the basis of pass, borderline or fail ratings. In particular, a significant number of subjects received a good/average rating on the simulator but a below standard rating on the road test, and vice versa.

The predictive value of another static simulator measure, Brake Reaction Time (a component of the well documented 'Cognitive Behavioral Driver's Inventory' (CBDI)), is also unclear (Engum et al., 1988, 1989; Engum & Lambert, 1990; Engum, Lambert & Scott, 1990; Lambert & Engum, 1990). For example, Brake Reaction Time was an unreliable component against both the State Drivers Test (Tennessee) and a psychologist's judgement of driving behaviour, and also a poor predictor of subjects total CBDI score (Engum et al. 1988).

Computer-assisted tracking simulation. Computerised tracking tasks represent another common type of driving simulation (van Zomeren et al., 1987). Tracking tasks are adversely affected following neuropsychological impairment and are positively correlated with higher order cognitive functions (Gianutsos, 1991). Compared with other aspects of simulation, tracking tasks also appear to be more predictive of actual driving behaviour (DeFazio, Wittman & Drury, 1992; van Wolffelaar, van Zomeren, Brouwer & Rothengatter, 1987; Gianutsos, 1994). In a direct comparison of real versus simulated tracking, for example, DeFazio et al. (1992) found a high correlation between a computer and car driving task for a small sample of university students.

Various computer assisted tracking simulations have been used in studies of neuropsychologically-impaired drivers. In one study, Gouvier et al. (1989) used a tracking simulator with a variety of modular adaptive controls. Here, two tracking scores, mean left-right and up-down tracking errors, were recorded for each of seven driving manoeuvres, repeated four times during the assessment. These same manoeuvres were also assessed in a small scale vehicle and in a full-sized modified car over closed road circuits. Despite a certain amount of overlap between groups, neuropsychologically-impaired subjects did less well on all measures. Combined results found that only up-down tracking scores were significantly correlated with small scale vehicle and modified car criteria. Unfortunately, however, these criteria were not validated against actual open-road driving.

In another study, a tracking simulator was used in a night driving simulation comprising a two lane road projected onto a video monitor (van Wolffelaar et al. 1987). Subjects were required to maintain a constant course deviation in the presence of sidewind factors. Sidewind factors of varying degree were introduced over a series of trials, both with and without feedback from the simulator. Significant group differences were found for degree of difficulty under which constant tracking could be maintained. Sidewind factor tracking scores were significantly correlated with Lateral Position Control driving in an instrumented vehicle and the Test for Advanced Drivers' (TAD).

Gianutsos and colleagues document use of the Driving Advisement System (DAS) and its updated form, the Elemental Driving Simulator (EDS) (Gianutsos & Beattie, 1990; Gianutsos, Campbell, Beattie & Mandriota, 1992; Gianutsos, 1994). This assessment is used to advise persons with known or suspected neuropsychological impairment about whether they have the cognitive prerequisites for safe driving. Implemented as hardware and software for IBM-compatible computers, the EDS prototype system comprises a baseline tracking task, a two-choice reaction time and tracking task, and, a hazard identification component added to the reaction time and tracking task. As part of the assessment, self-appraisal data of cognitive abilities related to driving is also collected on computer. Research has shown that the DAS compares well with other simulator measures and with driving a year later (Gianutsos & Beattie, 1990; Gianutsos et al., 1992). To date, research on a large sample of elderly drivers, and smaller groups of neuropsychologically-impaired and normal drivers, supports the feasibility, reliability and discriminative validity of the EDS procedure (Gianutsos, 1994).

Small-scale vehicle simulators. Small-scale motorised vehicles are also used in the assessment of drivers with neuropsychological impairment. These vehicles would seem more face valid than other simulation measures since they involve a limited form of actual vehicle operation, usually over a closed-road driving course. Despite documentation of an assortment of small scale vehicles, ranging from modified wheelchairs to purpose-built motorised component cars, there is promising but limited evidence to justify their use as an assessment tool (Schweitzer, 1986; Gouvier et al., 1989; Kewman et al., 1985; Hale, Scheitzer, Shipp & Gouvier, 1987). For example, in one study, the use of a small scale vehicle around a closed circuit was related to actual driving performance on a full-scale course (Gouvier et al., 1989). However, the assessment failed to distinguish between able, spinal cord-injured, and neuropsychologically-impaired subject groups.

Small scale vehicles tend to be used for training rather than the direct assessment of neuropsychologically-impaired drivers. For example, tracking task performance on a small electric-powered vehicle has been used as a driver training tool, which was somewhat effective for neuropsychologically-impaired subjects (Kewman et al., 1985).

In summary, driving simulation to date can only reproduce certain aspects of the driving task. Thus, measures that are obtained through simulation place an emphasis on individual skills rather than aspects of the wider driving environment, such as road safety goals (Urhlander et al., 1972). Simulation research is, therefore, best viewed for its role in the overall assessment picture; for instance, the advantages of driving simulator measures over other driving-related measures such as psychometric testing, or the value of driving simulations in measuring the abilities of neuropsychologically-impaired drivers. High cost of implementation and a frequent lack of validity, reliability, and normative data are also important considerations in the use of some simulated techniques. In the near future, simulation will be enhanced by techniques such as virtual reality which will enable subjects to experience much more realistic driving simulation, and will force researchers to re-evaluate the role of simulation in assessment.

GENERAL ACCIDENT DATA

Background

Validity of accident data. A wide range of studies and reviews have focused on accident data and driving behaviour (Cooper, 1990; Evans, 1993; Fahrenkrug & Klingeman, 1993; French, West, Elander & Wilding, 1993; Hakamies-Blomqvist, 1994). Broadly speaking, the validity of accident data is compromised by the definition of what constitutes an accident, indices of outcome and severity, and the type of recorded accident data. Definition of an accident is frequently constrained by whether or not it has been reported to an authority (Risk, 1981), and by available information (Galski et al., 1993). Nevertheless, despite these complications, accident frequency is a common method of gauging road safety and receives greater interest than non-accidental driving as a measurement criterion (Zimolong, 1981).

Accident data is often implemented in the task analysis of specific driving situations. Evidence suggests that driver workload is correlated with detection failure and accident risk (Hancock et al., 1990). More common, however, are studies which analyse the relationship between accident statistics and driver characteristics (Forbes, 1972; Fahrenkrug & Klingemann, 1993; Peck, 1993; Sivak, 1981). The validity of these studies is limited by single factor approaches and broad assumptions about accident causation. In contrast, there are a lack of holistic approaches to the epidemiology of traffic accidents which accommodate the combined effects of multiple factors. For instance, a 'systems' model approach would interpret traffic accidents as a failure within the person-machine-environment system. Where apparent failure occurs is open to interpretation (Willumeit et al., 1981).

Research designs. Accident data can be obtained from several sources using different research methods. A common method of investigation are large scale studies using archival data. However, archival records are often unreliable due to changes in policy and documented recording of events (Elvik, 1988; Nicholl, 1981; Zimolong, 1981). Apart from these types of classification errors, archival sources may be insufficient when used out of context (Nicholl, 1981). Hospital injury data, for example, should not be viewed without subsequent analyses of vehicle and accident characteristics, despite the fact that extent of injury (human consequences) is the most accepted index of accident severity.

Interview and questionnaire techniques are also used to collect accident data. Here, a more complete and integrated picture of individual drivers is possible through differentiating accident types. For example, one study of persons with CVA obtained accident data using operationally defined categories such as minor incidents and incidents causing damage which were/were not reported to an insurance company (Simms, 1985b). Similarly, Cooper (1990) used an interview technique to elicit more qualitative data on accidents among several groups of older drivers. This type of data would appear to be a better indicator of driving patterns and is more relevant to drivers with impairment where numerous small incidents are equally important in an overall configuration of driving (Simms 1985b). On the other hand, there is a reliance on self-report and memory for events over what is a highly sensitive topic.

Other research designs have examined the interplay between a number of individual and environmental factors. For example, one longitudinal study examined accident characteristics of older drivers, with emphasis on responsibility for self-caused accidents (Hakamies-Blomqvist, 1994). Here, accidents caused by the older subjects were different from the younger comparison group. Older subjects had more accidents at intersections, caused either by the subject not seeing or not acting quickly enough to another vehicle turning into their path. In another study, which adopted an integrated approach, the role of driving exposure in crash risk between drivers and driving environments was examined (Chipman, MacGregor, Smiley & Lee-Gosselin, 1993). Here, there were apparent differences in crash risk per kilometre which could be explained by differences in typical driving speed and environment, regardless of personal factors examined (e.g. age, gender). Further, exposure time was better than distance in explaining crash risk among drivers and regions with very different driving patterns and environments.

Analysis of accident data. The use of group data for making assumptions about the individual is problematical, regardless of whether data is derived from archival or other sources. Research shows that accidents are highly variable, and thus may not be a valid indicator of driving behaviour for within subjects analysis, let alone between groups of subjects. Generally, there is a poor correlation between accidents in one period and accidents in another (Hauer, 1986), although this is also dependent on what time frames are used for data collection. In this regard, Forbes, Nolan, Schmidt & Vanosdall (1975) note that the "inherent unreliability of low probability events such as accidents makes predictive validity essentially impossible at the individual level" (p.273). However, they regard that accident data may be of practical use in the comparison of large groups of drivers over relatively long time periods.

Interpretation of any data set is also limited by the range of different driving situations from which the accident data is taken. As highlighted by Cooper (1990), most studies do not include contextual factors such as driving conditions, the impact of stress or fatigue, or whether the accident was the fault of the driver in question. Michon & Fairbank (1969) provide the anecdote of the driver who is not involved but may be the cause of the accident itself!

Overall, there are many constraints on the use of accident data as either correlates or predictors of driving behaviour. The predictive power of individual data is controversial because of high variability and the way in which analysis collapses numerous factors. Evidence suggests that many characteristics of individual drivers lack stability in certain driving situations, and therefore, cannot be used as overall predictors in accident involvement (Forbes, 1972: Sivak, 1981; Hauer, 1986).

Human factors and traffic accidents

Not all drivers share equal risk of accident involvement. Some early studies have examined the role of information processing as predictors of accident involvement. In one study, subjects with similar driving experience were tested for their abilities to process information, measured as simple and choice reaction time (Fergenson, 1971). Interestingly, there was a significant interaction between a slowed reaction time and both accident and violation records. Similarly, Mihal & Barrett (1976) took laboratory measures of field dependence, selective attention, and complex reaction time, and found a significant relationship to accident involvement in commercial drivers. In contrast to Fergenson's (1971) findings, however, simple and choice reaction time did not show a statistically significant relationship.

Personality factors have also been implicated in accident involvement. In a frequently cited study by Loo (1979), Eysenck's extroversion dimension was examined at the subscale level. When the subscale 'impulsivity' was broken into primary components, measures of sensation-seeking and decision time were found to be related to measures of driving behaviour. Fast decision time was positively correlated with frequency of accidents, however, this effect was not statistically significant when partialled out from other measures. This finding has been supported by subsequent studies using the Eysenck Personality Questionnaire (EPQ) (Jin et al., 1991).

In other studies, the role of social deviance, Type A behaviour patterns and decision making style were examined in relation to accident frequency (French, West, Elander & Wilding, 1993; French, West, Elander & French, 1993). Data, obtained for drivers from the general population over a three year period, indicated that of these personality factors, social deviance was positively correlated with accident rates independent of age, gender and annual mileage. Consistent with other studies, the relationship between personality and accident rate appeared to be mediated by faster driving speed, that is, subjects with a tendency toward sensation seeking drive faster and take more risks.

Evidence suggests that other single human factors are implicated in traffic accidents (Roberts, 1971). In this regard, it is interesting that accident frequency appears to be the most common driving fitness criterion for older drivers (Retchin & Anapole, 1993; Hakemies-Blomqvist, 1994) and in individuals who suffer from epilepsy (Andermann et al., 1988; Hansotin & Brost, 1993), dementias (Lucas-Blaustein, Filipp, Dungan & Tune, 1988; Madeley, Hulley, Wildgust & Mindham, 1990), psychiatric disorders (Noyes, 1985), and, alcohol and drug impairment (Fahrenkrug & Klingemann, 1993). However, recent multivariate studies have found that a combination of human factors (especially age, experience, and, prior traffic violation) correlate with accident likelihood. Still, no single variable, or combination of variables can be causally-implicated in accident frequency (Peck, 1993). Therefore, it is controversial to stereotype subgroups as being accident prone (McKenna, 1982; Wilson & Jonah, 1987).

Neuropsychologically-impaired driver studies. Accident data is frequently implicated in research on neuropsychologically-impaired drivers (Sivak et al., 1981;

Simms, 1985b; Katz et al., 1990; Priddy et al., 1990). However, an actual index of documented accidents is hard to come by since quantitative methods are the main source of analysis employed. Furthermore, defining actual reference populations for any specific group of drivers is a major problem (Elvik, 1988). Although the relationship of specific deficits to traffic accidents has not been established, the presence of neuropsychological impairment has been shown to increase error during driver performance evaluations, (Priddy et al., 1990). Furthermore, although traffic accidents are the cause of a large proportion of head injuries (Garcia, 1993), there is conflicting evidence over whether the number of accidents is over-represented by head-injured persons as a group. Literature reviews suggest they are not (van Zomeren et al., 1987; Katz et al., 1990).

ACCIDENT AND NEAR ACCIDENT ANALYSIS

Background

Accident and near-accident analyses are alternative measurement methods which use accident or traffic conflict ratios (Sivak, 1981; Zimolong, 1981). Here, the advantage is that the data is mediated by time span, speed, and other driving conditions. Different accident/conflict ratios may be proposed for sites and types of road manoeuvres and "are suggested as a measure of the hazard perceived by the road users" (Zimolong, 1981, p.39).

As with accident data, definitional problems exist with near-accident analysis. Conflicts may be defined using a range of evasive action rules. Alternatively, a conflict may be defined in terms of potential severity, and is usually indicated by a measure of the time available to perform an evasive action. Near-accident studies are usually situation-dependent and validated against existing accident criteria for a particular setting, thus making comparisons between studies difficult (Sivak, 1981). Overall, while variability in road and traffic flow characteristics can threaten reliability of near accident analyses, these factors can also be a good source of information (Risk, 1981).

Near-accident analysis research may involve general observational recording in traffic (Egberink, Stoop & Poppe, 1988) and/or quasi experimental designs which investigate the interaction of specific variables with hazard perception (Hancock et al., 1990). These methods are reliant on subjective reporting of data (Forbes, 1972). However, such post-hoc reconstructions of multiple events that happened rapidly may be poorly observed or subject to bias (Sheehy, 1981; Shinar,1978; Shinar, McDonald & Treat, 1978). On the other hand, this type of data can be a source of important information, such as personal and emotional conditions, that may be otherwise unobtainable (Forbes, 1972).

As with accident frequency, there is inconclusive evidence for a role of human factors in near-accident analysis, particularly the psychological abilities and characteristics associated with human error (McKenna, 1982). However, Sivak (1981) notes more convincing evidence for the effects which result from physiological changes, including fatigue, aggression, alcohol, and drug impaired states (Fahrenkrug & Klingemen, 1993; Shinar et al., 1978; Thompson et al., 1993).

Neuropsychologically-impaired driver studies. Unfortunately, the use of a near-accident analysis technique derived from actual on-road driving has not been documented in available studies of neuropsychologically-impaired driver groups. Rather, simulated hazard perception has been employed in laboratory situations (Armsby, Boyle & Wright, 1989). Consequently, the majority of these studies are unlikely to identify critical skills, which, when deficient, could cause accidents due to the large gap between real life accidents and laboratory analysis (McKenna, 1982).

Overall, evidence from accident counts or other methods of accident and near-accident analysis is variable in both the general and impaired driving literature. There is no convincing evidence for the role of accident data in research on neuropsychologically-impaired drivers. Attempts to discover psychological variables which are peculiarly associated with accident occurrence have produced largely negative or ambiguous results (Little, 1970; Cantilli, 1981). Much of the variance in accident research can be explained in terms of the range of methods, analyses, and, the highly specific nature of a number of studies. More research is needed, particularly in the area of use of accident data for more qualitative and functional analysis of driving.

PRACTICAL DRIVING EVALUATION

Background

Driver licensing tests are an integral and important aspect of road safety, although in many respects licensing procedures have become a political issue in our highly mobile society, where driving is regarded as a right rather than a privilege (Engel, 1994; Wright et al., 1984). The underlying notion exists that almost every candidate presenting for a licence will eventually get one (Perkins, 1984).

Practical driving evaluation can comprise various formal and informal methods of assessing an observable sample of driving. Formal on-road driving tests are typically used to assess learner competencies in the acquisition of a driver's licence which is mandatory in most countries. These make up the bulk of all practical driving evaluations. Shinar (1978) points out that "all licencing programmes are basically tests that evaluate the potential driver's ability to negotiate safely on the road and in the presence of other drivers" (p.131). Whether this can be achieved, however, is a contentious issue, as the validity of driver testing is frequently compromised (Norcini, 1994; Haladyna, 1994). Other formal tests may avail for special licences and endorsements such as those required by taxi drivers, heavy transport licensees, and over 70's drivers. Informal methods of evaluation can include special circumstances such as an occupational therapist's evaluation of adaptive aids over an open- or closed-road course. With few exceptions, the available literature on practical driver testing appears to be deficient of the rigorous validation studies typical of psychometric testing instruments (Gianutsos, 1994).

Criterion-related validity of driving tests. Inadequate operational definition underlies many of the problems faced with establishing reliable criteria for measurement of driving. As already discussed (Chapter Two), there are few guidelines for identifying, instructing and promoting certain levels or standards of driving. Thus, establishing adequate criteria which define driving competence is difficult and multifaceted (Engel, 1994, Evans, 1991; Haladyna, 1994; Norcini, 1994).

As part of criterion-related validity, content validity of practical driving tests is limited by measurement of a small range of driving skills which are directly observable in a limited environment. Consequently, perceptual motor tasks are predominantly measured by standard driving tests, while internal states such as motivation, attitude, attention, decision making, and other psychological processes, are not adequately covered (Ash, Baehr, Joy & Orban, 1988). This limitation calls into question the validity of driving test criteria as a sole predictor of the driving ability of individuals who have sustained neurological damage (Kaufert, 1988).

Similarly, the construct validity of standard driving tests is reduced by measures which neglect the extremes of a persons driving capability. In this context, Little (1970) noted that driving tests "cover only the basic minimum knowledge involved in operating a motor vehicle and in no sense attempt to measure the ability to cope with emergency situations or even with normal traffic problems" (p.265). Ethical, social, and practical implications, also prevent evaluation of many driving behaviours critical to driver safety in high risk situations. On the other hand, evidence from training and defensive driving courses does not necessarily suggest that drivers equipped for emergency situations are more able to respond effectively and safely (Evans, 1991).

Additional driving test criteria. In conjunction with practical driver testing, many formal evaluations require general knowledge of road laws and a test of visual acuity. Some also require concurrent medical examinations, although there is inadequate evidence to suggest this is valid for the general population (Little, 1970).

General knowledge of road laws is typically measured by written and oral tests. The efficacy of pen and paper tests as a component of driver licencing has been investigated using traffic violations as a criterion. However, there is a question mark over the validity of such tests for predicting safe driving (Conley & Smiley, 1976). Written tests are poorly correlated with subsequent measures of road safety, partly due to acquisition of road knowledge during the course of driving (Ash et al., 1988).

In a practical driving evaluation, vision testing typically involves a test of visual acuity only (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners*, 1990). Despite this, there is evidence to suggest that other visual factors are relevant, and maybe more important in the driving process. In general, little research has examined the effectiveness of other physiological and medical criteria, as used in conjunction with practical driver testing. Both visual and medical factors, as individual characteristics of drivers, will be discussed in forthcoming Chapters.

In the case of the neuropsychologically-impaired driver, Simms (1987) points out that it is crucial that existing medical and visual bars to holding a licence are diagnosed early in the assessment picture. Simms (1987) stresses that these need to be separate criteria not to be confused with other assessment issues.

Predictive validity and reliability of driving tests. The principle aim of a driving test is to prescribe a level of driving skill or driving competence. However, Wright et al. (1984) state that there is no clear evidence to support that a standard licencing test score can predict performance post licence, particularly in the case of learner drivers. They argue that "a driving test may perform the valuable function of setting a basic criteria for skill but we cannot expect the pass/fail judgement made in the test to convey anything more that at the time of testing the applicant did, or did not perform safely. Whether the driver so licenced will continue to behave that way is a matter which the test cannot predict" (Wright, Hatten & Perkins, 1984, p.183).

Reliability of driving tests is compromised by a lack of repeatable measurement due to variable testing situations, routes and assessors. As with other measures of functional ability, it is almost impossible to control for situational and motivational variables as well as other performance-related factors inherent in the testing of individuals (Kaufert, 1988). Cross validation of test results is, therefore, a major problem.

Inter-rater reliability has clearly been found to differ as a function of the type of driving test used. In particular, inter-rater reliability ratings of tests based on clearly defined specific tasks tend to be higher than ratings for more global and continuous driving evaluations. In this respect, Perkins (1984) stresses that possible improvements to increase the reliability ratings of some tests may be at the expense of validity as it pertains to the interrelatedness of behaviours and the traffic environment. A study by West et al. (1993) observed driving over a predefined urban and motorway test route, and found good interrater reliabilities for overall skill and safety ratings. However, the level of agreement differed for individual variables which made up these global ratings. That is, agreement was higher on some of the more clearly defined variables such as speed (determined from odometer readings) and lower for more subjective measures such as 'preferred distance to car in front'.

Examiners can have slightly different criteria for rating driving behaviours. In addition, the reliability of the assessment may be affected by time frames and definitions of when behaviours begin and end. Continuous rating runs the risk of examiners missing some behaviours in the process of recording others. For some practical tests this is overcome by having defined rating and recording periods (Wright et al., 1984). An examiner's position in the vehicle and the slightly different visual angles that result have been considered to affect inter-rater reliability. One examiner is usually positioned in the front and one examiner in the rear of the vehicle when ratings of the same sample of driving behaviour are made. Further, the potential threat to the safety of vehicle occupants has also been found to have an effect on examiner reliabilities. For example, Forbes et al. (1975) found a significant difference between examiners on aspects of skill, especially when "observers experienced difficulty in focusing on psychomotor skill behaviour only and ignoring potential hazard" (p. 269). Similarly, while variables such as calmness and attentiveness had good inter-rater agreement in the West et al. (1993) study, the variable 'aggressiveness', which suggests a risk factor while driving, did not reach such a high level of agreement. In the literature, the use of trained examiners or observers has consistently shown to improve the reliability of practical driving measurement.

Neuropsychologically-impaired driver studies

In the practical assessment of neuropsychologically-impaired individuals, both closed- and open-road driving measures have been used. In many cases, a lack of description of exact measures and administration procedures creates problems when different studies are compared. Documented below are those studies which provide a more detailed description of various practical driving measures.

Closed-road measures. Closed-road measures are usually informal evaluations which involve driving a course, such as a carpark or section of a road, without interaction with other motorists. With this limitation, closed-road measures are best used as part of an overall assessment incorporating open-road tests, although some studies have relied on closed-road measures alone. As an example, Stokx & Gaillard (1986) conducted a study of neuropsychologically-impaired subjects and controls over a closed section of a highway. On the four elementary driving tasks which were assessed, there were no statistically significant differences in the number of errors between the two groups, although performance was slower among the neuropsychologically-impaired subjects. In another study, Gouvier et al. (1989) compared neuropsychologically-impaired, spinal cord-injured and able drivers on eight driving manoeuvres over a large closed course. This closed-road measure correlated well with small scale vehicle and psychometric measures in distinguishing between groups of drivers, with neuropsychologically-impaired drivers performing significantly worse (Gouvier et al., 1989). Unfortunately, the relationship between closed-road course and actual on-road driving was never established in this study. The practical utility of the closed-road measures as a driving criterion was therefore unknown.

The relationship between closed- and open-road driver evaluation has not been well documented, although it is recognised that closed-road courses have limited scope and lack interaction with other traffic (Gouvier et al., 1989). As with simulated driving, closed-road measures are, at best, more appropriate as tools for driver training and evaluation of adaptive aids than for actual driver testing (e.g. Quigley & deLisa, 1983; Jones et al., 1983: Simms, 1981, 1984).

Open-road driving measures. Open-road driving measures are undertaken in real traffic conditions and comprise a range of evaluations, formal and informal. Overall, data suggests that neuropsychologically-impaired individuals may perform less well than controls on practical open-road driving measures, although there is considerable variability among results. This variability is considered to be a function of a wide range of impairments and the different driving measurement criteria used. For the assessment of neuropsychologically-impaired drivers, open-road driving measures may be specifically developed or adapted from existing general driving tests.

Wilson & Smith (1983) developed a driving assessment for individuals with CVA which comprised a 20-minute drive in city and motorway traffic to a private road. Specific manouevres such as backing and three-point turns were included. Scoring was based on a task analytic framework, with specific items of the test drive being rated independently. Inter-rater reliability was deemed to be high. Results showed that subjects scored significantly worse on a number of items throughout the assessment. A factor analysis revealed that these poorly performed items loaded highly onto categories of visual searching skill, lane position, speed control and skill in coordinating separate visual scans, accounting for 74% of the overall variance.

Another study of drivers with CVA utilised a number of the test items from the Wilson & Smith (1983) study (Nouri & Tinson, 1988). Here, two independent raters (the researcher and a driving instructor) assessed each subject at the same time over the same piece of driving. In this study, individuals' driving performances were independently categorised into good, average, borderline or below standard, by each rater. Results showed only fair agreement between raters, although many of the neuropsychologically-impaired subjects were judged borderline or below standard.

In a well known study, van Zomeren et al. (1988) used two practical driving measures and a series of neuropsychological tests in the assessment of neuropsychologically-impaired subjects with matched controls. The principal on-road measure was the formal 'Test for Advanced Drivers' (Groningen- The Netherlands) which focuses on traffic insight and risky habits over a set course and uses a more general functional rating procedure. Another important feature of this test is that assessment is designed to offer a self-critical evaluation intended for all drivers. Results for the Test for Advanced Drivers (60 minute course) showed a tendency for poorer performance by the neuropsychologically-impaired subjects, but no statistically significant differences in the number of identified errors. Importantly, qualitative information suggested that the type of errors made by neuropsychologically-impaired subjects were a greater threat to traffic safety. In the same study, an informal test, comprising an on-road lateral position control driving task was also conducted, which required subjects to maintain a straight course at 90km/hr over 60 km on a four lane highway. With this measure, subjects in the neuropsychologically-impaired group performed significantly worse than the control subjects, although the performances were still within the normal range for all but one subject.

Another study used a 30-minute administration of the 'Test for Advanced Drivers', on a sample of 20 subjects with neurological damage (van Wolffelaar et al. 1987). In addition, subjects were evaluated using a tracking simulator, neuropsychological tests and two informal driving measures. These driving measures comprised the same test of lateral position control used by van Zomeren et al. (1988) and a traffic merging task.

For the traffic merging task, subjects were in a parked vehicle at a crossroad, and were asked to respond whether it would be safe to emerge in traffic each time a warning signal lit up in their vehicle. On the Test for Advanced Drivers, the subjects' performance was lower than for the general population, although only two of the 20 subjects did not pass the test. Neuropsychologically-impaired subjects displayed significantly larger swaying amplitudes on the lateral control tasks compared with controls which was consistent with van Zomeren et al. (1988). Furthermore, neuropsychologically-impaired drivers exhibited a longer than average decision time on the traffic merging task.

Hartje et al. (1991) used the standard German driver licensing test 'Technische Uberwachungsvereine TUV' and a series of psychological tests to assess a large group of neuropsychologically-impaired subjects. Results showed that a high proportion (55%) of subjects failed the practical test. Multiple regression analysis indicated that the 'careful observation' component of the driving test, which indicates degree of traffic insight, was one of the best discriminators for pass or fail on the driving test. Thus, lack of insight was characteristic of those subjects who performed poorly.

Graduated driving evaluation. In the neuropsychologically-impaired driver literature, a variation on standard driving test procedures are graduated driving assessments which rely initially on closed-road measurement, on the basis that risk is diminished by allowing progression to an on-road driving evaluation.

Graduated driving evaluation methods have been used in a number of studies on neuropsychologically-impaired drivers (Cimolino & Balkovec, 1988; Engum & Lambert, 1990; Galski et al., 1990, 1992). Here, a practical driving evaluation is incorporated only when satisfactory performance has been achieved on other measures. A consequence of this approach is that the proportion of positive outcomes on open-road driving assessments presumably increases when the poorest subjects are eliminated. Success rates for on-road driving tests can be seen to be quite high. However, inconsistent findings (Galski et al., 1990, 1992) suggest that the use of exclusionary tests as predriver assessment criteria must be cautioned. In one of these studies, an occupational therapist conducted an evaluation of 26 tasks, "that were believed to require an integration of basic driving skills with adequate processing speed and other executive abilities (e.g. judgement)" (Galski et al., 1990, p.710).

Assessment was initially on a closed-road course and then progressed onto open-road driving. Despite good face validity, only six of the 26 closed-road items (caution, backing up into a lot, braking, parking on a grade, lane use, and, indicating right of way) correlated with pass or fail on the open-road. Simulator and psychological testing measures in this study also bore little relationship to open-road driving outcome, possibly due to ceiling effects inherent in the design of this study.

Replication of this same study, however, found quite different results (Galski et al., 1992). In the subsequent study, 64% of the on-road driving outcome was accounted for by the closed-road course results. Behavioural indices (inattention and distractibility) were shown to be more important than operational measures (performance of actual driving manouevres) in differentiating neuropsychologically-impaired subjects.

While these results are promising, it is unclear whether such methods are effective in predicting driver abilities of neuropsychologically-impaired persons nor drivers in the general population (Croft & Jones, 1987). There is no evidence to suggest that a performance level on closed-road evaluation might serve as a cut-off for determining whether the subject should be assessed on the open road.

Overall, research into practical driving assessment reflects both the need for a wider theoretical base, and the difficulties encountered with performance and its measurement. While practical driving assessment encompasses a range of methods, formal standardised test procedures are predominantly the domain of new driver licencing. Validation and reliability studies are especially lacking in more specialised areas of driver evaluation. In particular, driving assessment in a rehabilitative context is an area which requires further investigation. Available studies demonstrate that current driver testing is limited by a lack of appropriate standardised measures and use of tests which have not been examined in terms of suitability for evaluation of neuropsychologically-impaired drivers. Current research on neuropsychologically-impaired drivers has found inconsistent results, partly as a consequence of a wide variation in assessment methods employed.

SELF REPORT EVALUATION

Background

The use of self-report data as an evaluative technique is a relatively recent development in the field of driving evaluation, and is recognised for having important theoretical and practical implications (McKenna, Stanier & Lewis, 1991). Research has focused largely on independent and comparative driver self-perceptions, on dimensions such as driver safety and competence. Advantageously, self-report measures are relatively simple and inexpensive to use. However, their validity and reliability tends to be variable (Cutler, Kravitz, Cohen & Schinas, 1993; Holland & Rabbitt, 1992; Rocca et al., 1986). There is a need for standardised measures of individuals' perceptions of driving and for more information on understanding the psychological processes involved in self-report measurement (Turrisi & Jaccard, 1991).

Independent driver ratings

There is contention over the accuracy of self-reported driver ratings when compared with other driving and driving-related measures (Holland & Rabbitt, 1992; Priddy et al., 1990; West et al., 1993). Importantly, however, self-report research covers a wide range of driver dimensions and uses different types of measures. For example, self-reported judgements relating to more complex variables, such as the effects of a progressive disease or the evaluation of one's visual ability, tend to be less accurate. There also seems to be greater discrepancy in personal perceptions as opposed to more general self-report judgements within the driving environment.

Several studies have investigated the potential role of driver self-report ratings in driving performance. One notable study examined older male driver's perceptions of their driving abilities combining a detailed self-report questionnaire with other measures (Cox, Fox & Irwin, 1989). Results showed that self-report indices were independent of actual driving and visual perception measures (Fox, 1989), as well as actual driving and motor skills (Cox, 1989). Subject self-reports overestimated measured abilities, with the exception of quite realistic self-perceived judgements of cognitive driving-related skills (Irwin, 1988). This latter finding is consistent with Priddy et al. (1990). Holland & Rabbitt (1992), however, found that subjects were generally unaware of age-related sensory and cognitive deficits in relation to their driving. Here, subjects who did perceive declines in ability also reported making sensible adjustments, and reported fewer accidents.

In a similar vein, Cooper (1990) conducted a large scale factor analysis of 5,000 accidents involving elderly drivers. This study revealed a fairly clear pattern of subject's driving perceptions. Self-reports were congruent for details such as weather conditions and driving manoeuvres, but not driving assessment proficiency when measured against driver accident criteria. Furthermore, interviewed subjects overwhelmingly reported more cautious and defensive driving habits. Almost all subjects felt they were of average (41.4%) or better-than-average (57.5%) driving ability. These results found a negligible decrease with age.

West et al. (1993) compared responses to a self-report questionnaire on driving style with driving assessment of a pre-defined urban motorway route. Here, self-reporting on certain aspects of driver behaviour could be reliably used in place of observational measures, notably driving speed and calmness. Observed driving speed also correlated with self-reports of accident involvement, while observer ratings of attentiveness and calmness correlated significantly with self-reports of 'deviant' driving behaviour.

Wilson & Wilson (1984) employed a questionnaire to obtain self-ratings of driving performance from volunteers who drove a test route. Compared with ratings of two trained observers who rode with each subject, results actually showed that subjects tended to assess their driving to be poorer overall. Factor analysis identified simple vehicle manipulation, vehicle manipulation in response to road, and other road user aspects (social components) as key variables. Road user or social components accounted for over half the observed variance among drivers and was deemed the most important area for research into self-evaluation.

In another recent study, neither self-report nor caregiver perceptions of driver ability consistently predicted performance of an on-road driving test which compared persons of mild and very mild senile dementia against matched controls (Hunt, Morris, Edwards & Wilson, 1993). Five of the 13 subjects in the mild group were judged unsafe drivers although this bore little relationship to the self-assessments made.

Comparative driver ratings

Positive self-bias is a phenomenon prevalent in all aspects of human behaviour (Arthur, 1966; McKenna, 1991). In driving performance, self-bias has been explored by a number of studies which make use of 'self' versus hypothetical 'other' or 'average' driver comparisons. The advantage of this type of scale is that validity of self-ratings is established against other driver criterion, providing insight into the perceptions involved. This method has also established that ratings indicate a positive self-bias rather than a downward comparison since other drivers are generally perceived to be of average skill (McKenna et al., 1991). Most studies find that self-ratings of driver behaviour tend to be overestimated, thus, individuals perceive themselves as more skilled across a number of driving dimensions (Svenson, 1978, 1981; Matthews & Moran, 1986; McCormick, Walkley & Green, 1986; McKenna et al., 1991), and less likely to be involved in accidents than their peers (Finn & Bragg, 1986; Holland, 1993; Guppy, 1993).

Interestingly, variations in the extent to which subjects overestimate their driving ability have been found for different populations (Zaidel, 1992). Average self-ratings of a New Zealand sample (McCormick et al., 1986), for instance, were found to be lower than ratings of American drivers despite the fact that both groups demonstrate positive bias. Further, a study by Turrisi & Jaccard (1991), for example, showed that alcohol-impaired drivers self-report differently, giving even more distorted and inflated views of themselves. Similarly, Guppy (1993) divided subjects on the basis of drinking and speeding violation history, and found that offenders perceived lower accident apprehension probabilities overall. This type of result suggests that there may be important implications for driver assessment and education.

Self ratings are influenced by a number of factors. Studies of driver perception have also taken into account the relationship between self-ratings and driver characteristics. Experience, gender, and age have all been implicated, although findings are mixed. McKenna et al. (1991) noted that positive self-bias was slightly reduced with experience, a finding which relates to Spolander's (1983) proposition that subjective driving skill is seen to influence driving style in young drivers. Evidence suggests a link with gender in which males highly overestimate their driving (McKenna et al., 1991). Consequently, self-evaluation measures and self-report of driving habits may have more predictive validity for female drivers (Cutler et al., 1993). A number of studies have found weak age effects in which middle aged drivers perceive themselves more realistically than older or younger counterparts (Holland, 1993; Guppy, 1993).

Many results suggest a combined effect of a number of factors in driving self-perceptions. For example, Holland (1993) found that age and driving experience (mileage) were not statistically significant independent predictors but when combined together with perceived control over the scenarios rated, these variables accounted for a significant amount of variance in subjects' ratings. Similarly, Guppy (1993) reported that age bias varied on the basis of perceived influence of skill for different driver scenarios.

Apart from the apparent contribution of a number of factors to an individual's perception of his or her driving, the wide range of self-report measures in the literature is problematic. While some studies have focused on specific bipolar semantic scales as a source of self-report data (McCormick et al., 1986; Wilson & Wilson, 1984; Svenson, 1978), others have used a more global rating scale across several statements (Cutler et al., 1993) or different driving scenarios (Guppy, 1993). The validity of either type of measure can be questioned in terms of realism and perception of meaning, although there is no available research which compares the effectiveness of the two methods. While both types of scale appear to be useful, the latter may give more insight as it is situation specific.

Neuropsychologically-impaired driver studies

The use of self-report data in neuropsychologically-impaired driver studies suggests that individuals' perceptions of deficits following neurological damage have implications for decisions to drive, as well as for use of coping strategies and compensatory techniques (McKinley & Brooks, 1984; McLean, Dikmen & Temkin, 1993). Evidence suggests that these driver self-perceptions may be related to severity and type of injury (e.g. Cicone, Wapner & Gardner, 1980). Self-report techniques are also invaluable in an educational and rehabilitative context, as they can assist in creating awareness and appreciation of positions held by both clients and the professionals working with them (Golper et al., 1980; Gianutsos & Beattie, 1991, McLean et al., 1993). Newcombe (1982) maintains that an individual's and relative's testimony is essential in driving assessment, particularly when it is difficult to measure driving as a function.

Crude self-report ratings have been incorporated into a number of neuropsychologically-impaired studies. In one study, the propriety of decisions were evaluated for a small sample of aphasic adults returning to driving following CVA (Golper et al., 1980). A rehabilitation team's assessment was matched against a group of aphasic subjects who had personally chosen to return to driving, and a further group of subjects who had chosen not to drive. Assessment involved psychophysical, neuropsychological, and speech pathology components. This study showed that subjects appropriately judged their own driving competency. No statistically significant group differences were noted with regard to age, time since onset, nor severity of communication impairment. Notably, professionals and subjects did not always base their decisions on the same underlying criteria. Overall, however, visuospatial criteria was considered highest for both groups.

Further, Priddy et al. (1990) used structured interviews to elicit information on self-imposed limitations on driving for a small group of neuropsychologically-impaired subjects of mixed etiology. Decisions not to drive were found to rest predominantly on individuals and significant others, who were considered to have a good awareness of the limitations associated with driving. It was concluded that "a valuable contribution to the assessment of driving potential after neuropsychological-impairment would be a measure of such awareness or willingness to compensate for deficits that affect driving performance" (Priddy et al., 1990, p.271).

In another study, neuropsychologically-impaired subjects rated their own global driving performance on a six-point scale (Hartje et al., 1991). Contrary to previous studies, individual ratings were not related to actual driver proficiency as assessed by a qualified driving instructor. While almost half of the subjects were failed by the driving instructor, all but one subject rated their driving to be at least sufficient. Hartje et al. (1991) concluded "the inadequacy of self-rating of driving proficiency makes it necessary to advise patients engaged in driving (and their relatives) that any change in their medical status would call for another examination of their fitness to drive" (p.172). This study is remarkably different from those of Golper et al. (1980) and Priddy et al. (1991) in that all subjects wished to continue driving. The extent to which this would affect subject's ratings of their own competencies is an important point for consideration.

Overall, driver self-ratings are an interesting and promising area for research. Insight into the accuracy of individual perceptions of driver ability has practical implications which are unable to be obtained through other methods of measurement. For drivers who have sustained neurological damage, self-ratings may have special implications for driving again. In particular, individual's perceptions of deficit and subsequent driving decisions may be related to use of compensatory driving strategies.

Chapter Four

DRIVER CHARACTERISTICS

This Chapter reviews the role of sociodemographic and other driver characteristics in driving research. Sociodemographic and other driver characteristics are important in general driving populations, however, their impact on the neuropsychologically-impaired driver has not been systematically investigated. Here, sociodemographic and personal characteristics that are represented differently among neuropsychologically-impaired drivers may be important for describing the driving behaviour of this group. Importantly, the relationship of driver-related variables such as visual functions, or the effects of fatigue and stress, to patterns of neuropsychological impairment are also relevant. Examination of these other driving facets has implications both at the preventative level, and at the level of intervention where driver assessment and retraining methods are employed.

INTRODUCTION

The sociodemographics and other driver characteristics reviewed in this Chapter are not exhaustive, due to the large body of research available for the normal driving population. Some variables receive more attention than others in the literature, however, such emphasis should not imply that other variables are intrinsically less important. Rather, various characteristics are prevalent for different reasons. For instance, some driver characteristics are more easily measured than others. Those, such as subject age and gender, can be represented simply as discrete data points. Conversely, other sociodemographic factors, such as driver experience, are more complex and multifaceted. Definition of driver experience or acceptable visual standards, for example, may involve several different quantitative or qualitative measures. Other driving related variables have received attention because of political and social implications, such as alcohol effects on driving. In this Chapter, each driving-related variable will be reviewed separately for the sake of clarity.

Research designs incorporating driver characteristics are largely based on survey data, and are cross-sectional rather than longitudinal in approach (e.g. Friedland et al., 1988; Galski et al., 1992; Kewman et al., 1985; Legh-Smith et al., 1986; Priddy et al, 1990). A cross-sectional approach is appropriate for some sociodemographic variables, such as gender. However, one measurement of a variable may limit interpretation of other driver characteristics, particularly over time. A clearer understanding of some relationships such as age and driving experience, or patterns of driving with lifestyle changes, may be possible if longitudinal analysis and specific case studies are undertaken (Katz et al., 1990).

For driving assessment of neuropsychologically-impaired subjects, personal characteristics associated with neuropsychological-impairment can introduce difficulties into some research designs. One of these difficulties relates to subject selection. Some research samples satisfy certain selection criteria, but others comprise amorphous subject groups where variables such as type of neurological damage or subject age, are not accounted for. With multivariate analytical approaches, the etiology of some neuropsychologically-impaired driver samples is important. Subject groups with cerebral vascular accident (CVA) or dementia, for example, may have similar driving experiences, attitudes and sociodemographics due to their particular age cohort. These factors may therefore contribute to a negligible amount of overall variance as compared to a more general neuropsychologically-impaired driver sample. Unfortunately, some research designs are constrained by small sample size and lack of subject description (van Zomeren et al., 1987).

Driver characteristics are important factors in the analytical approach taken by studies of neuropsychologically-impaired drivers. The emphasis of single factor studies may differ from multivariate approaches, where a number of variables are simultaneously investigated in the individual. Single factor studies may distort the importance of certain driver characteristics in the absence of an integrated model of driving. On the other hand, multivariate analyses can be limited by arbitrary categorisation of driver characteristics into specific dimensions or sets. Cutler et al. (1990) exemplify this point with the Driving Appraisal Inventory (DAI), where several behavioural characteristics are amalgamated into a driver 'carelessness' dimension.

SOCIODEMOGRAPHIC VARIABLES

Age

Age is utilised when setting legal limits on driving and is more frequently related to aspects of driving behaviour than any other sociodemographic variable. Age has been correlated with many facets of driver performance and behaviour (Ball & Rebok, 1994; Hartje et al., 1991; Planek, 1981; Retchin, Cox, Fox & Irwin, 1988; Spolander, 1983), driver risk-taking (Brown, 1982; Finn & Bragg, 1986; Hemenway & Solnick, 1993; Jonah, 1986a, 1986b), incidence of motor vehicle accidents (Eisenhandler, 1990; Evans, 1991; Hakamies-Blomqvist, 1994; Retchin & Anapolle, 1993), and, self-evaluation of driving (Guppy, 1993; Holland, 1993; Matthews & Moran, 1986). However, the relationship between age and driving is complicated by several contributing factors. There is also considerable diversity into how the relationship between age-related factors and driving has been investigated.

Most of the age-related research focuses either on the young or elderly driver, with little evidence of patterns which may occur between these two extremes. Problems exist in defining these groups of older or younger drivers, with studies using different age ranges. One literature review chose not to include research based on broad description of young drivers, maintaining that driving of a 16-year old cannot be likened to that of a 25-year old given that a wide range of experiences may change behaviour in these formative years of driving (Jonah, 1986). Planek (1981) noted inconsistencies in setting the lower age limit for elderly drivers. The various restrictions already in place for older drivers can also have a confounding effect on how this population is defined. A number of questions concerning driving behaviour of older adults have been raised as a result of the increasing aging population in the Western world and the concurrent increase in the number of elderly drivers (Retchin & Anapolle, 1993). Research findings stress that "aging is important to the consideration of road safety in so far as it involves changes in driver performance" (Planek, 1981, p. 171).

Age and accident risk. There are mixed conclusions over the relationship between age and driving. Planek (1981) maintains that driver performance, measured in terms of number of accidents and taking into account miles driven, follows a U-shaped curve with age. However, in their review, Retchin & Anapolle (1993) state that accident rates are not substantially higher among older drivers after adjusting for mileage. Based on empirical findings, several important features are noted with regard to drivers of differing ages. In particular, type of accidents reported are different, and responsibility for causing accidents appears to proportionally increase for elderly drivers (Cooper, 1990). Another consideration is that accident statistics are subject to variable influences across the age groups. Epidemiological studies show that younger drivers are at greater risk of being involved in causality accidents than their older counterparts (Jonah, 1986b). On the other hand, older drivers are more vulnerable to injury and are therefore more susceptible to becoming accident fatalities (Planek, 1981).

There is a complex relationship between age and driving experience. A longitudinal analysis, comparing different age cohorts, found that fatality rates declined with increasing birth year (Cooper, 1990). This result was largely explained by driver experience which accumulates with years of driving (Evans, 1993). Different conceptions of driver experience, however, need to be taken into consideration, given that experience is not entirely time-dependent (Spolander, 1983). When comparing cohorts, one must consider the role of driver training, better road conditions, safety of modern vehicles, as well as an increased chance of survival from a medical perspective.

Age and driving ability. Age plays more than just a chronological role in relation to driving ability. Planek (1981) indicated that chronological age alone does not reflect a person's skills or capacities. Rather, age affects both driving behaviour and performance in terms of age-related factors or life stages. That is, as a consequence of the ongoing process of change in biological, social and psychological factors which occur at different rates for different individuals (Marottoli, 1993). There are different conclusions regarding age-related changes in psychophysical capacity (Ball & Rebok, 1994; Colsher & Wallace, 1993; Korteling, 1990; Marottoli, 1993). Evidence suggests that visual functions, search and detection of cues, paced task performance, short term memory, problem solving, and decision making all decline with age. Due to individual variability, however, the importance of these in relation to any driving criterion is unclear (Planek, 1981). Psychologically, inconsistencies can also be related to the over-learned nature of the driving task and the evidence for compensatory techniques used by some individuals. Both of these phenomena have been documented in investigations of psychophysical deficits on driving (Brouwer, Rothengatter & van Wolffelaar, 1988; Eisenhandler, 1990; Hakamies-Blomqvist, 1994; Planek, 1981; Spolander, 1983).

Actual driving ability may not deteriorate with age, particularly when individuals can make use of driving behaviour strategies to compensate for cognitive or physiological deficits. In one notable study, Hakamies-Blomqvist (1994) investigated safety implications for the use of compensatory strategies in driving behaviour. Fewer accidents associated with night driving, poor road or weather conditions were recorded for the older drivers; who were also less likely to be hurried, intoxicated or distracted by stressful non-driving events. Responsibility for accident causation was not statistically significant in relation to any of these variables in the older driver group.

Age and driving attitudes. Driving behaviour appears to be closely related to stages in the life cycle (Furnham & Saipe, 1993; Hemenway & Solnick, 1993; Jung & Huguenin, 1992). Notably, younger and older drivers can be contrasted on the basis of social psychological and personality factors. Although the exact nature of these relationships is unclear, they almost undoubtedly incorporate age-related perceptions, attitudes and beliefs (Cosher & Wallace, 1993). For instance, evidence suggests that increased risk acceptance and willingness to commit traffic violations is more typical of young drivers. Greater risk-taking by younger drivers is also consistently supported by observational studies and self-reported data (Evans, 1991; Hemenway & Solnick, 1993).

Driving outcome may be also mediated by more complex relationships. Differing accident statistics for younger and older drivers can be explained by differences in typical driving speed and environment (Chipman et al., 1993; Waseilewski, 1984). Other safety-related factors such as seat belt use and type of vehicle (Jonah, 1986; Shinar, 1978), miles driven (Retchin & Anapolle, 1993), amount of night driving (Warren & Simpson, 1976), and, alcohol impairment (Jonah, 1986a; Mayhew & Simpson, 1983), have all been considered to mediate accident outcome. Part of the difficulty in interpreting such findings is the underlying assumption that risk factors and driving ability are causally related. Cooper (1990) also makes a point that media attention and social stereotypes help to promote certain images of drivers across the age groups. Evans (1991) draws attention to the use of vehicles for motives other than driving such as an outlet for independence and peer acceptance. Despite an absence of controlled studies, this phenomenon is almost certainly significant in the enhanced motor vehicle accident rates of younger drivers.

Driver's personal perceptions and risk evaluation are frequently unexplained despite the importance of age-related factors in self-perception of driving behaviour (Cooper, 1990; Finn & Bragg, 1986; Groeger & Brown, 1989; Jung & Huguenin, 1992; Lourens, 1992; Matthews & Moran, 1986; Spolander, 1983). The research has only recently recognised these as important, especially where there are implications for intervention and implementing social change. In a behavioural analysis of young drivers, Jung & Huguenin (1992) identified a number of influences on driving behaviour including need for stimulation, age-related values, family life, mass media influence, performance orientation, inexperience with alcohol, educational factors, and financial upkeep versus safety issues. In this, and other similar studies, it has been proposed that young drivers can be influenced toward a safety-oriented view of driving, rather than believing it to be mainly important as an activity (Jung & Huguenin, 1992; Lourens, 1992, Zaidel, 1992).

Age may also be a relevant factor in self-ratings of driving behaviour. Coupled with lack of experience, younger drivers were less likely to realise their limitations for driving (Spolander, 1983). Mathews & Moran (1986) investigated different types of self-report evaluation and found that younger drivers were more confident in their ratings overall. Self-ratings of younger drivers showed a marked dissociation between perceived and actual ability as well as a tendency to view themselves as immune from higher levels of driving risk. This result was not typical of the older drivers. In another study of personal ratings, Holland (1993) found that amount of self-bias decreased with increasing age and was independent of years of driving experience. Further, Guppy (1993) found a tendency for self-bias in all drivers with only weak age effects.

In summary, age does appear to be an important variable in relation to driving, although the exact nature of the relationship is unclear. Variable age-related effects have been found for both driver performance and behaviour measures. There are methodological problems with sample definition and choice of driver measurement criteria.

Age and neuropsychologically-impaired drivers. Age has not been systematically investigated for neuropsychologically-impaired drivers. However, one review does raise the question of age-related effects (van Zomeren et al., 1987). Age-related effects have been also consistently documented in driving simulation research.

From available evidence, there are similar trends between studies of subjects with neuropsychological impairment and subjects from the normal driving populations. Such studies have shown that older subjects have greater difficulty acquiring or adapting to a driving-simulated task (Cimolino & Balkovec, 1988; Crook et al., 1993). Thus, there are important implications in choosing simulator evaluation with older driver populations.

Other neuropsychologically-impaired driver research which relies heavily on laboratory-based cognitive tasks has also documented age-related effects, with older subjects scoring less well. Engum et al. (1990a) found age to be a confound in comparing neuropsychologically-impaired subjects with controls in their study. Significant regression effects were found in which age correlated with a number of items in the Cognitive Behavioural Drivers Inventory (CBDI). Error scores, when corrected for age, found that differences between groups on several cognitive tasks, especially those with a timed component, were no longer statistically significant.

In relation to age, results of neuropsychologically-impaired driver studies incorporating on-road driving criteria are less clear. Here, driving experience is frequently confounded with age. Age effects are also difficult to ascertain in many research designs, where wide age ranges are reported within subject groups (e.g. Galski et al., 1992). Alternatively, age may be characteristic of the type of neuropsychological impairment in the samples investigated (Friedland et al., 1988; Kewman et al., 1985; Legh-Smith et al., 1986; Priddy et al., 1990). Further, while a number of research designs have utilised age-matched control subjects (van Zomeren et al., 1988), the extent of possible age-related effects is seldom considered further.

Neuropsychologically-impaired driver research suggests that proportionately fewer older subjects are judged capable of driving (e.g. Nouri & Tinson, 1988) compared with younger subjects (e.g. Rothke, 1989). A few studies have also noted that a younger age of onset for neurological disorders such as dementia or cerebral vascular accident, is significantly correlated with continuation of driving (Gilley et al., 1991; Legh-Smith et al., 1986). Similarly, Hartje et al. (1991) found a significant interaction between aphasia symptoms, age, and practical driving ability, which showed that aphasic subjects of advanced age were more likely to fail an on-road driving test. No statistically significant differences in age-related driving performance were found for subjects without aphasia. This study emphasised the importance of examining potential interaction of age-related effects with other variables.

Overall, age-related effects significantly relate to driving performance. However, it is difficult to assess the relative effects of age from other subject characteristics, such as the nature of the impairment being investigated, or the various assessment methods used. Aside from the relationship between age and the increased likelihood of certain neuropsychological disorders and types of neuropsychological damage, age is an important variable in relation to morbidity and recovery of function (Lezak, 1995). Evidence suggests that while it is difficult to separate the effects of aging on neuropsychological deficit, subject's age at onset of neurological damage is an important factor (Lezak, 1995; Walsh, 1994). Older subjects generally have longer recovery periods and tend to show only partial improvement (Adamovich, Henderson & Auerbach, 1985; Gronwall, 1989; Lezak, 1995; Ruff et al., 1993). Here, it is difficult to assess how much recovery of function is confounded by a decline in motor and cognitive function due to the normal process of aging (Lezak, 1995). Importantly, due to progressive loss of brain tissue with advancing age, older subjects have fewer available resources to cope with neuropsychological impairment. Whatever the case, age-related effects are an important consideration in the assessment of neuropsychologically-impaired drivers.

Gender

Until recently, gender effects on driving were not systematically studied, despite existing stereotypical views. Research has predominantly focused on all male samples with little detailed analysis of gender differences. Historically, the literature has noted proportionally more males in the driving population (Planek & Fowler, 1971). Interestingly, while the proportion of female drivers has increased over the years, driving patterns for females are found to be different, with more inner city and short trips than male counterparts (Barjonet, 1988). The number of females in the older driving population, however, has always been proportionately higher, probably due to longer average life expectancies for females (Planek & Fowler, 1971; van Knippenberg & Huijink, 1988). Despite this, distance travelled annually has been found to decrease at an earlier age for females. Distance travelled by older females is significantly less than older males, however, patterns of activities is also a significant factor (Wouters & Wellman, 1988). All of these points have implications for the role gender plays in the driving literature.

Gender and accident risk. In terms of accident involvement, females are less likely to be involved in reported accidents. On the other hand, young male drivers have a higher incidence of reported accidents (Groeger & Brown, 1989; Williams, 1985). Research has sought various anatomical, social and functional explanations as to why this is the case, but no clear answers have been found. From an anatomical basis, Evans (1991) investigated the female-to-male fatality risk ratio of vehicle occupants as an explanation for gender differences. No real gender differences were found in the likelihood of injury for young and middle aged persons. Results were analysed to take into account social ramifications of where male and female occupants typically sit in a vehicle. Other social explanations for differential accident involvement of males and females have generally been poorly investigated, although different attitudes toward driving risk are thought to be important (Barjonet, 1988; Bristow, Kirwin & Taylor, 1982). Some authors refer to 'extra motives' in the use of vehicles to impress and enhance status, particularly in males, but there have been no specific studies documented (Evans, 1991; Naatanen & Summala, 1976). Mannering (1993) investigated accident trends and found that incidence of motor vehicle accidents was more variable for female compared with male drivers. Unfortunately, little could be concluded from this study due to a largely disproportionate sample size (Peck, 1994). Finally, other gender explanations may be implicated from studies which have suggested functional differences between males and females on reaction time and other psychomotor tasks (Lezak, 1995). While such tasks appear to be related to driving, specific gender effects on actual driving is unknown.

Recent evidence suggests that gender differences in accident involvement may virtually disappear when other personal and social factors, such as experience, miles driven, typical driving speed, and driving environment, are taken into account (Chipman et al., 1993; Papacostas & Synodinas, 1988). Mannering (1993) comments on the high correlation that generally exists among many driver characteristics. Consequently, there are difficulties in using traditional statistical approaches to quantify the role gender plays in the relationship between driver characteristics and accident risk (Chipman et al., 1993; Cooper, 1990; Evans, 1991; Mannering, 1993).

Some of the most interesting and useful gender-based driver data is found in self-evaluations of driving behaviour. While there is a positive self-bias in self-made judgements about driving, females consistently make more accurate ratings of their driving overall (Cooper, 1990; Cutler et al., 1993; Groeger & Brown, 1989; McKenna et al., 1991; Spolander, 1983). In one large study, for example, males rated themselves higher than the average driver on all behaviours, and across a wide range of scenarios (McKenna et al., 1991). There were several scenarios where females rated themselves less positively than males and others where females showed no bias at all in comparison to the average driver. Notably, results for the McKenna et al. (1991) study showed little difference between gender ratings of the average driver on any of the behaviours. When driver experience (years driving and weekly mileage) was controlled for, there was a small reduction in the strength of the self/average driver by gender interaction.

In summary, it appears that gender differences have no statistically significant effects on driving *performance*. However, the suggestion of gender differences in driving *behaviour*, as evidenced by self-report studies, may have future implications for designing driver intervention and education programmes.

Gender and neuropsychologically-impaired drivers. Few studies have investigated gender effects in the literature on neuropsychologically-impaired drivers. Further, most studies are disproportionately based on male subjects with samples either being exclusively or predominantly male (Friedland et al., 1988; Gilley et al., 1991; Golper et al., 1980; Jones et al., 1983; Katz et al.,. 1991, van Wolffelaar et al., 1988). While there is a slightly higher proportion of males in the total driver population, there are a number of other likely explanations for this phenomenon. First, there is greater representation of males in neurological injury statistics, both through a higher number of accidents (Dacey, 1989, Kraus & Nourjah, 1989; Lezak, 1995), and through increased likelihood of disorders such as CVA (Hopewell & Price, 1985; Lezak, 1995). Second, social factors, such as a higher proportion of males in the work force, implies that the need for males to resume driving following neurological damage may be greater (Legh-Smith et al., 1986). Overall, further consideration needs to be given to the gender imbalance in studies of neuropsychologically-impaired drivers.

Other sociodemographic variables

The effects of other sociodemographic variables on driver behaviour are not extensively documented, and only tend to be examined in terms of alcohol-related incidents, other traffic convictions and accident fatalities. With the use of this criteria, inconsistent results have been found for education, ethnic background, IQ, and occupation. In particular, the way in which all of these variables are studied suggests that the results can be explained by other related factors, particularly socioeconomic status and attitudinal variables. Individual variables such as educational, cultural, and socioeconomic background tend to be examined in the wider context of psychosocial models, such as those explaining risk management (Kidd & Houlton, 1993; Zaidel, 1992).

Research has noted that failure to control for socioeconomic and sociocultural influences may reflect some sort of bias in driving opportunities. For instance, aspects of the driving environment and certain vehicle characteristics of high versus low socioeconomic groups may predispose some individuals to the likelihood of being convicted or being involved in traffic accidents (Jung & Hugenin, 1992). With reference to education, Hemenway & Solnick (1993) found that drivers with more than a high school education were more likely to both speed and be involved in an accident. By contrast, other studies have also found higher accident and conviction rates in drivers with a poor education (McLellan et al., 1993). One explanation is that this is more a reflection of the type and image of the vehicle these individuals are more likely to be able to afford to drive than actual educational factors. Similarly, Popkin & Council (1993) maintains that the lower socioeconomic status of some ethnic groups is associated with a higher incidence of unsafe vehicles being driven. This may coincide with an increased chance of being stopped by traffic authorities, as well as an increased likelihood of accident where injury is reported.

The relationship between intelligence and motor vehicle accident criteria is also unclear. For example, van Zomeren et al. (1988) maintain that IQ, as a measure of intelligence, varies widely within a normal driving population with no apparent relation to driving skill. Conversely, O'Toole (1988) found a negative relationship between IQ and number of motor vehicle accidents. Overall, it is difficult to ascertain whether increased accident fatalities arise from lower than average ability for cognitive aspects of driving, or whether it more likely reflects socioeconomic correlates of intelligence test scores. Other explanations, such as higher IQ drivers being more susceptible to diversion from the task at hand, are also feasible.

The relationship between occupational status and driving appears to be closely dependent on socioeconomic status (Studuto et al., 1993). However, a separate body of research in the literature focuses on driver research for specific occupational groups, that is, where an individual's employment involves driving. This literature has investigated the relationship between driving criteria and various characteristics of professional drivers, such as attitudes (Shouksmith, 1989), fatigue (Hartley, Arnold, Smythe & Hanson, 1994), stress, illness and mortality (Mulders et al., 1988). Due to the specific occupational groups sampled, there are difficulties with generalising these results to the general driving population.

Other sociodemographics and neuropsychologically-impaired drivers

Consistent with the general literature, few studies have extensively described sociodemographic features of neuropsychologically-impaired drivers. Some focus has been given to intelligence, as measured by IQ test scores, and resumption of driving following neuropsychological impairment. Here, there is some confusion as to whether IQ scores should be used in a general context, or whether they should be used as indicators of impairment. Van Zomeren et al. (1988) point out that the practical value of IQ testing in driving assessment is ambiguous, as a score yields too crude an index of impairment to be of much use. A few studies have used IQ as a criterion for matching subjects and controls (Katz et al., 1990; van Zomeren et al., 1988). However, the problem arises that IQ does not differentiate between persons with low scores and those with normal premorbid scores who have sustained extensive neuropsychological damage. Gauging premorbid IQ has limitations, however, one study of drivers with dementia found that premorbid IQ and continuation of driving showed a significant positive correlation (Gilley et al., 1991).

There is some consensus that IQ may be important only when it lies at the lower limit of the normal range (Hopewell & Price, 1985; van Zomeren et al., 1988). At this level, there may be consequences for insight into the strategic and tactical levels of driving (van Zomeren et al., 1988), although this proposition does not appear to have been examined experimentally. In general, the most interesting empirical evidence comes from Hopewell & Price (1985) who found a highly significant difference between mean WAIS scores for neuropsychologically-impaired subjects who continued to drive versus those who did not. Notably, only one subject with an IQ score below 80 was judged able to drive following a practical evaluation. This particular subject had been an experienced chauffeur before his neurological damage, suggesting that experiential factors may have contributed to his overall driving ability (Hopewell & Price, 1985).

There are some sociodemographic variables associated with patterns of neuropsychological impairment, particularly as they result from injuries through motor vehicle accidents and assault (Kraus & Nourjah, 1989; Lezak, 1995). Premorbid characteristics, such as education and socioeconomic status, are important predictors of successful rehabilitation following minor head injury, but are less important when injury is moderate or severe (Dikmen, McLean & Temkin, 1986; Rimel, Giordani, Barth & Jane, 1982). Recent research also suggests that sociodemographics play a role in the rehabilitation referral process, particularly when definitive clinical evidence is lacking (Wrigley, Webb & Fine, 1994). Overall, however, there is a lack of systematic investigation of a range of sociodemographic variables in the literature on neuropsychologically-impaired drivers.

PERSONALITY-RELATED VARIABLES

It is difficult to draw firm conclusions about the relationship between personality variables and driving. In part, this is due to limitations with personality measurement (Silverstone, 1988). For example, temperament, motivation, attitudes, and styles of thinking may be viewed indiscriminately and studies are often poorly focused. Nevertheless, there are a number of interesting findings. One review suggests a link between broad personality characteristics and accident involvement under conditions where character traits are relatively stable (Evans, 1991). For many studies, accident data is the sole driving criterion, while others attempt to identify driving styles.

Personality typologies

The earliest research was dominated by the concept of an individual being 'accident prone', such that certain individuals possessed enduring character traits which predisposed them to accidents (Little, 1970). However, there was no evidence to suggest the concept was stable over time (Shinar, 1978). Recently, research has identified a number of wider approaches which contribute to the likelihood of having an accident (McKenna, 1982).

Broad constellations of 'irresponsible' and 'high risk' behaviours have also been associated with various subgroups of drivers. For instance, chronic alcohol-impaired drivers have been characterised in this way (Donovan, Marlatt & Salzberg, 1983). Shoham et al. (1984) report on a number of personality variables which profile recidivist traffic offenders. Two types of drivers, 'anxious' and 'reckless', were identified on the basis of distinct interactions between the variables impulsiveness, internalisation of norms, anxiety and sensation seeking, coupled with past history of traffic and criminal offences. In another, more recent study, a telephone survey of 1800 drivers found that personal tendency toward high risk-taking and hostility was significantly related to bad driving (Hemenway & Solnick, 1993). This study has been criticised for sampling error as well as for the reliability and validity of the data collection methods employed (Peck, 1994).

While personality and other related variables such as alcohol consumption are implicated in accident involvement, evidence is totally reliant on the results of correlational studies (Cremona, 1986; Noyes, 1985; Silverstone, 1988). In a review, Noyes (1985) considers personality variables to be poor predictors of driving behaviour due to the transient nature of many traits and the large amount of variance accounted for by situational factors.

Personality disorders

Some reviews have noted a relationship between driving behaviour and antisocial and sociopathic personalities (Evans, 1991; McGuire, 1976). Others have suggested certain personality characteristics and psychopathology, including low tension tolerance, immaturity, personality disorder and paranoid conditions, were likely traffic accident risk factors (Cremona, 1986; Tsuang, Boor & Fleming, 1985). Evidence suggests that social maladjustment is an over-represented factor in individuals involved in fatal accidents (Evans, 1991). The precedent was set in an early study conducted by Mayer & Treat (1977), who developed a series of questions and tests pertaining to 20 personality characteristics which were empirically related to driving behaviour. Subjects were matched groups of recent accident-history and accident-free students.

Discriminant function analysis identified six tests, five of these being social maladjustment measures, which differentiated the accident and accident-free groups. The research found that accident or accident-free group membership could be correctly predicted for a further 12 out of 14 new subjects on the basis of responses to the six tests.

Personality inventory scores

Relationships between specific personality subscale scores and driving behaviour have been reported in a number of general studies. For example, one group of studies attempted to discern the relationship between Type A and B behaviour, as measured by the Jenkins Activity Survey (JAS), and typical driving habits of university students (Synodinas & Papacostas, 1985; Papacostas & Synodinas, 1988). Type A behaviour related significantly to one of four dimensions of driving behaviour, namely 'externally-focused frustration'. This dimension consisted of emotional reactions to the actions of other drivers on the road, and of directive behaviours towards them. The results showed no differences between Type A and Type B individuals with respect to general freeway driving, which was perceived as relatively stress free.

The Eysenck Personality Inventory (EPI) has also been used in several driver behaviour studies. Loo (1979) examined the roles of the primary personality dimensions of impulsiveness, sensation seeking and decision time from Eysenck's Extroversion dimension in relation to driver behaviour and the ability to perceive traffic signs. Findings showed that higher extroversion was associated with poorer performance on both driving-related tasks and driver records. Furnam & Saipe (1993) investigated personality correlates of drivers convicted for speeding and reckless driving. High psychotism and low neuroticism scores were obtained using the EPI. A shortened version of the Sensation Seeking Questionnaire identified high Thrill and Boredom susceptibility scores in the convicted drivers. While convictions were positively correlated with high risk taking, they were negatively correlated with age, gender, and years driving experience. Absence of a control group was a limitation of this study. Another study used the EPI and the Sixteen Factor Personality Inventory (16PF), and found that high neuroticism and low affection subscores were primarily related to stress and ineffective coping strategies in middle-aged drivers (Dorn & Matthews, 1992).

Further studies have examined the concept of locus of control in relation to aspects of driving behaviour. Using Rotter's Internal-External Locus of Control scale, Gulian et al. (1990) found no relationship between respondents' locus of control and reported daily driving stress. This result was not consistent with empirical findings in which high internal locus of control is related to reduced stress levels. Responses to the Cognitive Failures Questionnaire, however, found that vulnerability to stress was consistently related to reported daily driving stress. Montag (1992) compared driving-related Internality-Externality (DI-E) scales with other personality scales across a large subject group. High DI subjects tended to be emotionally stable, conforming, compulsive, active, and, empathic. High DE subjects believed in external causation and tended to show low conformity, low emotional stability, low energy level, lack of compulsion and egocentricism. Gulian et al. (1990) concluded that these influences on style of thinking were applicable explanations for accident causation.

Overall, a wide range of personality-related variables may be seen to predispose individuals to high risk driving and/or to react to situations in the driving environment, placing them at higher accident risk. Current findings have implications for targeting certain characteristics and behaviours through education and intervention programmes. More research is needed, however, to systematically investigate personality effects on driving performance and behaviour.

Personality-related variables and neuropsychologically-impaired drivers. Personality-related variables have received very little attention in relation to neuropsychologically-impaired drivers, despite a number of calls for research in this area (Golper et al., 1980; Hopewell & Price, 1985; van Zomeren et al., 1988). The importance of research is emphasised where certain characteristics, emotional behaviour, and, personality changes have been implicated through neurological damage (Lezak, 1995; Walsh, 1994). Some studies concur that many of the most prominent and disabling problems associated with neuropsychological impairment are emotional in nature, and have a profound influence on adjustment and successful rehabilitation (Dikmen, Temkin & Armsden, 1989; Lezak, 1995; Prigatano, 1987). There is a lack of agreement, however, as to whether emotional and personal styles can be attributed to neuropsychological impairment (Adamovich et al., 1985; Dikmen et al., 1989; Hall et al., 1994; Prigatano, 1987). A number of reasons, including a lack of objective measurement, and premature causal inference, are given for this. Prigatano (1987) concludes that the role of pre- and post-morbid personality characteristics in relation to neuropsychological impairment has been inadequately explored.

In a review of the handicapped driver, Bardach (1971) refers to the highly individual nature of adjustment to various types of impairment, but points to the contribution of personality, emotional problems, and other transient states. Here, driving patterns are influenced by stress and circumstance which bear a direct relation to cognitive and perceptual difficulties in the case of the neuropsychologically-impaired driver. According to Bardach (1971), rigidity in responding, so often characteristic of neuropsychologically-impaired individuals, effects change on personality and is expressed through egocentricism and maladaptive anger, impulsiveness and irritability. These characteristics typify what Bardach (1971) considers to be important limitations for driving.

Overall, the evidence for a relationship between driving and personality variables in the neuropsychologically-impaired population is largely indirect. While methodological limitations are realised, further study into the effects of personality-related variables on driving behaviour may be warranted.

DRIVING-RELATED VARIABLES

Driving experience

Defining driver experience. Although driving experience is considered an important variable in research, there are inconsistencies with definition and measurement. Driving experience has been operationally defined as the result of various levels of training and education (Evans, 1991), frequency of driving or mileage covered (Chipman et al., 1993), number of years driving (McKenna et al., 1991), and as self-reported confidence at-the-wheel (Job, 1990).

No single operational definition of driving experience is an ideal measure, although the number of years and frequency of driving together may be a better indication of experience (Evans, 1991; McKenna et al., 1991). One reason for this is that age can be more effectively controlled for using both criteria. While experience may be more important than age, the relationship between these two variables is not altogether clear (Evans, 1991). Also, if driving experience is defined without an indication of how much driving is undertaken by an individual, there is the problem of differential exposure to accident risk (Chipman et al., 1993). Exposure time is even better than distance travelled in explaining accident risk, as evidence suggests that accident risk is several times higher by mileage in inexperienced drivers (Spolander, 1983). It is important to acknowledge that the various definitions of driving experience are mediated by different aspects such as driving history, regular and specific patterns of driving, and, situational variables, as well as internal driver characteristics and attitudes. For example, one multivariate study found that experience was a factor of risk. However, other aspects of driving record, particularly citation history, were among the strongest predictors of accident occurrence (Peck, 1993).

As already indicated, the criteria for gauging the effects of driver experience is typically accident rate. There are, however, a number of problems with this measure as well. First, while accident rates are highest in young drivers, this cannot be attributed entirely to lack of experience (Evans, 1991). Nevertheless, in young drivers, certain types of accident are more prevalent, particularly those seen to relate to driver skill. Second, for experienced and highly skilled drivers the relationship with accident rate is more complex, as existing driving habits and higher risk taking may offset many of the benefits gained from increased skill (Shinar, 1978). In addition, driver experience and exposure to risk are often confounded, with time behind the wheel necessary to gain experience and at the same time increasing risk of an accident because of inferior skills (Jonah, 1986). Evans (1991) makes the point that experiential factors, such as increased driving skill and knowledge, are not the most important variables in accident avoidance. Here, driver performance and driver behaviour are not treated separately in studies of risk, and situational variables are often left unexplained.

Driving experience has also been defined as a function of driver confidence at-the-wheel. Research has associated driver experience with reduced fear and increased confidence, even to the extent that it may be viewed as maladaptive (Job, 1990). Spolander (1983) found that inexperienced drivers are comparatively more stressed in emergency situations, and have a greater tendency to over-react, or to panic, than experienced drivers. In another study, driving experience also appeared to play a role in a study of driver self-evaluations (McKenna et al., 1991). When years driving and weekly mileage were controlled for, other differences in driver self-ratings were either reduced or disappeared. Consequently, driving experience may mediate driver judgements of overall driving skill and safety. In the majority of self-report studies, inexperienced drivers are significantly more likely to inflate their abilities (McKenna et al., 1991; Spolander, 1983).

Few studies have examined the effects of more than one or two years driving experience. Indeed, in some cases, there is no distinction between short- versus longer-term experience. Despite this, perceptual-motor skill components of driving are probably developed relatively early on, while other cognitive aspects, such as traffic judgement, are procured over a much longer period (Evans, 1991; Perkins, 1984). Unfortunately, there is a lack of empirical support for this notion, primarily due to difficulties in conducting experimental and longitudinal research in the area. On the other hand, learning theory suggests that driving performance is different in early stages of learning and gaining experience (Perkins, 1984; Spolander, 1983). Automation of components of the complex task results in a reduction in the amount of mental capacity assigned to basic underlying processes (Anderson, 1982; Linton & Wickens, 1991; van Zomeren et al., 1984, 1985).

When defined by educational and training criteria, evidence relating driver experience to various driving outcomes is controversial and rather scarce. Little (1970) noted that driver education course graduates have shown better accident records in the first few years than those not taking the course. However, decisions to take such courses is a self-selective process and may therefore be a confounding variable. Kroj (1981) reported no real effect of a number of driver improvement programmes in reducing young driver recidivism. In a more general review, Evans (1991) states that there is "no convincing evidence that driver education, or increased driving skill and knowledge, increase safety" (p.156). Evans (1991) believes that driver safety cannot be learned through direct feedback, as given in education courses, but "requires the absorption of accumulated knowledge and the experience of interaction of others" (p. 156). Further, another extensive literature review on the effectiveness of defensive driving courses found that traffic violations decreased, but there was no evidence for a reduction in accident rate (Lund & Williams, 1985).

Distinguishing experienced versus unexperienced drivers. The majority of studies define driving experience as number of years driving, annual mileage, or a combination of these two. In one study, simulator and instrumented car driving were compared between a small sample of newly licensed inexperienced drivers and a group of experienced drivers (Blaauw, 1982). The latter group were defined as being three years post-licence and who drove at least 30,000 kilometre annually. Overall, there was a better correspondence between simulated and instrumented car driving for the experienced drivers in tasks of varying complexity. Interestingly, experience versus inexperience could be more easily differentiated on the simulator measure, although the performance of inexperienced drivers had a much greater variance. However, results from other laboratory-based studies of driver experience tend not to support those found in the field. Most importantly, evidence for faster speeds, poorer speed adaptation in all driving situations and longer reaction times in inexperienced drivers, tends not to have been exemplified in laboratory studies (Spolander, 1983). Consequently, this raises questions pertaining to the validity of measures other than real driving in gauging the effects of driver experience.

Shinar (1978) cites the results of a study where acceleration, braking and galvanic skin response were measured for experienced and inexperienced drivers. In this study, experienced drivers recorded increased braking behaviour and increased galvanic skin response while driving over a narrow bridge, while inexperienced drivers did not. Overall, greater speed variability was observed for the inexperienced drivers. These trends are consistent with a number of other field studies. For instance, Spolander (1983) found that, although there was greater variance in the situational responses of a group of new drivers, evasive actions generally showed much slower recovery. Other studies have found that steering behaviour is more erratic in inexperienced drivers, with directional control of the vehicle requiring constant monitoring (Shinar, 1978; Evans, 1991). Further, Shinar (1978) states that the experienced driver can more readily make decisions while driving, suggesting that this is because of the automation of many basic responses so that less of a decision is involved. However, where driver reaction times are involved, age must also be considered as an important factor (Shinar, 1978).

In the case of more experienced drivers, Evans (1991) stresses that in emergency situations, full attention is able to be easily redirected onto the driving task. This is supported by results from driver eye movement studies which consistently find differences between experienced and novice drivers, with the latter apparently more unskilled and overloaded in the acquisition of visual information (Evans, 1991). Further, Brown (1982) found that distant hazards are perceived less well by inexperienced drivers, who are preoccupied with their immediate environment.

In summary, driver experience appears to be an important variable in a number of studies (Evans, 1991). Effects of experience have been shown for both driver performance and driver behaviour. However, inconsistencies with measurement and defining what is meant by driver experience limits comparison between studies.

Driving experience and neuropsychologically-impaired drivers. A number of studies have incorporated a measure of driving experience in their description of neuropsychologically-impaired subjects. Hartje et al. (1991) set a lower limit of 30,000 miles driving experience as inclusion criteria for subjects in their research. The majority of other studies use comparable driving experience, measured in annual mileage (van Wolffelaar et al., 1987; van Zomeren et al., 1988) or average distance travelled per day (Friedland et al., 1988) as a criterion for matching subjects. The most extensive detail is reported in a study by Simms (1985) who collected data on annual mileage, type of journeys and typical use of a vehicle. In this study it is interesting that accident rate was not contributed to by distance driven.

Driving experience may play an important role in the assessment of neuropsychologically-impaired drivers. In a study by van Zomeren et al. (1988) driving experience was not statistically significant in relation to an on-road test of lateral position control, but was significantly correlated with judgements made on the extensive "Test for Advanced Drivers". These findings have implications for a practical on-road driving component in the assessment process, and may in part explain inconsistencies in the relationship between laboratory based tests and real driving. Gilley et al. (1991) also stress the importance of driver experience in the assessment process, and as a baseline for gauging individual performance levels. Thus, in the absence of data on mileage driven and driving conditions, the relative risk of driving in patients with dementia is uncertain. Further, the potential risk for unsafe motor vehicle operation may be underestimated by the reliance on accident rates alone (Gilley et al., 1991). Driver experience thereby creates a context for driver evaluation.

Previous driving experience serves as a useful indicator for gauging changes in patterns and amount of driving in relation to neurological damage. Many subjects choose to alter their driving to compensate for their disabilities, avoiding certain types of driving such as long distance trips or high density traffic situations. These types of adjustments have been documented some of the most important aspects of a successful return to driving (Priddy et al., 1990; Simms, 1985; van Zomeren et al., 1987).

All of these studies emphasise the importance of previous driving experience as a component in the resumption of driving following neurological damage. Qualitative evidence from a number of studies suggests that subjects who were more experienced prior to their neuropsychological impairment may buffer a number of residual effects, including those relating to type and extent of impairment (Hopewell & Price, 1985). Further research is needed to examine the role of experience in the assessment of neuropsychologically-impaired drivers.

Visual factors

The relationship between visual factors and driving has been covered in numerous comprehensive literature reviews (e.g. Charman, 1985; Chernysheva, Rozenblym, Yachmeneva & Eremin, 1993; Hills, 1979; Leibowitz, 1993; North, 1985; Welner, 1987). Driver vision and perception play a key role in the driving process, and it has been estimated that 90-95% of the input to the brain during driving is visual (Charman, 1985; Evans, 1991; Hills, 1979; Rockwell, 1972; Welner, 1987).

Despite the importance of visual factors, there is little agreement on what constitutes a level of visual fitness for driving (Charman, 1985). For example, there are different standards for different occupational drivers (Mars & Keitley, 1990). Nevertheless, while visual fitness standards are varied, almost all measures comprise a test of visual acuity only. For example, private licence holders in New Zealand "require visual acuity using both eyes together with or without corrective lenses of 6/9" *(Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990, p.63) as measured by the Snellen chart. Persons with one eye are not excluded from driving providing vision in the eye is good. Vision testing must be carried out by a medical practitioner in drivers aged 71 years, and repeated annually for drivers aged 76 and over.

Recent reviews of driver visual requirements are critical of visual fitness assessments based on visual acuity alone (Chernysheva et al., 1993; Leibowitz, 1993). Nevertheless, visual parameters other than visual acuity appear to be important to driving, embracing cognitive as well as sensory aspects of vision. Thus, a driver's visual functioning can be seen as an amalgamation of acuity, expectancy and perceptual style, hazard perception and associated reaction times, adaptation to speed and relative movement, colour vision and responses to varying illumination, and the ability to judge distance and depth (Hills, 1979; Welner, 1987). Although some open suggestions are made, no legal standards for these other visual conditions are stipulated, despite evidence that they may be important to safe driving.

Numerous studies have investigated the role of specific visual aspects that span the normal-impaired continuum of driver vision. At the sensory level, for example, good vision is regarded as important to safe driving, although measures of visual acuity have not been statistically significant in relation to motor vehicle accident rates (Evans, 1991; Little, 1970; Hills, 1979; Welner, 1987). The relationship between the extent of visual field and accident occurrence is unclear (Ball & Rebok, 1994; Decina & Staplin, 1993; Johnson & Keltner, 1983). Nevertheless, object detection, either moving or stationary, within the visual field may be more important than resolution of detail (North, 1985; Reinhardt-Rutland, 1989). A large study comprising a wide cross-section of drivers found that visual acuity or horizontal visual field were not independently related to accident involvement (Decina & Staplin, 1993). However, the combination of visual acuity, horizontal visual fields, and broad contrast sensitivity criteria was significantly related to increased accident involvement in drivers older than 65. Use of non-accident criteria is less common in the literature, although some studies suggest that sensory visual factors have a more important role in driving than accident data shows. For example, one study reported that restriction of the binocular field to 40% or less significantly reduced driving accuracy, and increased the time taken to complete a driving course (Wood & Troutbeck, 1992).

At a cognitive level, the relationship between field dependence and perceptual style has been investigated, with variable results (Mihal & Barrett, 1976; Hills, 1979; Shinar, McDowell, Rackoff & Rockwell, 1978; Welner, 1987). Welner (1987) emphasises the difficulties in acquisition and selection of the necessary visual information from the driving environment. Evans (1991) notes that higher level visual search and pattern recognition skills are more important in driving than optimum performance of simple visual tasks.

Importantly, visual factors are known to be variable and highly sensitive to changes within the driver (Welner, 1987). Numerous personal variables have been found to influence visual ability including age, experience and skill level, and various transient states (Evans, 1991). For example, a number of observational studies have examined interactions between eye movements and driving. Here, visual search varies with driver experience, how much information is presented to the driver, and, the effects of alcohol and fatigue (Rockwell, 1972). Driver search behaviour is also related to other factors such as perceptual style, particularly field dependence and scanning (Shinar et al., 1978).

Apart from driver visual and perceptual limitations, physical restrictions to visibility while driving, such as obstructed vision and reduced visibility at night, are important variables which cannot always be included in research. Some literature reviews emphasise that the interaction between all of these visual factors must be examined for a study to have ecological validity (Leibowitz, 1993; Welner, 1987). While the presence of physical deficit is more easily measured, other visual factors are difficult to determine. The type of research methods employed are therefore an important consideration in the literature. While visual abilities of drivers have been investigated through accident studies, driver-vehicle observations and psychophysical studies, each of these has limitations. For example, use of accident data is limited since it is impossible to evaluate many visual factors or their contribution to accident involvement. A large number of other variables are seen to contribute to accident involvement which limit the use of this criterion. For instance, while Ball et al. (1993) found that eye health status, visual sensory function, and age were significantly correlated with accidents, these variables were relatively poor at discriminating between accident-involved and accident-free drivers. Similarly, Evans (1991) points to data for young drivers, where visual acuity is best but high accident rates prevail.

A number of literature reviews are critical of the apparatus available for measuring visual abilities (Chernysheva et al., 1993; Leibowitz, 1993). North (1985) states that many driving measures are insufficient and non-standardised. In addition, some of the more well known tests, such as the Titmus and Keystone apparatus, are not optimal for measuring an adequate range of visual components (Szlyk, Fishman, Master & Alexander, 1991).

There are a number of other considerations which are relevant in research on vision and driving. Visual aids, such as corrective lenses and vehicle mirrors, are available to optimise driving vision and have implications for research results (Evans, 1991). In addition, many studies overlook the potential use of compensatory strategies and any implications such strategies may have for safe driving (North, 1985). There has been little investigation of possible disparity between visual capabilities and the way in which they are used.

In summary, the literature on vision and driving is complex and, in many respects, inconclusive. While vision, in a general sense, is clearly important to driving, Welner (1987) points to the need for studies which "expand current understanding of the role and relative importance of specific visual inputs" (p.136). Limitations in the use of various research designs and measurement of visual components are a main feature of the research.

Visual factors and neuropsychologically-impaired drivers. A large number of studies include visual screening criteria when recruiting neuropsychologically-impaired driver subjects (Hartje et al., 1991; Katz et al., 1990; Simms, 1985). Standards for visual acuity are the most common criteria, starting from a minimum specification of 20/40 vision (Katz et al., 1990). A few studies have also specified visual field criteria, as illustrated by a requirement for subjects to possess visual fields spanning 140° on the horizontal axis, with at least 75° and 35° to temporal and nasal fields respectively (Katz et al., 1990). Yet another study excluded subjects with any sign of double vision (Hartje et al., 1991). Some of the most comprehensive criteria is included in a study by Simms (1985) who screened for visual acuity, involuntary eye movements, squints and head postures, lower quadrant loss, and, a minimum horizontal visual field spanning 120°.

Results of the above studies generally indicate that visual screening criteria was not sufficient. Among those subjects screened, visual deficit was still an important reason for poor performance on driving tasks or neuropsychological tests. Hartje et al. (1991) found that only visual field deficits were related to overall driving performance among neuropsychologically-impaired subjects. In this study, all subjects with visual field deficit failed. Interestingly, Katz et al. (1990) showed a higher than usual success rate on practical driving and neuropsychological test measures, although it was not possible to conclude that this is a function of prerequisite visual standards. Overall, there is a consensus that visual factors are important. In studies which do not specify set visual criteria, or rely on existing driver standards for visual acuity, significant effects have been shown for extent of visual field, sensory degradation and visual angle, visuomotor coordination and visuospatial analysis (Galski et al., 1990, 1992; Stokx & Gaillard, 1986; van Wolffelaar et al., 1987; van Zomeren et al., 1988).

Different assessment standards for vision limit comparison between neuropsychologically-impaired driver studies. Such comparisons can be further compromised by the validity of some techniques which measure visual ability. For instance, even when a simple measure of visual acuity is taken, there is a need to be aware of possible difficulties in the use of eye charts by neuropsychologically-impaired subjects, including the ability to recognise and name letters (Shute & Woodhouse, 1990). Yet, despite these complications, visual factors are reported as having considerable weight in the assessment of neuropsychologically-impaired subjects for driving again (Gianutsos, 1991; Golper et al., 1980; van Zomeren et al., 1987). Literature from assessors working in the field reports that up to 10% of drivers are excluded from driving again on the basis of visual defect (Shute & Woodhouse, 1990; Simms, 1985).

It is apparent that there are more questions than solutions concerning the role of visual factors in the assessment of neuropsychologically-impaired individuals, let alone for application to a practical task such as driving. Visual disabilities following neuropsychological impairment are variable (Benton & Tranel, 1993; Brooks, 1984; Newcombe, 1982; Vothengatter, 1987), however, these factors are seen as important predictors of successful rehabilitation (Ruff et al., 1993). Visual factors are also noted for their long term effects (Benton & Tranel, 1993; Newcombe, 1982).

Overall, visual components are significant and demonstrate many of the largest task effects when comparing neuropsychologically-impaired drivers with controls. Many of these task effects relate to cognitive-perceptual rather than sensory aspects of vision, although these two areas have been poorly defined. Further consideration for measurement of cognitive-perceptual aspects of vision will be given in Chapter Five.

Medical conditions

Empirical research into the relationship between medical conditions and fitness to drive is limited, even despite enormous public and professional concern as to what legal barriers should exist to prevent individuals with chronic and acute conditions from driving. Current guidelines for medical conditions and driving are available which make broad recommendations on a fairly limited empirical base (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners*, 1990; Raffle, 1995). Those conditions which receive attention include heart disease, diabetes, epilepsy, sensory deficit, and disorders of the nervous system. Reference is also made to various physiological impairments and psychological states which may preclude safe driving.

Physical impairment alone is not a contra-indication to driving, and with the availability of many technological and vehicle adaptations it is possible for many physically disabled people to drive a car (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990; Raffle, 1995). The effect of various psychiatric disorders on fitness to drive has been poorly documented, with limited and inconclusive findings about how to determine driving ability of those who suffer from mental illnesses (Metzner, Dentino, Godard & Donald, 1993).

Generally, there is a lack of empirical evidence for specific conditions with neurological and psychological bases (Noyes, 1985; *Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990; Raffle, 1995). Despite this, some research exists for restrictions placed on epilepsy (Andermann et al., 1988; Spudis, Penry & Gibson, 1986), sleep apnea (Findley, Weiss & Jabour, 1991) as well as dementias and aphasias (Gilley et al., 1991; Lucas-Blaustein, Filip, Dungan & Tune, 1988, Madeley, Hulley, Wildgust & Mindham, 1990). Those studies which find relationships between certain conditions (e.g. epilepsy) and driving almost exclusively use accident statistics as a criterion and fail to take into account problems encountered with this sort of data (Little, 1970; Evans, 1991; Gilley et al., 1991). It is difficult to determine whether the medical condition was the causal factor, and whether actual accident rates are higher than average for the particular group in question (Spudis et al., 1986). More often than not, there is no account of the wide variation within any one condition nor the interaction with onset, progression, duration and treatment effects (Gilley et al., 1991). In addition, the relationship of other personal variables in the overall driving picture is frequently overlooked (Golper et al., 1980).

Measurement and sampling problems are also apparent when the focus is on cessation of driving through a medical condition. Importantly, the role of various professionals in the assessment process is unclear and ethically controversial, with the onus frequently put on general practitioners to both detect the problem and make recommendations for driving (Andermann et al., 1988). Ultimately, in many cases, it is the individual who decides whether or not to heed to advice given, or who may choose to cease driving on the basis of personal decisions or those made by others. These outcomes are likely to bring about different biases and are an issue for the selection of research samples. Unfortunately, information on driving behaviour obtained before the onset of medical conditions or the effects of non-compliance on imposed driving restrictions almost defy study, even though this type of research could be a valuable information source.

Overall, there is little data to suggest what proportion of drivers cease driving due to a medical condition, nor what patterns of driving cessation might persist for specific conditions. Information from licensing bodies is regarded as incomplete and possibly inaccurate (Evans, 1991). A few independent researchers have investigated driving cessation using survey methods, although these studies are also limited by how information is elicited. In a noteworthy study, Campbell, Bush & Hale (1993) conducted a large community investigation of medical conditions associated with driving cessation of older adults. It was found that of 59% of subjects who had voluntarily stopped driving, 32% of these gave medical conditions as the reason. These were predominantly visual, with a smaller proportion of CVA, Parkinson's disease and syncope. Apart from its large sample size, an advantage of this study was an interest in gathering information which reflected the wider context of driving cessation issues. More of this type of research is necessary in understanding the role of medical factors in driving.

In summary, a number of medical conditions are generally viewed as important as deciding factors for fitness to drive. Unfortunately, medical guidelines available are based on limited research findings and poor measurement criteria.

Medical conditions and neuropsychologically-impaired drivers. The effects of other medical and disabling conditions have not been specifically investigated on neuropsychologically-impaired drivers. However, in accordance with existing medical guidelines, a number of studies specify exclusion criteria for subjects on the basis of conditions that may have an effect on driver safety. Several studies specify an absence of epileptic seizures (Gouvier et al., 1989; Hartje et al., 1991; Katz et al., 1990; Simms, 1985) while others have excluded subjects on the basis of sudden attacks of faintness or dizziness without warning (Simms, 1985), and poorly controlled diabetes mellitus (Hartje et al., 1991). Friedland et al. (1988) ensured that subjects had been checked for other other medical explanations in their study of drivers with Alzheimer's disease. Galski et al. (1992) required that subjects were free of medical conditions or medication that would impair motor ability, cause drowsiness or compromise performance or safety. Simms (1985) notes that approximately 5% of applicants for driving again may be excluded on the basis of such medical criteria. While this figure is not high, difficulty in specifying some conditions is a limitation of their use as medical criteria, and may be further complicated in the presence of neurological damage.

For neuropsychologically-impaired drivers, there are few studies which investigate the actual impact of other medical criteria on driving. However, one interesting study found that medical status played a greater role in subject's personal decisions, compared with professional's evaluations, concerning return to driving (Golper et al., 1980). This finding was particularly true for older subjects, and is consistent with findings based on an older normal driver population (Campbell et al., 1993). On the other hand, critics suggest that many medical conditions bring about unnecessary stigma when assessing the driving status of neuropsychologically-impaired individuals (Drachman, 1988, Spudis et al., 1986). Here, in the presence of medical conditions, professionals may neglect to weigh up other individual factors and personal costs. Rather than excluding on the basis of medical criteria, Drachman (1988) argues that "limitation of the privilege to drive should be based on demonstration of impaired driving performance" (p.787).

Unfortunately, neuropsychological impairment may bring about a host of conditions or residual effects which may preclude driving (Raffle, 1985). Apart from visual conditions already discussed, effects on the sensory system, epilepsy, seizures and syncope, amnesias, as well as physical disabilities such as hemiplegia are relatively common (Adamovich et al., 1985; Gronwall, 1989; Heilman & Valenstein, 1993; Kraus & Nourjah, 1989). Few studies have attempted to isolate these medical conditions in research on the neuropsychologically-impaired driver. One exception, investigated the driving ability of neuropsychologically-impaired subjects with and without aphasia (Hartje et al., 1991). Results of this study showed that average driving behaviour was impaired in a significantly higher number of aphasic compared with non-aphasic subject groups, although, there was considerable individual variation in performance. There was also a significant interaction with age. The presence or absence of aphasia alone, therefore, was unable to predict driving ability.

A few studies in the literature have used comparison groups to separate out the effects of neuropsychological impairment (Gouvier et al., 1989; Simms, 1984). The results of these studies tend to show that the driving performance of individuals with physical disability is usually judged as acceptable, though not always in the same range as able drivers. While neuropsychologically-impaired drivers tend to perform less well than both groups, comparative studies do suggest that drivers who are different from the normal population may be judged fit to drive at a generally lower, but still acceptable, standard.

Overall, the evidence suggests that while medical conditions may play a role in the driving assessment process, there is insufficient evidence to support the use of any reliable medical criteria on exclusionary grounds. In the case of neuropsychologically-impaired drivers, further research is needed before specific recommendations can be made.

Transient states

Fatigue. Fatigue is a generic concept designed to account for reversible human declines arising from previous activity (Nelson, 1981). Fatigue can be defined as "a situation in which the person considers himself or herself unfit to continue performance" (Nelson, 1981, p.183). Evidence suggests that fatigue is likely to result from the relatively unchanging conditions experienced when driving for long periods and under certain conditions. It is important to bear in mind, however, that the problem of fatigue and driving can be investigated from two angles, namely: *operational* fatigue produced by driving; and the *effects* of fatigue on driving (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990). Regardless of how it is defined, fatigue has been cited as the possible cause of approximately 4% of accidents (Shinar, 1978).

There is an important differentiation between physiological and psychological fatigue (Brown, 1994; Little, 1970; *Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners, 1990*). Physiological fatigue arises from "prolonged static muscular contraction, caused by incorrect posture, or by tension resulting from anxiety or excessive vehicle vibration" (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990, p.108). Further, Nelson (1981) points out that physiological fatigue may be reflected by changes in arousal, where the driver becomes less alert under conditions of reduced psychophysical arousal. Psychological fatigue is "largely focused on changes in perception, mood, and thinking as a result of fatigue and largely determined by factors which affect neural arousal" (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990, p.111). Thus, the definition of fatigue is not simply related to energy expenditure (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990; Raffle, 1985). Rather, it may be described as a subjective personal state combined with measurable effects. The most common effect of fatigue is noted to be critical non-performance, which, in the early stages, manifests itself as inattention (Nelson, 1981). Increasing reports of complaint correspond with this linear fatigue effect. However, evidence shows that the effects of fatigue, can, in many instances, be observed before a driver is fully aware of it (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990).

There may be special cases of fatigue, including visual fatigue which is exacerbated by driving in certain conditions of poor visibility or prolonged glare. In addition, fatigue can be viewed as a symptom, since it may be associated with medical conditions or treatments. There is also evidence for the combined effects of fatigue and other driving-related variables. Research reviewed by Evans (1991) suggests that novice drivers tire more easily due to the more taxing nature of the driving task in the pre-autonomous stage. In another literature review, Nelson (1981) considers factors such as motivation, anxiety, distraction, tolerance and boredom as influencing overall perceptions of fatigue. Fatigue is enhanced by personal factors relating to arousal, anxiety, stress, and the effects of alcohol and drugs (Brown, 1994; Gulian et al., 1990; Hoyos, Galssterer & Stotz, 1981; Nelson, 1981; Summala & Mikkola, 1994; Willumeit et al., 1981).

In a recent study, Hartley, Arnold, Smythe & Hansen (1994) found progressive changes in psychological performance measures (controlled psychomotor tasks and reaction times) and physiological (endocrine and cardiac) measures of truck drivers over five and six day round trips. Interestingly, solo drivers were more adversely affected by these measures of fatigue. This research exemplifies the multifaceted effects of fatigue within a naturalistic setting.

In general, there are a number of important issues concerning the investigation of driver fatigue. Willumeit et al. (1981) point to a lack of good measures and studies which examine real as opposed to simulated driving. Whatever research method is used, Shinar (1978) emphasises that the effects of fatigue on driving behaviour is not "a simple two-step process in which we are fully alert at one moment, and then oblivious to the visual environment at the next" (p. 41). Instead effects need to be monitored as they would be in a vigilance task. In this respect, the effects of fatigue are more easily measured in the laboratory, where data can be readily recorded at any time. Unfortunately, this advantage is, in many respects, outweighed by the lack of ecological validity of laboratory measures. Still, some studies do attempt to simulate a wide range of components from the driving environment. For example, Moren et al. (1989) report a modification of an environment within a simulated vehicle, where it was found that noise, infrasound and temperature affected physiological measures of driver wakefulness over prolonged simulated driving.

In the field, there is often a reliance on self-reporting of the psychological effects of fatigue. As one self-report study has shown, variation may also be due to how and when data is collected (Nelson, 1989). This research identified systematic discrepancies in self-perceptions of fatigue associated with driving. At the end of fatigued driving, different impressions were gained from verbal reports and the nature of self-ratings drivers provided. Nelson (1981) states that it is through perception that the individual makes and maintains effective contact with the environment. Such findings, therefore, give added value to the use of self-reported measurement techniques.

In summary, a number of definitions and methods for measuring fatigue are apparent in the general driving literature. Research has shown a close correspondence between physiological and psychological fatigue. Most studies demonstrate a negative correlation between increased fatigue and decreased driver performance. Some research has reported on changes in driver behaviour to accommodate the effects of fatigue.

Fatigue and neuropsychologically-impaired drivers. The effects of fatigue on neuropsychologically-impaired drivers has been poorly documented. Despite this, some research emphasises the possibility of increased mental and physical fatigue as noted in the general neuropsychological literature (Katz et al., 1990; Madeley et al, 1990). In rehabilitation of individuals with neuropsychological impairment, Wrightson (1989) maintains that fatigue is "probably the most important single factor that patients must deal with in returning to work" (p.24). A number of reviews also suggest that, for neuropsychologically-impaired subjects, the situation of exposure to fatigue is much more fragile (Hall et al., 1994; McLean et al., 1993; Wrightson, 1989). As a consequence of fatigue, Wrightson (1989) states that function deteriorates, stress accumulates and symptoms such as headache, dizziness and irritability appear. In relation to driving, the effects of fatigue are related both to an increased susceptibility as a general state, and, increased likelihood of fatigue as a result of the driving task.

In one study, an absence of fatigue was specified as a criterion in recruiting subjects (Katz et al., 1990). Here, an increased susceptibility to mental fatigue, or the inability to sustain consistent cognitive performance, was considered an important factor in driving. However, measurement and ethical problems involved with this research raise questions concerning the practicality of using this type of criterion. Other research on neuropsychologically-impaired drivers has relied on survey data to elicit information on subjective experiences of fatigue. Studies have found that some subjects report efforts to modify their driving behaviour and avoid long periods at-the-wheel, in order to counteract the effects of an increased susceptibility to fatigue (Madeley et al., 1990; Simms, 1985).

Overall, a few studies provide evidence suggesting fatigue effects have important implications for neuropsychologically-impaired drivers. However, there is a need for systematic investigation to clearly define these effects and the exact nature of the relationship.

Stress

Stress is a loosely applied term which may be defined in numerous ways. In particular, lack of distinction between the role of internal states and external stressors has been noted as a source of confusion in the driving literature (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990). In one definition, driver stress is viewed as a function of "factors intrinsic (traffic conditions) and extrinsic (personal life) to driving" (Gulian et al., 1988, p.342). Here, stress is examined as a general appraisal of driving, and also as an appraisal of specific driving incidents. In this respect, the transient nature of driver stress is also an important component in research. In a review, Evans (1991) suggests "emotional stress may produce short or medium term departures from an individual's long term average driving behaviour" (p.148).

A number of studies in the literature have focused purely on physiological measures of driver stress, including galvanic skin response, heart rate, muscle tension and other changes in physiological arousal. These states are commonly measured during simulated driving. For example, Evans (1991) cites a study where galvanic skin response could be unobtrusively measured through changes in electrical conductivity of a subject's hand on the steering wheel. Such studies have been criticised for their lack of ecological validity, particularly with regard to loading of factors to elicit stress responses. Physiological measurement is more difficult in studies of real driving, where techniques used may appear more obtrusive. As an example, constant heart rate was monitored in a small scale study investigating the relationship between stress, road design features and driving incidents (Robertson & Goodwin, 1988). With physiological studies, lack of specificity in the cognitive labelling of a physiological measure poses problems for the interpretation of a stress response. Research which incorporates physiological with other forms of measurement therefore tends to be more robust.

Aside from physiological studies, early stress literature documents some retrospective analyses of accident data investigating the relationship between accident occurrence and significant life events and hassles (Evans, 1991; Isherwood, Adams & Hornblow, 1982; Shinar, 1978). Weak to moderate correlations were found between intrinsic stressful events and incidence of motor vehicle accidents, however, it appears this research failed to take into account the balance of situational factors or extrinsic stress as part of the overall picture. The research has also been criticised for disregarding individual variation in intensity of stress reactions in response to different life events (Silverstone, 1988).

Research which focuses on a range of self-reported indices of driver stress is a fairly recent addition to the literature. An informative group of studies have developed several measures of driver stress (Gulian, et al., 1988, 1989; Glendon, Dorn, Matthews & Gulian, 1993). Gulian et al. (1988) report results of a sample of drivers who responded anonymously to the General Driving Behaviour Inventory (GDBI). Factor analysis found a cluster of driving behaviours and feelings about driving/other drivers which predicted driver stress. Independent predictors included increased frustration in failure to overtake, driving enjoyment versus dislike, and increased alertness. Interestingly, overall evaluations of driving-induced stress were relatively high, irrespective of driving experience. Further, individual ratings of aggression, frustration and competitiveness were closely related to and predicted driving-related stress. Increased alertness was also a factor in stressful driving situations. Good test-retest reliabilities have been found for the Driver Stress Scale (Glendon et al., 1993).

Subsequently, a diary study by the same group of researchers examined daily behaviours and feelings while driving. The purpose was to ascertain driving stress levels and changes in these as a function of time of day and day of week. It was found that stress did vary across the day and week and was also related to driving conditions as well as an individual's perception of driving as a stressful behaviour. Age, experience, health, and amount of sleep also related to daily driving stress. These findings led to the conclusion that "tracing a sample of drivers' daily responses to travelling by car shows that driving stress is a global syndrome with a causal network of factors which spreads beyond the actual journeys made" (Gulian et al., 1990, p.15). These findings therefore add support to driver stress comprising both intrinsic and extrinsic factors.

The combination of behavioural and physiological variables give a further insight into the nature of stress measurement and driving. For example, Hoyos (1981) conducted some preliminary work into stress measurement and the effects of long-duration car driving. A small group of drivers were asked to evaluate aspects of personal strain, including intensity, duration, and perceived control on a nine-point scale. Car handling variables and a number of subjects physiological responses including pulse rate, muscle tension and electrodermal response were recorded over the same sample of driving. Results found a close association between physiological and psychological measures of stress. In another interesting study, Hentschel, Bijleveld, Kiessling & Hoseman (1993) examined stress in truck drivers who were assigned to driving either a standard or technically optimised truck. They also found psychological measures of anxiety and defence mechanisms, physiological measures, and situational variables were closely interrelated.

Finally, one of the most comprehensive investigations of driver stress is a longitudinal study of city bus drivers incorporating a range of epidemiological studies, surveys, field experiments, ergonomic and laboratory studies (Mulders et al., 1988). A feature of this research was the attempt to match driver stress with health-related outcome. Results showed no altered task performance in drivers with and without impending health problems. On the other hand, increased neuroendocrine activity was typical of driver in early stages of stress-related illness. Further, subjective measures of workload suggested that the increased neuroendocrine reactions during driving were a sign of stress encountered in meeting high task demands and an adequate performance level. A major implication of the findings was the general importance of individual differences in vulnerability to stress and the related outcome measures.

In summary, the relationship between stress responses and driving is complex. Numerous measures of stress have been documented in the literature and effects on both driving performance and behaviour are apparent. Studies have also found that physiological and psychological measures of stress are clearly interrelated.

Stress and neuropsychologically-impaired drivers. Although stress has not been specifically examined in relation to the neuropsychologically-impaired driver, some papers suggest a greater risk of high stress while driving (Hopewell & Price, 1985). Evidence demonstrates greater difficulty experienced with tasks requiring complex cognitive processing and an increased stress response (Gronwall, 1989; van Zomeren et al., 1987). Gronwall (1989) emphasises "the persistent cognitive fragility" (p.159) to stress in the presence of neurological damage. Another review suggests neuropsychologically-impaired subjects are both more easily stressed and also tend to operate in a more stressful environment (Hall et al., 1994). Assuming these findings generalise to practical driving, execution of the task may be seen to generate increased stress levels, especially in situations of high load such as heavy traffic, multiple hazards and long distance travel (van Zomeren et al., 1988). The research also refers to the use of compensatory strategies to avoid extrinsic stressors created by difficult traffic or lengthy driving periods (van Zomeren et al., 1987, 1988). Avoidance of these situations has been viewed as an important and necessary part of an individual's adjustment to safe driving following neurological damage.

Evidence also suggests that intrinsic stressors may play an increased role in the driving of neuropsychologically-impaired individuals. In a review of driving within psychiatric populations, Noyes (1988) highlights an increase in the relationship between stressful life events and accident involvement. Both the type and timing of events are seen to be important. Two comprehensive reviews refer to difficulties with adjustment and the role of transient emotional problems as stressors which reflect on driver performance and behaviour (Bardach, 1971; van Zomeren et al., 1987).

Overall, there appears to be a relationship between stress and driving of neuropsychologically-impaired individuals. Currently, however, there is a need for more empirical research to ascertain whether real differences exist between neuropsychologically-impaired and general driver populations.

Alcohol and drugs

In relation to driving, alcohol consumption receives more attention than any other single variable investigated (Evans, 1991; Simpson & Warren, 1981). Research in the area has been carried out, not only for reasons of road safety, but for social and political ramifications as well (Evans, 1991). Despite extensive investigation, there are numerous problems faced interpreting the research. First, there is no agreed definition of intoxication, with legal usage covering a wide range of criteria (Hammer, 1987). Consequently, it is difficult to make comparisons between studies that rely on different levels of consumption, and also different measures of those levels.

Further, due to ethical concerns with any applied research, laboratory studies offer the only environment where alcohol intake can be monitored and examined under rigorously controlled conditions. Evidence for the importance of alcohol in traffic safety is therefore largely indirect, using data from cognitive tasks and simulated driving, and based on pooling findings from a large body of laboratory research. The main limitation of the laboratory research is that performance effects in real traffic can only be inferred (Simpson & Warren, 1981). A review of the laboratory research finds that the majority of studies have demonstrated impairment at .07% blood alcohol concentration. However, different categories of tasks have shown performance deficits at different levels of intoxication. Most susceptible at lower levels are divided attention tasks, followed by information processing and psychomotor tasks. Effects on reaction time have shown the most variability (Evans, 1991). Unfortunately, little evidence is available to suggest changes in performance with increasing magnitude of alcohol impairment. Wide individual differences, such as age and driving experience, are apparent for all of the findings available.

The primary effects of alcohol have been measured as increased traffic accident risk, mainly through retrospective analysis of accident data. These studies are unable to distinguish between performance or behavioural changes in driving as a result of alcohol consumption (Evans, 1991). Further, accident statistics as a measure of outcome may be confounded as studies have identified that alcohol consumption corresponds with increased susceptibility to injury, including fatal injury, (Evans & Frick, 1993; Evans, 1991; Stark, 1988).

Research into the effects of alcohol on driving behaviour has received less attention than effects on driving performance. Investigation of behavioural and emotional effects on driving is characterised by a wide range of observational and self-report measures, many of which are unstandardised (Evans, 1991). A number of sociobehavioural factors have been examined such as effect of and compliance to personal consumption limits, which tend to suggest that it is difficult to change behaviour (Guppy, 1988). Another important general finding is that subgroups of alcohol-impaired drivers have been identified, and these subgroups differ on a number of variables (Biecheler-Fretel

& Danech-Pajouh, 1988; Wilson & Jonah, 1985). For example, convicted alcohol-impaired drivers are found to have more irresponsible attitudes and indulge in increased risk taking (Donovan et al., 1983; Furnham & Saipe, 1993; Wilson & Jonah, 1985). An interactive effect with personality and sociodemographic variables is also characteristic of this group, suggesting a typology of alcohol-related behaviours. In a review of the literature, Dennis (1993) identifies chronic alcohol abusers as another subgroup, whose permanent effects of alcohol result in a pattern of impairment which generally has not been addressed by the research.

The literature on drugs and driving is also characterised by a lack of empirical evidence (Beeley, 1985; *Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990). Available literature sets out some very general effects of major drug groups (eg. hypnotics, sedatives, benzodiazepines, antidepressants, antipsychotics, and antihistamines) with respect to driving (Beeley, 1985). Various sources, however, also acknowledge that the information available makes little allowance for variable dosage or use outside of that prescribed on medical grounds (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990; Raffle, 1995). All of these issues are important in making decisions about how drug phenomena should be studied. In terms of practical application, a need has also been identified for more rigorous prescribing and dispensing practices with regard to public awareness of potential drug effects on driving (de Gier, 1987). Further, there is a paucity of information concerning the role of individual factors, including interactive effects with personal variables such as age, personality, and general cognitive-psychomotor functions, as well as with other drugs and alcohol (Gerhard & Hobi, 1984; Hammer, 1987; Reuben et al., 1988; Slater & Guppy, 1988).

Drug effects on driving. Consistent with the ethics of alcohol research, most of the evidence regarding drug effects on real driving is indirect. Most data relates to effects on various performance measures in the laboratory (Gengo, Gabos & Mechtler, 1990). Here, it has generally been found that many commonly used medicinal drugs possess the potential for seriously degrading human performance (O'Hanlon, 1987). Despite this, reviews indicate a lack of quantitative literature specifying actual commercial drugs and objective chemical measures (Evans, 1991). Furthermore there is limited consensus on what drugs or drug combinations should be studied (Beeley, 1985; *Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990; Warren & Simpson, 1981).

O'Hanlon (1987) points out that there is evidence to suggest that drugs of the same therapeutic class, such as analgesics, antihistamines, antidepressants and antihypotensives, possess the potential to have notably different effects on driving. Thus, in many cases, broad generalisations resulting from few studies in the literature would appear to be inappropriate. Further, there are problems with the research in the inclusion of a broad range of subjects and assessment instruments in trials and studies of the effects of most types of drugs (Benkert, 1990; *Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990). Many studies have been criticised for their use of healthy young subjects who are given limited dosage, so that results may have little bearing on the effects of the drug for a chronic user, or someone who may have developed strategies to compensate for residual effects (Shinar, 1978). Importantly, this approach fails to take into consideration possible benefits of the therapeutic effect of drugs on driving, which may in fact outweigh, or counterbalance, apparent side effects. Further, drugs have different effects at different phases, such as when an individual is being stabilised as opposed to later in the treatment process. Research has also neglected implications for long and short term use of drugs (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990).

Compared with the alcohol literature, drug studies carried out in the field are scarce. Laurell (1990) notes that this is partly due to a lack of correlational studies, with fewer drug screening procedures being carried out legally, and the infeasibility of random checks. A few studies, however, have been based on retrospective accident data. For instance, Skegg, Richards & Doll (1979) used an innovative approach where a comparison was made between prescriptions for the previous three months for victims of fatal driving accidents and a group of controls. Those involved in accidents were five times more likely to have been prescribed minor tranquillising medications. One criticism of this type of research is that pre-existing medical conditions, for which drugs are prescribed, may increase the likelihood of fatality in traffic accident statistics.

In alcohol research, studies using real driving pose enormous ethical constraints, and comprise only a very small portion of the literature. There are problems, still, with the ecological validity when subjects other that those medically prescribed a drug are employed. Limitations exist therefore, with all of the research methods reported in the available literature, and there is a lack of comparison between different techniques. One exception, is a study of the sedative effects of the antihistamine drug Diphenhydramine, which combined laboratory, on-road, and self-report assessment methods (Cohen et al., 1984). A double blind within groups design was used with different concentrations of the drug and a placebo being administered over different occasions. Results indicated that the laboratory tests were more sensitive to drug effects than measures of actual driving. Visual analogues found that subjects rated themselves mentally and physically sedated on the highest dose, but that this did not coincide with a personal rating of impaired driving. This study raises a number of questions concerning measurement, and also the contribution of other variables, such as driving experience, to the overall drug effect. Unfortunately, few studies investigate these issues further.

In summary, the relationship between alcohol, drugs and driving present a difficult area of investigation. Ethics and design of research generally compromise the validity and reliability of research findings. The majority of studies do not investigate both effects on driving performance and behaviour, and a range of research and extraneous variables make comparison between the studies problematic.

Alcohol, drugs and neuropsychologically-impaired drivers. Few studies have examined the effects of alcohol on neuropsychologically-impaired drivers. Evidence from the general literature, however, suggest that alcohol has an exaggerated effect on task performance when neuropsychological impairment is also present (Gronwall, 1989; Lezak, 1995).

A relationship between a higher rate of alcohol consumption and increased accident risk has been associated with some personality and psychiatric disorders (Cremona, 1986; Noyes, 1985). A similar trend has not been investigated for neuropsychologically-impaired drivers. On the other hand, a few neuropsychologically-impaired driver studies report subject awareness of the effects, and voluntary abstinence from alcohol, along with other compensatory strategies employed for driving (Friedland et al., 1988; van Zomeren et al., 1988).

The relationship between use of pharmacological drugs and the driving of neuropsychologically-impaired individuals has been poorly investigated. Nevertheless, a number of important concerns can be raised. Many individuals referred for neuropsychological assessment are on a drug regimen, including medication for behavioural or mood disturbance, tension, anxiety, sleep disturbance, other neurological and/or medical disorders (Lezak, 1995). Compared with the normal driving population, one could assume that neuropsychologically-impaired individuals therefore ingest proportionally more drugs with potential effects on driving performance. Further, in a study of drivers with dementia, Gilley et al. (1991) alerted to the dilemma between disease progression and treatment effects as influences on driving fitness. Results of the study suggested that pharmacological agents with sedative properties may add to risks associated with driving by persons with dementia. In another study, Madeley et al. (1990) considered the potential effects of levodopa on driving of subjects with Parkinson's disease. Of special concern were subjects' reporting "on-off effects" from their medication. Subjects reported that there were times when they would not feel safe to drive and would refrain from doing so. Implications of these findings were first, the accuracy of subjects' judgements and intentions for safe driving. Second, the crucial timing of assessment of fitness to drive in relation to subject's status.

As with the normal driving population, the question of drug effects must take into account the reason for, and details of, the medication prescribed. From a practical viewpoint, the question is not how individuals drive with medication as compared to without, but how they do under regular treatment in comparison to controls. Overall, there is a need for further research in this area, with emphasis on subjects with neurological damage. Further information regarding specific drug effects is also required with application to this population.

Chapter Five

DRIVING AND NEUROPSYCHOLOGICAL ASSESSMENT

Neuropsychological test data is more commonly used as a predictor of driving outcome than any of the other clinical measures. However, the role of neuropsychological tests in the assessment process has not been systematically investigated in relation to actual driving skills. As a background to the present study, this Chapter reviews a range of clinical variables as indicators of neurological damage, and the role of neuropsychological tests in the driving assessment of neuropsychologically-impaired subjects.

INTRODUCTION

While there is limited information on the relationship between clinical variables and driving, one review states that "it would seem reasonable to assume that fitness to drive can be predicted, to some extent, from clinical characteristics of a brain-damaged patient" (van Zomeren et al., 1987, p. 700). Here, measurement of clinical variables encompasses information from specific categories of impairment, indices of severity and other outcome measures, as well as neuropsychological test variables. In this context, neuropsychological test data is more commonly used as a predictor of driving outcome than any of the other clinical measures. However, the role of neuropsychological tests in the assessment process is open to validity and reliability criticisms. Interestingly, few studies have systematically investigated the relationship between actual driving skills and psychometric test performance (Brooke et al., 1992; Rothke, 1989).

Some studies have examined other clinical variables, such as severity of neurological damage, as predictors of driving outcome. However, most emphasis remains at a descriptive level and samples tend to be heterogenous; both of these are limiting factors in data analysis (van Zomeren et al., 1987). Nevertheless, the nature and severity of neurological damage is clearly important, and temporal factors such as progression and duration are important (Lezak, 1995). Which subjects should be reassessed for driving, and when, are also relevant considerations. Other important mediating variables include individual insight and the use of compensatory techniques, together with premorbid characteristics such as previous driving experience and psychosocial factors.

Overall, there is need for more detailed description in order to develop a clearer understanding of the whole context of neuropsychologically-impaired driver assessment (van Zomeren et al., 1987). There is a lack of driving-related research which utilises multivariate techniques across a range clinical measures in the same sample. This is a limitation on the identification of useful predictors of assessment outcome.

DIAGNOSTIC CLASSIFICATIONS AND DRIVING

Broad neurological categories, with separate recommendations for driving, are available to medical practitioners and other professionals (*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners,* 1990). In addition to medical criteria, many recommendations based on accident and traffic violation statistics do not necessarily provide relevant clinical information. Literature reviews are critical of the exceptionally broad diagnostic and disability categories which are also carried over to research settings (e.g. van Zomeren et al., 1987). These broad categories often incorporate psychiatric illness and wider neurological disorders. Within neuropsychologically-impaired samples, head traumas (penetrating and closed head injuries) are often not separated from vascular disorders (CVA) nor degenerative disorders (e.g. dementias of the Alzheimer's or Parkinson's type).

The use of diverse subject groups is a limitation in the evaluation of other clinical diagnostic variables. As an example, important differences between head injury and

CVA are found both in initial neurologic insult and eventual residual effects, and may explain tendencies toward focal, unilateral versus diffuse damage (Rosenthal, Griffith, Bond & Miller, 1983). Similarly, there are differences between the effects of slowly progressive versus acute neurological damage. Importantly, these broad diagnostic categorisations may also encompass very different etiological factors, such as age.

The use of specific diagnostic categories in research has the advantage that distinct databases can be developed for future reference. However, van Zomeren et al. (1987) contend whether recommendations for driving can be made on this basis. Here, there is still potential for an array of physical and mental sequelae which would preclude broad generalisations for rehabilitation management (Rosenthal et al., 1983). Severity of a condition, degree of deficit, and time elapsed since injury are also potentially important. Attempts to focus research on specific neurological categories are generally limited to a small sample size. Taken together with the range of assessment methods used, comparison between studies is limited.

Clearly, neuropsychologically-impaired drivers may be different not just on the basis of disorder alone. Consequently, van Zomeren (1987) suggests that people with neurological damage may not necessarily represent a high risk group. The issue raised here is whether general statements concerning neuropsychologically-impaired drivers are appropriate for individual cases. With the use of integrated approaches to driver theory and assessment, a better understanding of the role of diagnostic classifications and the implications for driving assessment will be possible.

Head injury

In many respects, individuals with head injury represent the most diverse group of neuropsychologically-impaired subjects in driving assessment. The variety of cognitive and behavioural deficits that result from head injury are difficult to assess fully (Brooke et al., 1992). Unfortunately, only a few neuropsychologically-impaired driver studies comprise samples which are exclusively head-injured (Brooke et al., 1992; Hopewell & Price, 1985; Kewman et al., 1985; Priddy et al., 1990; Stolx & Gaillard, 1986; van Wolffelaar et al., 1987; van Zomeren et al., 1988). The majority of these subjects have experienced severe injury, which accounts for approximately 10% of all head injuries

(Lezak, 1995). Still, even within this small proportion of the head-injured population, there is considerable individual variability as reflected by the wide range of assessment outcomes. In this respect, Garner (1990) emphasises that each individual case as "unique in the complexity of the clinical picture he may present" (Garner, 1990, p.5).

Individuals with closed head injury make up the majority of neuropsychologically-impaired subjects who undergo an assessment for driving again. This proportion is consistent with general statistics on the etiology of neurological damage, and over half of these head injuries result from motor vehicle accidents (Heilman & Valenstein, 1993; Kraus & Nourjah, 1989; Lezak, 1995). Subsequent neuropsychological impairment is generally diffuse in nature, and is typically characterised by compromised mental speed, attention, and cognitive efficacy (Gronwall, 1989; Lezak, 1995; Prigatano, 1987; Walsh, 1994). When these injuries are severe, difficulties with high-level concept formation and complex reasoning are apparent. Other typical effects include irritability, fatigue, inability to concentrate, and confusion. Notably, many of these more general effects of neurological damage are thought to interfere more with driving ability than the impact of specific lesions (Hopewell & Price, 1985; Stokx & Gaillard, 1986; van Wolffelaar et al., 1987; van Zomeren et al., 1987). In agreement, Lezak (1995) points out that "the similarities in the behavioural patterns of many patients, especially those with closed head injuries, tend to outweigh the individual differences" (p.172).

Medical records of the specific nature or site of head injury are rarely documented in driver research, and have not been systematically related to any driving measures. In a review, van Zomeren et al. (1987) tentatively suggest that frontal symptoms and lesions to the right hemisphere pose a greater threat to driving. These individuals exhibit problem solving and memory-related deficits, as well as a tendency toward impulsive behaviour. Personality and social problems are also predominant. Sensory alterations, including effects on visual competency, may contribute to complaints of dizziness and imbalance.

The impact of specific patterns of deficit on driving tends to be best indicated by neuropsychological test results. For example, several studies have found significant relationships between various driving measures and performance on perceptual (especially visuomotor) and/or spatial orientation tests (Brooke et al., 1992; Priddy et al., 1990; van Wolffelaar et al., 1987; van Zomeren et al., 1988).

Most subjects with head injury perform less well than controls on driving assessments. Considerable variability in performance within head-injured groups, however, appear to be attributed to a wide range of subject variables (Brooke et al., 1992; Hopewell & Price, 1985; van Wolffelaar et al., 1987; van Zomeren et al., 1988). For example, there are differences in passage of time since head injury for different subject groups. Length of coma and PTA, is also varied among most studies of head-injured drivers. Importantly, Hopewell & Price (1985) found that length of PTA was significantly related to pass/fail rates on a practical driving test. Unfortunately, there is no comparative research with groups who have been impaired as a result of mild, or even moderate, head injuries. Furthermore, some research draws attention to possible selection bias within groups of severely head injured subjects, as they are recruited through various rehabilitation settings (Brooke et al., 1992).

Other issues are relevant to the assessment of subjects with head injury. For example, few studies evaluate the effectiveness of assessment through follow-up procedures. One study sought driving outcome data through an unsystematic investigation of number of accidents within two years of assessment (Hopewell & Price, 1985). Data suggested that 22% of subjects had had accidents on follow-up, although it was unclear how this figure compared with individuals from a control group. No research has retested subjects with practical driving measures, although there is some evidence that head injured groups respond to training in various cognitive and driving-related tasks (Hopewell & Price, 1985; Kewman et al., 1985, Sivak et al., 1984a, 1984b).

Finally, various etiological factors may be important head-injured drivers as opposed to other neuropsychologically-impaired groups. Head-injury statistics reflect a higher proportion of males, especially in the early to middle adulthood range. Motor vehicle accidents are a main causal factor (Lezak, 1995). Within this group, age and an increased likelihood of repeated head trauma are important moderator variables in relation to injury severity and subsequent improvement (Heilman & Valenstein, 1993; Kraus & Nourjah, 1989; Vogenthaler, 1987).

Cerebral vascular accident (CVA)

Subjects with CVA are also a prominent group in research on neuropsychologically-impaired drivers (Jones et al., 1983; Quigley & DeLisa, 1983). Survey results suggest that approximately 50% of drivers will continue to drive following CVA (Cimolino & Balkovec, 1988; Legh-Smith et al., 1986). Several assessment and retraining programmes are specifically aimed at individuals with CVA (Everard, 1983; Legh-Smith et al., 1986; Matsko, Boblitz, Glass & Rosenthal, 1975; Nouri & Tinson, 1983; Wilson & Smith, 1983). Consistent with other neuropsychologically-impaired driver research, a similar relationship between driving measures, neurologic outcome and severity is shown in subjects who have experienced CVA (Legh-Smith et al., 1986; Shute & Woodhouse, 1990; Stolx & Gaillard, 1986).

The literature suggests that lesions to the right hemisphere which result in left hemiplegia, are a greater threat to driving skills than left-sided lesions, which result in right hemiplegia (van Zomeren et al., 1987). Studies show that left hemiplegics are judged less favourably as drivers, especially where skills such as adequate visual scanning and proprioception are affected (Quigley & DeLisa, 1983). Here, the biggest problem is "caused by the phenomenon of unilateral neglect, which is usually manifested on the left side of the patients field of vision" (van Zomeren et al., 1987, p.700). Some of these studies report anecdotes from on-road driving assessments where subjects have not attended to pedestrians and cyclists, nor merging traffic, on the affected side (Everard, 1983; Legh-Smith et al., 1986; Wilson & Smith. 1983). A number of studies also report subjects' difficulty in attending to more than the immediate task at hand, in both neuropsychological and driving evaluation (Wilson & Smith, 1983). Here, there are particular problems with rapid sequencing of information.

Driving assessment of subjects with CVA is complicated by the increased likelihood of both physical and cognitive impairment. Physical difficulties in driving are commonly associated with left hemiparesis, as the practicalities of gear changing and use of foot pedals are affected more when driving on left-hand drive roads (Everard, 1983; Quigley & DeLisa, 1983). These, however, are frequently overcome with adaptations and/or the use of an automatic vehicle (Bardach, 1970; Ship, 1986; Shore et al., 1980).

There is little direct evidence of specific driving difficulties encountered by subjects with right hemiparesis. For these subjects, verbal impairments which result from damage to the contralateral left hemisphere, are typically identified through psychological test evaluation. However, these deficits do not appear to be central to the driving task, except where communicating and following road directions are concerned (Bardach, 1971).

A number of etiological factors may contribute to research trends and assessment outcome when subjects with CVA are compared to other neuropsychologically-impaired drivers. The incidence of CVA is on the decline due to the identification of many of the risk factors involved (Lezak, 1995). For individuals who have experienced CVA, however, there is a likelihood of repeated CVA and further neurological damage (Goldberg & Berger, 1988; Lezak, 1995). Characteristically, there is a greater proportion of males and older individuals in the CVA population, which increases the chance of age-related effects on assessment measures (Banks, 1986; Legh-Smith et al., 1986; Lezak, 1995). As an example, age was important in a study which compared subjects with CVA and a significantly younger group of disabled drivers (Cimolino & Balkovec, 1988). Here, training and evaluation was largely carried out on a driving simulator. The CVA subjects found it difficult to adapt to the novel simulated task, and were more likely to show perseveration effects from actual driving.

Dementias

The effects of the various dementias on driving has recently become a popular area for research (Lucas-Blaustein et al., 1988; Oliver, 1991). However, this area comprises a smaller and more separate group of studies on neuropsychologically-impaired drivers. Research suggests that "driving among individuals with incapacitating dementing illness may be an unrecognised, potentially serious problem" (Lucas-Blaustein et al., 1988, p.1087) and emphasises the lack of guidelines for driving assessment of these subjects. Unfortunately, no specific cutoff points in disease progression have been established for when subjects are no longer able to continue driving.

Most studies focus on cortical dementias, such as Alzheimer's disease (Deiter & Wolf, 1989, 1990; Drachman, 1988, 1990; Friedland et al., 1988; Mozar & Howard, 1989). Notably, however, the distinguishing characteristics of various dementia types are only identifiable in the early stages of disease (Lezak, 1995). Among cognitive changes associated with the dementias, attention, inability to concentrate, and psychosocial regression are pronounced. However, there is considerable variability in deterioration patterns, which are ultimately global in nature (Gilley et al., 1991; Lezak, 1995; Walsh, 1994). This feature distinguishes drivers with dementia from drivers who have suffered acute neurological injury where the question is whether they can resume driving. For subjects with dementia, the concern is whether they should cease driving, and if so, when. Age is clearly an important factor with incidence of dementia (Gilley et al., 1991; Lezak, 1995). However, there is a need for age-matched controls, as it is unclear whether there is a greater driving risk compared with persons of similar age. The slowly progressive nature of the disease is another limiting factor in comparisons with other neuropsychologically-impaired groups presenting for driving assessment.

The evaluation of drivers with dementia adopts a slightly different measurement approach. Most studies have relied on surveying informants, which typically includes reporting on accidents and driving incidents since onset of the disease. A criticism of these methods is that it is difficult to capture disease progression when the data collected is retrospective. Large-scale survey data suggests that approximately two thirds of subjects continue to drive after disease onset, although this is mediated by age of onset and type of dementia (Gilley et al., 1991). Subjects with Alzheimer's disease were more likely to continue driving for longer, and were less concerned about whether they should stop driving. Findings show that driving and accident and traffic violation rates are greater compared with age-matched controls. However, a significant relationship between these variables and subject's use of medication is also apparent.

In one study of subjects with Alzheimer's disease, subject reports indicated an accident rate 4.7 times higher than age-matched controls (Friedland et al., 1988). While half of the subjects surveyed had stopped driving since onset, disease severity and corresponding psychological test performance were not related to accident rate. Another similar study found that 41% of subjects were causally involved in accidents since onset of dementia (Lucas-Blaustein et al., 1988). In this study, some psychological test scores showed better performance in those still driving. Interestingly, none of these results interacted with any demographic variables. Characteristic of disease progression, qualitative reports for both studies suggested that getting lost while driving was a problem experienced by most subjects.

Assessment for driving for subjects with subcortical dementias, notably Parkinson's disease, has not been so readily studied in the literature. One small study examined performance of subjects and age-matched controls on a driving simulator measuring simple and choice reaction times (Madeley et al., 1990). Here, severity of Parkinson's disease was significantly related to both accuracy and reaction time on a driving simulator. However, there was no data to suggest subjects had been given any form of on-road driving evaluation.

NEUROLOGIC OUTCOME MEASURES AND DRIVING

Literature reviews identify a relationship between neurological status and ability to drive (e.g. van Zomeren et al., 1987). Although specific group comparison of subjects with differing degrees of neurological damage has not been undertaken, this relationship has been shown in post hoc analyses of data from individual neuropsychologically-impaired subjects within a data set. Subjects with more severe neurological damage do not perform as well on selected tests of neuropsychological function and tend to show poorer performance on practical driving tasks. Studies have also found that fewer people with severe neurological damage choose to resume driving (Golper et al., 1980; Legh-Smith et al., 1986; Madeley et al., 1990). Lezak (1995) states that "severity is by far the most important variable in determining the patients ultimate level of improvement" (p.285). Findings suggest that age is an important moderating variable.

Despite these findings, there is the issue of whether structural and or other clinical status measures are suitable for applied research. Structural measures cover a range of clinical tests, which demonstrate a relationship between extent and severity of structural damage (Stein, Spettel, Young & Ross, 1993). These are "designed to quantify and augment the neurological exam and assist in diagnosis" (Kolb & Whishaw, 1985, p.105). Clinical tests include Electroencephalography (EEG), Electromyography (EMG), and cerebrospinal fluid analyses as well as modern imaging techniques such as Computerised Transaxial Tomography (CT scan) and Nuclear Magnetic Resonance (NMR). Neuropsychologically-impaired driver research is notable for an absence of information from structural damage measures. Indeed, only two studies have included a standard CT scan as part of their subject assessments (Brooke et al., 1992; van Zomeren et al.,1988). Brooke et al. (1992) used "abnormality on a CT scan" (p.178) as a criterion for selection. However, this study did not attempt to document, or relate to the research outcome, any aspect of the detected neurological damage. In the other study (van Zomeren et al., 1988), CT scan results showed all subjects had neurophysical sequelae, while "special attention was given to dysfunctions that could possibly interfere with driving ability" (p.91). The CT scans revealed focal and diffuse atrophy of unilateral or bilateral nature. However, none of the neurologic variables correlated with either psychological test results or driving criteria.

Aside from the extent of structural damage, neurological status can be determined from other clinical criteria (Uomoto, 1990). During the acute phase, measures of coma duration and length of post traumatic amnesia (PTA) may be taken. Subsequently, global disability measures and time post onset are typically used as indicators of chronicity (Hall & Johnston, 1994). Both acute and chronic measures have been documented in research on neuropsychologically-impaired drivers, and will be discussed in more detail below.

A number of validity and reliability criticisms have been raised over clinical assessment measures (Hall & Johnston, 1994; Johnston et al., 1992). For example, Johnston et al. (1992) stress that "when the terms "mild", " moderate", and "severe" are used in traumatic brain-injury rehabilitation without reference to an objective measure, they are applied so inconsistently as to be nearly meaningless" (p.S-4). There are difficulties, however, in finding other suitable criteria for damage severity that will provide an objective framework for the interpretation of data in applied research studies (Newcombe, 1982). Hall & Johnston (1994) note that while indices of neurological status may be regarded for their ability to predict outcome, these indices are medically-oriented, and are used primarily in acute hospital settings early after injury. It is also unclear as to what role these measures play in a rehabilitative context. Nevertheless, early measures of neurological status are not directly related to functional outcome (Brooks, 1984; Newcombe, 1982). In part, this lack of sensitivity is due to the contribution of other variables in the recovery process. As one example, the effects of adaptive and compensatory behaviours play an important role in the assessment of individuals (Brooks, 1984). Further, evidence suggests that not all problems encountered by neuropsychologically-impaired persons are solely related to neurological damage (McLean et al., 1993). Many of these, such as irritability, anxiety, fatigue, and headaches, may actually play a more important functional role in the rehabilitative process.

The reliability of assessment measures limits any conclusions that can be drawn from neurological status measures and outcome relationships (Brooks, 1984). While structural indices use precise measurement instruments, the range of functional measures available generally "have not undergone the kind of rigorous development that results in robust and useful instruments" (Johnston et al., 1992, p.S-3). There is a lack of reliability and standardisation studies available. Further, there is considerable variability in assessments made by different raters and across different institutions (Rimel & Jane, 1983). Problems also exist with the use of repeated measures, and there are few longitudinal studies which monitor improvement. Comparison between subjects, both within and across different studies, is complicated by measurements being carried out at different time intervals (Brooks, 1984).

Information from acute injury

Rimel & Jane (1983) state that meaningful evaluation of duration of coma and PTA parameters of severity of neurological function has been hampered by the use of unstandardised and purely descriptive terminology. While each are considered to be differentially related to later cognitive performance (Brooks et al., 1980), the literature finds few direct comparisons between the most common measures of neurological status (Hall & Johnston, 1994). Overall, there is a positive correlation between duration of coma and severity of neurological damage, which has been increased by the introduction of more standardised measurement. However, the relationship between indices of coma and functional measures such as driving, is inconclusive, as only limited data is available. Use of PTA duration as a measure of neurological status is hampered by use of various operational definitions. While PTA has been used to predict outcome in a number of studies, its use in relation to driving outcome is unclear.

Duration of Coma There is a general acceptance that changes in the level of consciousness constitute the earliest sign of neurologic deterioration after head injury (Rimel & Jane, 1983). Literature reviews report that duration of coma is positively correlated, but not synonymous with severity, especially in the middle range of measurement (Hall & Johnston, 1994; Lezak, 1995; Newcombe, 1982). The utility of a general measure of coma duration, however, was increased with widespread adoption of the Glasgow Coma Scale (Teasdale & Jennett, 1974), which incorporates measures of coma depth in addition to length (Lezak, 1995). The Glasgow Coma Scale is a simple standardised measure of eye opening, motor and verbal indicators of coma severity, usually administered and scored on a regular basis until an accepted level of recovery is achieved. This scale has lessened both variability of measurement and the influence a number of situational variables which affect a day-based measure of coma duration (Brooks, 1984; Newcombe, 1982). In a review of the literature, Hall & Johnston (1994) report that a score on the Glasgow Coma Scale, within 24 hours of injury, is a more robust predictor of outcome than duration of coma. Unfortunately, however, a limiting factor in research on drivers with neuropsychological impairment is the use of coma duration rather than the specific scoring criteria of the Glasgow Coma Scale.

For driving, duration of coma has been used exclusively (Gouvier et al., 1989) or in combination with other measures (Brooke et al., 1992; Priddy et al., 1990; Stolx & Gaillard, 1986) as an index of neurological status. In these studies, subject groups were heterogenous for duration of coma, thereby limiting any comparisons that could be made. Despite this limitation, average duration of coma in days suggests that the majority of subjects in the impaired driver literature have experienced a severe injury on the basis of this neurological status measure (Uomoto, 1990). One study is noteworthy for its use of practical driving criteria in combination with measures of neurological status (Priddy et al., 1990). Here, there were statistically non significant differences in coma length of subjects and driving outcome. The majority of subjects in this study had experienced fewer than four weeks in coma, which on average was less than subjects in Stokx & Gaillard's (1986) and Gouvier et al.'s (1980) samples, but is still within the serious injury range.

Other studies in the driver literature use coma duration purely for description of subjects in their samples, but do not directly analyse this data in relation to functional outcome from driver or neuropsychological test measures. In Stokx & Gaillard's (1986) sample, the average duration of coma was 75.8 days, with a range between zero and 300 days. Their results showed that neuropsychologically-impaired subjects performed slower on reaction time and driving tasks compared with normal controls. Gouvier et al. (1989) describe a neuropsychologically-impaired subject group with a coma duration ranging from seven to 56 days. This experimental group also performed significantly worse than controls on selected psychological tests and driving performance measures. In another study, neuropsychologically-impaired subjects, with a coma duration of at least one hour, scored lower than controls on neuropsychological tests (Brooke et al., 1992). However, driving test results were less discriminative of the two groups, with seven of the 13 being judged safe to drive. The small subject size and an imbalance in the number of subjects in the experimental and control groups may have accounted for these results. Nevertheless, it was apparent that neurological damage in the experimental group was less severe than in other studies, as indicated by a shorter coma duration for the majority of subjects.

Post Traumatic Amnesia (PTA). There is disagreement as to whether duration of Post Traumatic Amnesia (PTA) is an effective marker of neurological status (Brooks et al., 1980; Hall & Johnston, 1994; Newcombe, 1982). Several operational definitions of PTA seem to exist, for instance Brooks (1984) states that PTA uses the length of time from injury to the time the individual is aware of regained consciousness, while Uomoto (1990) states it is the time until continuous memory on a daily basis is re-established. On the other hand, Artiola i Fortuny et al. (1980) report that some standardised criteria for this measure are available. Lezak (1995) states that PTA duration typically lasts about four times the length of coma, and correlates well with Glasgow Coma Scale ratings.

Few studies have established PTA as a significant predictor of subsequent neuropsychological test performance (Brooks et al., 1980). One of the greatest problems is that this measure involves a high degree of monitoring, and is therefore highly subject to rater variability and different institutional conventions (Hall & Johnston, 1994). Uomoto (1990) states that PTA ratings are mainly obtained from self-report and significant others in the case of mild injury, where an individual is discharged soon after trauma treatment.

The use of PTA as an index of severity of neurological damage is variable in studies of neuropsychologically-impaired drivers,. Van Wolffelaar et al. (1987) used length of PTA, defined as the number of days between head-injury and the return of continuous day-to-day memory, as a sole indicator of neurological status. A range of 11 to 124 days was reported, although this data was not utilised in relation to outcome on any of the other research measures. Hopewell & Price (1985) measured length of PTA from the day on which a subject could first be administered the Galveston Orientation

Amnesia Test (GOAT) until three consistent days of normal orientation were achieved. Here, there was a significant difference in length of PTA between neuropsychologically-impaired subjects who were judged safe or unsafe to drive on the basis of a practical driving test. Results showed that "although many patients with relatively short durations of PTA were unable to drive, only two patients with a PTA duration of longer than ten weeks were able to resume driving" (Hopewell & Price, 1985, p.6).

By contrast, van Zomeren et al. (1988) found that length of PTA was not related to outcome on two practical driving measures. Further, the length of PTA correlated with some speeded cognitive tasks, but bore no relationship with other neuropsychological test measures. Given such different results from the Hopewell & Price (1985) and van Zomeren et al. (1988) studies, it is interesting that a comparable mean PTA duration was found of 68 and 73 days respectively. A notable difference in van Zomeren et al.'s (1988) study, was a comparatively younger sample; this age-related factor could have affected the outcome. It was impossible to tell whether the two studies were using the same PTA criteria, as van Zomeren et al. (1988) did not provide an operational definition of this measure.

Chronicity: time since onset information.

Evidence shows that the brain is able to compensate, to variable degrees, for loss of tissue from a variety of causes (Cope, 1990). Evidence suggests that time since onset of neurological damage is a mediating factor in the relationship between severity of injury, specific task performance, and functional outcome. Individual variability, however, makes it extremely difficult to predict outcome at different periods following neurological damage (Brooks et al., 1980; Dikmen et al., 1986). Individual factors such as onset age and the normal cognitive aging of older persons are examples of important variables in the relationship with length of time following onset (Lezak, 1995). For neuropsychologically-impaired drivers, however, there has been little investigation of time since onset information in relation to resumption of driving, or driving outcome.

Distinction is generally made between short and long term outcome following neurological damage, with evidence from case reports of prolonged and even delayed improvement (Cope, 1990; McKinley et al., 1981; Stein et al., 1993). Follow-up studies of subjects with severe neurological damage have found considerable variability with respect to types and combinations of impairment several years post-onset, although in the majority of cases, residual effects are apparent (Levin, Grossman, Rose & Teasdale, 1979; Rappaport, Herrero-Backe, Rappaport & Winterfield, 1989; Tate, Fenelon, Manning & Hunter, 1991).

Evidence also suggests that, as time elapses, different relationships between residual complaints and severity of impairment emerge (Lezak, 1995; Rappaport et al., 1989; van Zomeren & van den Burg, 1985). For example, complaints about attention, concentration, and speed of information processing tend to persist into the chronic stage (Brouwer, Ponds, van Wolffelaar & van Zomeren, 1989; Gronwall, 1989; Hall & Johnston, 1994; Levin, High, Goldstein & Williams, 1989). On the other hand, immediate memory span and the ability to learn new material are more likely to show improvement as a function of exposure and the passage of time since onset (Lezak, 1995; Schweinberger et al., 1993; Walsh, 1994). Further, a number of behavioural complaints and reported intolerances tend to persist as a function of individual coping and aspects not directly related to initial damage (Brouwer et al., 1989; Dikmen et al.,1986a, 1986b; Hall & Johnston., 1994; McLean et al., 1993; van Zomeren & van den Burg, 1985).

The complexity of the cognitive function being examined may contribute to differing improvement curves (Cope, 1990; Lezak, 1979, 1995). Most studies find that improvement varies with the specific nature of the tested cognitive function, task complexity and severity of damage (Lezak, 1995; Walsh, 1994). For example, performance functions are shown to recover at a slower rate than verbal functions, possibly because the initial deficit on these tasks is greater. Importantly, severity of injury may not have any specific effect on rate of improvement, despite contributing to a significantly lower level of neurological outcome (Stein et al., 1993; Walsh, 1994).

A range of neuropsychologically-impaired driver studies utilise time since onset criteria as part of their subject description. Time since onset spans a wide range in most research samples. For example, one group of studies used subjects ranging between one month and 17 years post-onset of neurological damage (Galski et al., 1992, 1993). However, several other studies specified minimum periods of between two and four years post-onset of neurological damage for inclusion into their research (Katz et al., 1990; Stokx & Gaillard, 1986; van Wolffelaar et al., 1988; van Zomeren et al., 1988). In another study, a minimum six months post hospital discharge was set as a subject criterion (Brooke et al., 1992). Unfortunately, none of these studies examined time since onset in relation to actual outcome on any driving measures. A methodological concern is that time since onset of neurological damage may correspond with changes in performance, or even critical periods in improvement (Brooks et al., 1984, Lezak, 1995). Gianutsos (1991a) stresses the importance of time since onset as a baseline in the comparison of research results.

An important feature which is usually overlooked is the interval between neurological damage and resumption of driving for the neuropsychologically-impaired driver. One exception, is the study by van Zomeren et al. (1988) in which subjects ranged between six and 24 months post-injury before driving again. Unfortunately, however, this variable was not analysed in relation to driving outcome. Overall, time since onset of neurological damage is a variable which awaits further investigation.

Global function and disability scale measures.

A wide range of global function and disability scales are available for use with individuals following neurological damage and other trauma (Hall & Johnston, 1994). These measures emphasise the value of assessing a person's functional independence, and are used mainly in the domain of the occupational therapist. The underlying implication is that basic living skills can be acquired despite fundamental deficits (Itoh & Lee, 1990; Simms, 1987).

In rehabilitative care, progress on these basic disability measures is the most frequently used means of marking individual progress, both short- and long-term (Johnston, Findley, DeLuca & Katz, 1991). The practical utility of this form of measurement is therefore a positive feature. However, reliance solely on nominal and ordinal scale data is a limitation (Itoh & Lee, 1990, Keith, 1984). A lack of validity and reliability data, and little research into standardisation of the various available scales, are also frequent criticisms (Chamberlain, 1988; Hall & Johnston, 1994; Johnston et al., 1991; Keith, 1984; Lezak, 1995). Since the underlying properties of many of the measures are unclear, there are limitations on their discriminatory power in comparative studies (Keith, 1984).

A popular group of measures are the various indices of Activities of Daily Living (ADL), which include self-care skills, and sometimes other functional skills as well (Wood-Dauphinee et al., 1988). One widely reported version, Barthel's Activities of Daily Living index (Mahoney & Barthel, 1965), monitors the process of return to near normal levels of functioning, including resumption of driving activity. A recent study using this index found that 59% of subjects were unable to drive one week following head trauma (VanDongen et al., 1993). At one month this figure was reduced to 27%, and by six months 89% of the 146 subjects had returned to normal activities.

Overall, there is a lack of evidence to justify the inclusion of global and disability rating scales in the driving assessment of neuropsychologically-impaired persons. One study found that CVA subjects who no longer drove were significantly more impaired in overall functional ability on the ADL (Legh-Smith et al., 1986). There was a high percentage of "normal' scores on Barthel's ADL for subjects who continued to drive. These high scores were accounted for by their ceiling effect, rather than normal ability of CVA subjects. Thus, Legh-Smith et al. (1986) concluded that the index had limited use in assessment, and suggested that criteria such as "being able to walk independently for 50 yards (45.5 metres) may not sufficiently constitute mobility for driving purposes" (p.202). Another scale used in this study, the Frenchay Activities Index (FAI) (Holbrook & Skilbeck, 1983), also discriminated subjects who were and were not driving. This scale was specifically designed for use with CVA subjects and measures constructive use of time, including amount of driving.

It is interesting that both ADL and FAI disability scales demonstrated an interactive effect with age and also ratings of depression. This finding supports Lezak's (1995) criticism that many scales make use of social and occupational outcome criteria which may be suitable only for younger adults. As expected, other research has found that subjects in their driving studies were categorised as having moderate or good functional recovery according to various global disability scales, such as the Glasgow Recovery Scale (Hopewell & Price, 1985) and the Ranchos Los Amigos Level of Cognitive Function Scale (Engum et al., 1988).

ADJUSTMENT TO NEUROPSYCHOLOGICAL IMPAIRMENT

The clinical relevance of personal adjustment following neurological damage has been recently well documented (Lezak, 1995). Important factors include the nature of ongoing symptoms and complaints, as well as social, emotional, and behavioural implications for the neuropsychologically-impaired individual. In particular, an individual's awareness and management of deficit underlies many of these factors and is central both to early adjustment and successful long-term rehabilitation (Lezak, 1995). Notably, the ability to develop and employ compensatory behaviours is dependent on awareness and insight, which is synonymous with higher level or executive functioning (Ponsford, 1990).

A range of other variables also mediate adjustment of neuropsychologically-impaired subjects (Lezak, 1995; Walsh, 1994; van Zomeren & van den Berg, 1985; Vogenthaler, 1987). These include the severity and site of damage, as well as premorbid characteristics and experiences (Lezak, 1995).

Methodological problems are a prominent feature in research on adjustment factors among neuropsychologically-impaired subjects. In particular, data is largely descriptive and collected by way of subject and relative's reports. A lack of well controlled studies makes it difficult to disentangle the specific and non-specific effects of neuropsychological impairment (McKinlay & Brooks, 1984).

One review suggests that adjustment and insight into neuropsychological impairment may be important in driving assessment (van Zomeren et al., 1988). Some driving test data has found that reduced traffic insight is a common reason for poor driving performance of neuropsychologically-impaired subjects. For example, subjects who were unsuccessful on a practical driving test could "obviously no longer adjust their own driving behaviour to that of other road users or to anticipate and avoid risky situations" (Hartje et al., 1991, p.171-2). Observations made by driving assessors also include evidence of emotional and behavioural effects such as impulsiveness, low frustration tolerance, and a lack of concern for other road users. Several studies provide anecdotal evidence of an association between subject symptoms, complaints, and alteration to regular driving patterns (Everard, 1983; Wilson & Smith, 1985).

Overall, there is an urgent need for further research in these areas (Brooke et al., 1992; van Zomeren et al., 1988).

Ongoing symptoms. An indication of ongoing symptoms following neurological damage is regularly sought in clinical practice, despite a general lack of definition of key terms and standardised measures. Lezak (1995) states that measurement is usually based on self-reported information, where the effects of impairment are assessed indirectly through the presence or absence of various complaints. The nature of symptoms reported and/or presented on checklists is varied, and may or may not be specific to the neurological condition itself. For example, in one study, van Zomeren & van den Berg (1985) differentiated residual complaints from intolerences following neurological damage. Here, intolerances comprised more general, indirect, and persistent effects (e.g. impatience, tiredness, headaches). While there are a range of symptom checklists available, a large number focus on these latter types of complaints.

There are several advantages in the use of symptom checklists in the small number of studies available (Lezak, 1995). There is evidence for reporting higher levels of dysfunction, which may be more important than clinical interview data. This type of information provides a good picture of the evolution of an individual's functioning following neurological damage. Initial validation studies also suggest that some symptom checklists are a useful guide for remediation and counselling, as some items may be sensitive to emotional and adjustment problems. Importantly, reporting of complaints or symptoms provides an insight into a subject's awareness of neuropsychological impairment; this is crucial both to understanding the effects of injury and to successful rehabilitation (Ben-Yishay et al., 1985; Johnson, 1987; Lam, McMahon, Priddy & Gehred-Schultz, 1988; Ponsford, 1990).

Some studies have investigated the extent to which the same symptoms are characteristic of subjects who are, or are not, neuropsychologically-impaired. Dikmen, McLean & Temkin (1986b) examined the Head Injury Symptom Checklist (HISC) and found that both neuropsychologically-impaired subjects and controls reported common symptoms, although neuropsychologically-impaired subjects endorsed more of them. In this study, number of reported symptoms was also positively correlated with severity of impairment.

Evidence suggests that accuracy of reporting may vary, depending on the actual symptom or complaint. For instance, Lezak (1995) cautions that subjects often misinterpret problems of mental efficiency associated with diffuse damage. In particular, slowed processing and attention deficits may be interpreted as memory problems. Analysis of subjects' performance on memory and attention tests, however, "typically implicates reduced auditory span, difficulty doing (or processing) more than one thing or stimulus at a time, and verbal retrieval problems" (Lezak, 1995, p.181).

For some neuropsychologically-impaired subjects, there may be difficulties with checklists in the form of pen and paper tests. These may arise through difficulties with written comprehension, following instructions, or writing. Further, responding is dependent on subjects' willingness to self disclose, which may be inherent in adjusting self-appraisal following impairment (Allen & Ruff, 1990). These factors increase the risk of random responding in subjects who are neuropsychologically-impaired (Priddy, Mattes & Lam, 1988). Consequently, the need to use other forms of assessment in conjunction with symptom checking methods is emphasised (Lezak, 1995).

Neuropsychologically-impaired driver studies focus on a syndrome rather than symptom approach to assessment and analysis. The opportunity exists to investigate the relationship between reporting of residual symptoms and complaints and aspects of driving following neuropsychological impairment. Brooke et al. (1992) even stress that it is "likely that a clinician's recommendations about driving are influenced by a patient's apparent failure to acknowledge deficits, low frustration tolerance or other common sequelae of head injuries" (p.177). Further research is needed in this area.

One study by van Zomeren et al. (1988) used a symptom checklist in their study of neuropsychologically-impaired drivers. While this checklist was not a well standardised measure, it was developed as a result of previous research with neuropsychologically-impaired subject groups. Results showed that all but one of the nine experimental subjects reported several residual complaints. Poor concentration, forgetfulness, intolerance of bustle, and general slowness were most frequently endorsed. By comparison, control subjects reported few, if any, complaints. These results were consistent with descriptions of subjects from previous research. Unfortunately, there was no specific investigation of the relationship of either number, or patterns, of symptoms to driving outcome in the van Zomeren et al. (1988) study. Nevertheless, the importance of collecting this type of data was emphasised as an integral part of adjustment and insight into the effects of neurological damage (van Zomeren et al., 1987, 1988).

Psychosocial functioning. Measurement of psychosocial adjustment is still in its infancy (Lezak, 1995; McKinley & Brooks, 1984). While several scales have been developed, these are yet to be validated and standardised. Newcombe (1981) stresses that without time-sampling of behaviour it is difficult to appraise and measure the nature of psychosocial change, and thus obtain more precise data than that currently provided by subjects and close relatives. Recent literature, however, emphasises that some of the most far-reaching effects of neurological damage involve personal and social competence, and other behavioural and emotional sequelae associated with psychosocial adjustment (Lezak, 1995; Ponsford, 1990; Tate et al., 1991).

Psychosocial adjustment is identified as a complex and heterogenous domain (Hall & Johnston, 1994). Effects on functioning may arise from different sources; notably, damage to brain structures that generate and modulate emotion (frontal lobes), damage to areas of perception and comprehension, as well as secondary sources related to adjustment, such as depression (Matson & Levin, 1990; Vogenthaler, 1987). Lezak (1995) states that the effects of neuropsychological impairment on psychosocial functioning result in changes which "generally involve either exaggeration or muting of affective experience and response" (p.188). Such effects become "symptoms of dysfunctional ability to control and direct behaviour" (Lezak, 1995, p.188). Further, one of the characteristics of psychosocial change is a less stable pattern of behaviour (Wood, 1985). Typical effects include reduced stress tolerance, increased emotional lability, verbal threatening and physical aggression, and coarsening or blunting of many social skills resulting in inappropriate behaviour without concern for others.

Research on psychosocial functioning shows a direct relationship between adjustment in neuropsychologically-impaired subjects, pre-injury status, and social support networks (Lezak, 1995). Subject's age is also an important contributing factor in psychosocial adjustment. Additionally, research shows that while some subjects' psychosocial functioning tends to show a marked improvement with time (Vogenthaler, 1987; van Zomeren et al., 1988), others have identified ongoing persistent effects (Oddy & Humphrey, 1980; Prigatano et al., 1984). These effects tend to be interfaced with cognitive problems, particularly lack of awareness and insight (Uomoto, 1990).

In the long term, therefore, a subject's realistic understanding of neuropsychological impairment is important to psychosocial adjustment (Lezak, 1995) and resumption of normal activities (Dikmen et al., 1986a, 1986b).

Psychosocial adjustment factors have been identified as very important in studies of neuropsychologically-impaired drivers. Several papers have commented on the role of psychosocial factors in readiness for driver evaluation (Bardach, 1970, 1971; Rothke, 1989). Further, these factors appear to influence acceptance of decisions concerning whether or not an individual is able to resume driving following neurological damage (Gurgold & Harden, 1978; Jones et al., 1983). Some studies have identified family support as a factor in psychosocial adjustment and in decisions about resumption of driving (Gurgold & Harden, 1978; Simms, 1987). During driver assessment, psychosocial factors, such as tolerance to stress and frustration, are critical on-road although they may not be directly measured by practical driving tests. Unfortunately, there is a lack of research comparing these factors in drivers from the normal population (Bardach, 1970; Hopewell & Price, 1985). Neuropsychologically-impaired driver studies emphasise that helping individuals to be objective about their skills is an important part of evaluation process (Quigley & DeLisa, 1983; van Zomeren et al., 1988). A review of the literature suggests the need for further research in this area (van Zomeren et al., 1987).

Compensatory behaviours. Compensatory behaviours are important mechanisms for improvement following neurological damage (Lezak, 1995; Walsh, 1994), although they have received little attention in relation to specific tasks such as driving. Consistent with other adaptive behaviours, compensation is difficult to describe and quantify. A review of the literature, however, states that "compensatory techniques and alternative behavioural strategies enable patients to substitute different and newly organised behaviours to accomplish skills that can no longer be performed as originally developed or acquired" (Lezak, 1995, p.286). Interestingly, recent research has established that after one or two years, improvement in neuropsychologically-impaired subjects is more likely a result of "learned accommodations and compensations than return or renewal of function" (Lezak, 1995, p.176).

Many neuropsychologically-impaired individuals are acutely aware of effects such as inefficiency, confusion, and distracted attention, and will try to compensate for these effects with strategies to avoid stressful and highly stimulating situations (Lezak, 1995). A critical factor in the use of compensatory strategies, therefore, is an individual's recognition and perception of deficit. Other factors, such as age and personality are also important mediating variables. Within this context, van Zomeren et al. (1988) maintain that "instrumental shortcomings of head-injured drivers do not result in dangerous driving so long as the subject is able to compensate" (p.95).

Unfortunately, few studies have specifically investigated compensatory strategies, probably because they are inherently difficult to measure (Golper et al., 1980). Nevertheless, a measure of one's awareness or willingness to compensate for driving-related deficits is crucial for future research (Priddy et al., 1990). Within this context, van Zomeren et al. (1988) suggest that insight and evaluation of "one's own performance on cognitive tasks of increasing difficulty might be examples of techniques that will, in future, allow us to predict the possibilities of compensation in head-injured subjects with cognitive deficits" (p.96). There is also the potential for training neuropsychologically-impaired individuals in the use of compensatory driving strategies (Golper et al., 1980; Madeley et al., 1990).

Currently, an individual's use of compensatory techniques is measured through subjective reports or naturalistic observation. Compensatory mechanisms involve decisions such as refraining from driving when tired or stressed, self-imposed restrictions on speed, and restriction of driving times and conditions. In one study, examples were given of subjects who had curtailed their driving to one or two essential trips per week (Lucas-Blaustein et al., 1988). According to van Zomeren et al. (1988), this type of 'anticipatory driving' may actually "be more important for a patient's fitness to drive than the degree of his cognitive deficits" (p.96). Further, increased driving skill and experience is implicated in those drivers better able to compensate for perceptual and kinesthetic problems (van Zomeren et al, 1987; 1988).

Overall, there is an emphasis on compensatory techniques to ensure "impairments are both recognised and minimised" (Jones et al., 1983, p.760). The use of compensatory strategies by neuropsychologically-impaired drivers has clearly been identified as an important area for further research.

NEUROPSYCHOLOGICAL TEST EVALUATION AND DRIVING

An impressive list of tests are available for the assessment of neuropsychological deficits (Lezak, 1995; Uomoto, 1990; van Zomeren et al., 1988). Neuropsychological test evaluation may incorporated in diagnosis, individual care and planning, rehabilitation and treatment evaluation, and research (Lezak, 1995). There has been a shift in emphasis from the use of neuropsychological tests for diagnostic purposes, to the measurement of function in cases where the diagnosis has already been verified (Hall & Johnston ,1994; Lezak, 1995; Ponsford & Kinsella, 1992; Walsh, 1994). In a functional context, it is current opinion that "when performed by a neuropsychologist experienced with traumatic brain injury and in the context of a wider assessment of the whole person, neuropsychological tests help to estimate prognosis and prescribe optimal rehabilitative interventions" (Hall & Johnston, 1994, p.SC-12).

Importantly, the validity, reliability, and applicability of neuropsychological tests may vary according to assessment purpose. Heinrichs (1990) uses the term ecological competence when referring to the use of neuropsychological tests to provide information on skills such as driving performance. In this context, many neuropsychological tests have been criticised as lacking in ecological validity, since actual neuropsychological test performance may be difficult to translate real world performances and goals (Johnston et al., 1991). In an ecological context, clinicians demand a high level of predictive validity to justify the use of a neuropsychological test in an assessment. Johnston et al. (1991) point out that due to specificity of measurement, neuropsychological tests cannot ensure predictive validity to an acceptable level.

By definition, relevant cognitive deficits and executive functions are measured differently by neuropsychological tests. Measurement of cognitive deficits "usually involve specific functions or functional areas" (Lezak, 1995, p.43), while corresponding executive functions are more globally concerned with how an individual goes about doing something, such as driving a car. In neuropsychological testing, the way behaviours are conceptualised is more suited to cognitive functions, where assessment enables fine discrimination. On the other hand, executive functions which are difficult to formally classify as test measures tend to affect expression of all aspects of behaviour.

Executive functions are typically assessed through their effects on cognitive measures in terms of "approaching, planning, or carrying out cognitive tasks, or in defective monitoring of their performance" (Lezak, 1995, p.43). Executive functions therefore involve capacities necessary for formulating goals, planning, carrying out plans to reach goals, and performing activities effectively. For example, one might be concerned about the ability to use environmental cues spontaneously; a particularly relevant factor for driving a car. Cognitive and executive functions are interrelated in the evaluation of any task. As an example, the capacity for sustained attention affects executive functions and cognitive planning (Lezak, 1995).

Other forms of validity also contribute to the value of neuropsychological tests in driving assessments (Angoff, 1987; Heinrichs, 1990; Keith, 1984). By convention, most neuropsychological tests are subject to rigorous validity and reliability studies which are an integral part of their standardisation as neuropsychological measures (Johnston, Keith & Hinderer, 1992). Many neuropsychological tests also have clinical and practical applications, such as advising people about known or suspected cognitive deficits (Gianutsos, 1991). Therefore, information gained from psychological testing can be fundamental in identifying impaired cognitive abilities pertinent to driving performance. Further, no other measures are equally able to provide valid and reliable information on component skills and underlying psychological processes (Gregory, 1990; Sivak et al. 1984, Wilson, 1987). Psychological test evaluations are, therefore, more sensitive to the subtleties of neuropsychological functions than other clinical measures (Johnston et al., 1991). In the interests of research, neuropsychological test measures have important implications for understanding aspects of driver assessment outcome.

Visual perception

Measurement of visual perceptual functions is complex. However, neuropsychological tests involving visual function are among the strongest correlates with practical driving test criteria. There are many aspects of visual perception which may be affected by neuropsychological impairment, and a range of psychological tests are available which assist in discriminating deficit in visual perceptual functions (Lezak, 1995). These tests are separate from standard tests of visual acuity, some of which are inherent in licensing procedures and medical examinations for driving fitness. With the use of psychological tests, measurement of visual perception typically overlaps with tests of orientation and attention, as well as those involving higher level executive functions. Thus, only by using different modalities, conditions, or combinations of functions, is an understanding of the nature of impairment gained (Banich et al., 1990; Lezak, 1995).

Poor performance on visual perceptual tasks is found in a number of clinical groups, as these abilities are affected by a wide range of impairments (Walsh, 1994). However, it has been suggested that since visuospatial and visuomotor functions are typically disrupted as a result of right hemisphere damage (Lezak, 1995), this may explain the lower success rate of left hemiplegic subjects in driver assessment (van Zomeren et al., 1987). Visual perceptual tasks are considered relevant to driving, and deficits in this area are among the more significant predictors of poor performance on practical driving measures for neuropsychologically-impaired drivers (Priddy et al., 1990; Quigley & DeLisa, 1983; Sivak et al, 1981; van Wolffelaar et al., 1987). Visuospatial and visuomotor functions, in particular, have been highly correlated with outcome on several driving tests. Importantly, research has also shown that improvement in visual perceptual skills through training is related to increased driving performance over a standardised driving course (Sivak et al., 1984).

Visuospatial abilities. One-, two- or three-dimensional tracking tasks are commonly used to measure visuospatial abilities of neuropsychologically-impaired drivers. These range from pen and paper maze tests (with an orientation component) to more face valid, in-car tests of lateral position control. The latter have obviously been developed specifically for driver assessment, but are poorly standardised compared to more traditional tests of visual perception. Computerised tracking tasks have also gained popularity as prerequisite measures in the assessment of neuropsychologically-impaired drivers, and have been significantly correlated with measures of practical driving ability (Gianutsos, 1991, 1994; Jones et al., 1983). Some evidence is available for criterion-related validity of the various forms of tracking measures. Lateral position control (measured as constant speed tracking in highway traffic), is significantly correlated with other tests containing visuospatial and visuomotor components, including the Benton Visual Retention Test-Revised (BVRT-R), Trailmaking A, and the

Minnesota Rate of Manipulation Test (van Zomeren et al., 1988). Compared with other neuropsychological tests containing visuospatial and visuomotor components, in-car lateral position control tasks are more often correlated with other practical driving measures (van Wolffelaar et al., 1988; van Zomeren et al., 1988).

Visuospatial abilities are also commonly measured through speeded tests which involve connection between items and symbols, such as Trailmaking A and B. In relation to actual driving criteria, results of these tests are mixed. For example, the Tactual Performance Test together with Trailmaking A and B, significantly differentiated successful and unsuccessful candidates on a practical driving evaluation (Brooke et al., 1992). In the same study, however, other driving criteria, based an examiner's judgement of whether drivers were safe or not safe, did not correlate with the neuropsychological test scores. Galski et al. (1993) found that time to complete Trailmaking A was highly significant in predicting outcome on practical driving criteria. In another study, Rothke, (1989) found that the Trailmaking A and B test did not correlate with outcome on a practical driving examination. Further, van Zomeren et al. (1988), found that although the Trailmaking A and B test did not differentiate success or failure on the Test for Advanced Drivers, there was a highly significant relationship between in-car lateral position control and both of these measures.

Visual recognition. Assessment of visual perception also includes tests of visual recognition. In this category, tests such as Judgement of Line Orientation have correlated significantly with driving status (Priddy et al., 1990). Similarly, Galski et al. (1993) reported that number of errors on the Visual Form Recognition Test was a highly significant predictor of outcome on a practical driving assessment. Van Wolffelaar et al. (1987) found that Judgement of Line Orientation and the Benton Visual Retention Test (BVRT-R) were the only significant clinical variables relating to performance on the standardised 'Test for Advanced Drivers'.

Complicated recognition tasks may also include elements of visual interference, as measured by figure ground tests (Lezak, 1995). Results for the commonly used Embedded Figures test are usually significantly lower for neuropsychologically-impaired groups compared with controls, but do not reach a level of significance in relation to any practical driving measures (Sivak et al., 1981; van Wolffelaar et al., 1987). Interesting results come from an early study of normal drivers, where the

Embedded Figures test was significantly related to perceptual style (Mihal & Barrett, 1976). Unfortunately, this finding has not been investigated further, nor in relation to drivers who are neuropsychologically impaired.

Other tests of visual interference cited in the neuropsychologically-impaired driver literature include Overlapping Lines and the Southern California Figure Ground test (Hartje et al., 1992; Sivak et al., 1981). In these studies, both tests significantly differentiated experimental groups from controls and were close to significant in determining driving assessment outcome.

Visual neglect and scanning. Additional visual perceptual abilities considered to be important to behaviour in traffic include visual neglect or inattention, and visual scanning (Hartje et al., 1992; Quigley & DeLisa, 1983). Fewer formal measures are available to assess these functions, although they may be inherent in tests of attention span and information processing speed (Hartje et al., 1992; van Zomeren et al., 1988). Informal measures, such as hazard identification from slide or videotape presentations of traffic situations, and other forms of driving simulation may also provide useful information (Hopewell & Price, 1985; Gouvier et al., 1989). Unfortunately, research in this area has not really progressed from the early stages of developing standardised measurement techniques, and results are unclear in relation to practical driving criteria.

Visuomotor abilities. The measurement of visual perceptual abilities for neuropsychologically-impaired drivers also enters the domain of motor functions. Tasks with a visuomotor component typically involve measurement of mental speed and coordination, in tests such as Trailmaking A and B, the Minnessota Rate of Manipulation Test, and various reaction time measures. These tests have all been correlated with real driving criteria (van Wolffelaar et al., 1987). However, many of these tests measure other aspects of visual ability and may also be used to assess executive functioning. Therefore problems exist with separating out possible confounding effects of the different functions. Similarly, where motor functions are being assessed, there is the need to ensure that these are not confounded with more general motor disturbances (Lezak, 1995). In driving assessment, the latter tend to be the realm of the occupational therapist, and are sometimes responsive to the use of adaptive driving aids.

Orientation and attention

The global nature of orientation and attention functions implies likely impairment from neurological damage (Lezak, 1995). While the two functions are interrelated, and often assessed together, orientation can remain intact when attentional deficits are mild. Attentional deficits, in particular, tend to persist well after other signs of neurological damage have been overcome (Walsh, 1994). Measurement of both functions appear closely related to the driving task.

Orientation. Orientation is defined as an awareness of self in relation to one's surroundings, which requires "consistent and reliable integration of attention, perception and memory" (Lezak, 1995, p.335). Impaired awareness for time and place is most common, and is reliant on "both continuity of awareness and the translation of immediate experience into memories of sufficient duration to maintain awareness of one's ongoing history" (Lezak, 1995, p.335). Orientation, therefore, is also closely related to the ability to retain information, but not necessarily the ability to verbalise it.

Tests of mental status typically assess orientation for time, place and person, in a very general sense. Other tests, however, are available to measure more specific components of orientation. For driving, measurement of orientation is relevant to one's sense of place, direction, and distance. Drivers must be aware of their own orientation in space and possess the ability to relate to the position, direction, or movement of other objects (spatial orientation). Unfortunately, there are no formal neuropsychological tests which measure spatial orientation in a traffic environment. Aspects of spatial orientation are, however, represented in some tests of visual perception, such as Judgement of Line Orientation, the Benton Visual Retention Test-Revised, the Tactual Performance Test, and the Rey-Osterrieth Complex Figure. While it is difficult to determine how total scores reflect an orientation component, each of these tests have demonstrated a significant relationship with various measures of practical driving outcome in neuropsychologically-impaired subjects (Brooke et al., 1992; Galski et al., 1993; Priddy et al., 1990; Rothke, 1989; van Wolffelaar et al., 1988).

Topographical orientation. Topographical orientation is critical for driving, and involves memory for familiar routes and directional sense. Here, impairment may result in reduced ability for revisualisation or "the retrieval of established visuospatial knowledge" (Lezak, 1995, p.348). Anecdotal evidence from neuropsychologically-impaired driver studies reveals that some subjects are unable to retrace familiar routes, and may easily become disoriented when driving home from places they regularly frequent (Friedland et al., 1988; Lucas-Blaustein et al., 1988). As part of topographical orientation, directional sense demands an ability to perform mental spatial rotations, and also incorporates left-right orientation. Confusion with the latter is often apparent following left hemisphere damage (Lezak, 1995).

Measurement of topographical orientation is not common in neuropsychological assessment, and subsequently there are few formal measures available (Walsh, 1994). The most closely related tests are those which measure route finding. Simm's (1985a, 1985b, 1986, 1987, 1989) inclusion of the Standardised Road Map Test of Direction Sense (Money, 1976), as part of an assessment programme for individuals with physical and neuropsychological impairment, is therefore an important contribution to the literature. The test involves subject's describing an hypothetical journey as it is traced along a pathway by the examiner. Results indicated, that for the majority of studies conducted on neuropsychologically-impaired subjects, the Standardised Road Map Test of Direction Sense was significantly related to in-car assessment ratings.

A functional sense of time, especially time estimation, is also related to the concept of orientation and is often impaired through neurological damage (Lezak, 1995). Again, there is are a lack of formal assessment methods, although the problem is usually overcome by simply asking the subject relevant questions. Although a sense of time would seem important for strategic levels of the driving task, such as planning to arrive at a certain destination in time, this has not been addressed in the neuropsychologically-impaired driver research.

Attention. Compared with orientation, the concept of attention is difficult to define in the context of driving, and must be monitored indirectly through other aspects of behaviour for which there is an attentional component (van Zomeren et al., 1985). Distracted attention, or impaired focused behaviours, for example, are typical deficits of attention. However, at a higher level, a definition of attention is difficult to separate from concentration and tracking, which affects the ability to maintain continued focus on problem solving or following a sequence of ideas (Lezak, 1995).

Distracted attention, or impaired focused behaviours, can be assessed through a variety of tests which measure vigilance or the ability to sustain and focus attention. The most common tests, however, monitor performance on simultaneous tasks such as item cancellation, where the subject must attend to one thing and not others. Here, a high error rate may reflect attentional disorder. However, as these tests involve a timed component, it is difficult to separate out the associated effects of speed of information processing (Lezak, 1995). Series of reaction time trials may also be used to complement other measures of attention. In addition, tests of short term storage capacity (e.g. digit span and tests of repetition), may be used on the principle that they examine how fast and how much the attentional system can handle.

At the higher level, assessment of attention focuses on complex mental operations involving divided or shifted attention, which relate closely to the executive functions. Measurement of attention alone is even more difficult at this level, where problems with separating out speed of complex information processing and tracking capacity are apparent (Uomoto, 1990). Neuropsychological tests such as the Stroop Colour Word Test, Paced Auditory Serial Addition Test (PASAT), Trailmaking A and B, and versions of the Symbol Digit test, are typically used to assess aspects of complex attention (Lezak, 1995; Walsh, 1994). However, caution must be given to other interpretations that can be attributed to poor performance on these tests, such as selective attention deficit and other problems with complex attention.

Vigilance. Tests which measure vigilance have not shown a clear relationship with outcome on practical driving measures for neuropsychologically-impaired driver subjects. Single factor studies have found that Letter Cancellation tasks bear no relation to driving test results (Hartje et al., 1992; Galski et al., 1993). However, multiple regression analyses have found that this same test was one of four significant predictors of driving outcome (Galski et al., 1990). While the correlation coefficient was quite low, it is interesting that one of the other significant predictors was an observed rating of inattention measured during actual driving. Results of simple paced tests, such as digit span, have also shown variable results, and are more likely to differentiate neuropsychologically-impaired subjects from controls than relate to any measure of practical driving (Quigley & DeLisa, 1983; Retchin et al., 1988; Sivak et al., 1981). The results of simple reaction time tests are also variable, and are less able to predict driving outcome than higher level choice or complex reaction time measures (Galski et al., 1993; Golper et al., 1980; Hartje et al., 1992; Madeley et al., 1990; van Zomeren et al., 1988).

Despite some uncertain test results, vigilance to the driving task is clearly important. Ability to sustain attention has been stressed as an issue for neuropsychologically-impaired drivers, especially when driving at night, or long distance over similar terrain. Here, a reduction in attention span, and an increase in the likelihood of becoming more easily fatigued, are seen as potential problems, which are difficult to assess objectively. Interestingly, evidence for possible reduction in attention span of neuropsychologically-impaired drivers has been noted from practical driving assessments of longer duration. Interestingly, Sivak et al. (1981) found that sustained attention, as measured by Porteus Maze Test scores, was significantly related to the driving quality of control subjects. The same result was not true of neuropsychologically-impaired subjects, although this group also demonstrated increased variability in individual test scores.

Complex attention. The ability to operate at, and sustain, a level of complex attention is also an integral part of the driving process. Traffic conditions require constant monitoring and responding to information from multiple sources within a dynamic environment. One of the biggest questions faced by assessors is to decide whether neuropsychologically-impaired drivers can deal with such complexity.

Neuropsychological tests which include an element of complex attention typically find significant differences between neuropsychologically-impaired drivers and controls (Katz et al., 1990; Sivak et al., 1984; van Zomeren et al., 1988). Fewer tests have actually been compared with real diving criteria. Here, unclear results have been shown for the well known Stroop Colour Word Test, which can reflect difficulty concentrating, warding off distractions, and ability to shift attention (Friedland et al., 1989; van Zomeren et al., 1988). Other tests requiring focused concentration and ability to shift, such as Trailmaking A and B, are significantly related to some driving criteria, specifically, tracking a constant path in traffic, which has a high complex visual search component (van Zomeren et al., 1988). Some interesting results have also been shown for the Symbol Digit modalities test. Gouvier et al. (1989) administered both oral and written versions and found that the oral test significantly predicted driving outcome assessed over a closed course. In one of several studies by Galski et al. (1993), the Digit Symbol subtest of the WAIS-R was found to relate significantly with driving test outcome.

Anecdotal evidence from research on neuropsychologically-impaired drivers suggests problems with inattention and ability shifting to attend to more than one stimulus at the same time. For instance, there are numerous accounts of difficulties attending to busy traffic, where amount and timing of responses to the driving situation become crucial (van Zomeren et al., 1987). Incidents of frequent inattentiveness to traffic signs and even total breaks in attention, where subjects proceeded to do other things without apparent concern for the driving task, are also examples from the literature (Quigley & DeLisa, 1983).

Memory

The measurement of memory spans a wide range of cognitive activities which represent all modalities. Lezak (1995) emphasises "differences in the degrees to which 'memory functions' become impaired and differences in their patterns of impairment attest to their anatomical and functional distinctions" (p.429). Memory is therefore subject to the influence of many factors which can be confusing in assessment. Apparent memory problems, for example, can actually be problems of attention or mental tracking interference. Importantly, also, memory functions operate with less than perfect efficiency for all subjects, not just those who are neuropsychologically impaired. A heightened sensitivity to age is also apparent in measurement of memory.

In the assessment neuropsychologically-impaired drivers, research on memory function has focused on aspects of immediate or working memory rather than long term or delayed memory. Visual memory is predominantly assessed. Notably, with only one or two exceptions, all of the "memory" tests documented in the driver literature may be regarded more for their visuospatial and perceptual motor integration than actual memory function (Uomoto, 1990). These same tests often involve a visuomotor response which can confound measurement of the memory component (Lezak, 1995). It is also interesting that even in one of the most popular tests of general memory function, the Wechsler Memory Scale (WMS), is by virtue of its scoring system, weighted more towards visual memory problems.

Neuropsychologically-impaired groups typically demonstrate impairment on tests of immediate recall or recognition, such as digit span. Such impairment typically shows little improvement since onset of neurological damage (Banich et al., 1989). Visual memory and recognition are thought to be important to the driving process as it may provide information about accuracy of perceptual discrimination. However, such information is difficult to obtain from available neuropsychological tests (Lezak, 1995), which may explain some of the variance in results of studies investigating the relationship between driving and memory. Most neuropsychologically-impaired driver studies that do assess a memory component are based exclusively on subjects with dementia (Hartje et al., 1991; Lucas-Blaustein et al., 1988).

The Benton Visual Retention Test-Revised (BVRT-R) measures visual recall and immediate memory span. This test is the most commonly used measure of memory function in neuropsychologically-impaired driver studies. From available evidence, the role of BVRT-R in the driving assessment process is promising, but not altogether clear. In a reasonably large study, Priddy et al. (1990) found that differences in BVRT-R scores between driving versus non-driving head-injured subjects were highly significant. In another study, the BVRT-R was one of two tests, from 26 independent measures, to significantly predict pass or fail on a preliminary driver screen (Galski et al., 1990). Unfortunately, correlations between the preliminary driver screen and an informal combined closed-road and on-road driving evaluation were not significant. Interestingly, a study by van Zomeren et al (1988) found no differences between subjects and controls in number of correct responses on the BVRT-R. Analysis of correlations, however, found that test results (number of correct responses) were significantly related to performance on an in-car measure of lateral position control. Neither the BVRT-R score nor lateral position control correlated with the standardised 'Test for Advanced Drivers' used in this study.

According to Lezak (1995), the BVRT-R is more highly correlated with measures involving design copying, constructional and visual perceptual abilities, than other tests of memory. The test is also particularly useful for indicating perseveration and visuospatial neglect. This information is interesting in light of evidence from other tests of memory which provide variable results for subjects with a range of neuropsychological impairments. Rothke (1989) found a significant relationship between subjects who passed a practical driving evaluation and better performance on the verbal delayed recall subtest of the Weschler Memory Scale (WMS). By contrast, Brooke et al. (1992) found no relationship between any WMS scores and driving assessment outcome. Similarly, Katz et al. (1990) found no correlation between Weschler Memory Scale Scores and a subject's number of reported motor accidents.

In the study by Rothke et al. (1989) significant results were also found between faster completion time on trials with the dominant hand for the Tactual Performance Test and successful driving outcome. Brooke et al. (1992) also found that the Tactual Performance Test was significantly related to subjects' driving assessment outcome. The Tactual Performance Test (which is part of the Halstead Reitan Battery), measures tactile memory, but is also valued as visuospatial performance task. While blindfolded, subjects are required to transfer shapes onto a formboard, over three trials, two with the dominant and one with the non-dominant hand. On completion, subjects must then draw the shapes.from tactile memory. Notably, neither of the above driving studies actually refer to this tactile memory score in their results, which suggests that memory component was not the significant part of the test. Further, it is interesting that Lezak (1995) maintains that the Tactual Performance Test is not a very discriminative test, but that it is highly sensitive to age effects, and not suited to measurement of functional capacities.

Two other memory tests, Logical Memory and Visual Reproduction, used in a series of studies by Simms (1985a, 1985b, 1989), failed to discriminate drivers from non-drivers among mixed groups of spina bifida and neuropsychologically-impaired subjects. Another test of memory, the Rey-Osterrieth Complex Figure Test has shown variable results as a predictor of driving outcome (Galski et al., 1993; Sivak et al., 1984b).

Generally, there has been a lack of research on aspects of delayed or long term memory in studies of neuropsychologically-impaired drivers. Unfortunately, the effects of neurological damage on aspect such as recall of road rules and remembering how to get to various locations, as well as personal orientation for retention of ongoing driving experiences, therefore, have not been investigated.

Reaction time

Reaction time is an integral part of both general and driving assessments following neurological damage (Tate et al., 1991; van Zomeren & van den Burg, 1985). In addition to measuring psychomotor speed, reaction time data can provide a means by which information on a wide range of possible deficits may be recorded through timed tests of decision time, perceptual processing, movement time, selective attention, sustained attention, susceptibility to mental fatigue, vigilance and mental effort (Braun, Daigneault & Champagne, 1989). Most frequently, reaction time measures are considered an index of information processing deficit (Elsass, 1986).

Various forms of reaction time measurement are common in studies of neuropsychologically-impaired drivers. However, there is no consistent methodology, despite documentation that small variations in reaction time procedure influence reaction time measured (Elsass, 1986; Stuss, Pogue, Buckle & Bondar, 1994). Comparison between studies is therefore difficult. Of the various forms of measurement, artificial reaction time measures are most commonly used (e.g. Galski et al., 1992; Hartje et al., 1991; Katz et al., 1990; Madeley et al., 1990; Nouri & Tinson, 1988). These include a wide range of documented methods ranging from simple and/or continuous reaction time to more elaborate versions such as computerised tests and elementary driving simulators. No direct on-road measures of reaction time have been singled out for analysis, although reaction time may be inherent in driving tests (Hartje et al., 1991).

Simple reaction time. As shown from neuropsychological studies, simple reaction time is inconsistent in differentiating neuropsychologically-impaired subjects from controls (Braun et al., 1989; Stuss et al., 1989; van Zomeren, Brouwer & Deelman, 1984). For the prediction of practical driving outcome, simple reaction time tests are also less reliable than those which measure choice and complex reaction time (Hartje et al., 1991; Madeley et al, 1990; van Zomeren et al., 1987).

Research suggests that it is irrelevant whether simple reaction time is measured in a car simulator or by other approximations of car driving, or whether more rudimentary methods are used. A number of researchers have used driving simulators only to measure simple reaction time with insignificant results compared with practical driving performance (Golper et al., 1980; Jones et al., 1983; Nouri & Tinson, 1988). Jones et al. (1983) speculated that simple reaction time, measured as braking using a foot pedal, was not by itself a reliable indicator of driving due to the availability of other methods of brake control (handbraking) and compensatory techniques in a real driving situation.

Choice reaction time. Driver studies incorporating choice reaction time measures have shown promising results. Outcome of a multivariate study resulted in a combination of computerised simple and choice reaction time measures being included in a final set of predictors for driving again (Gouvier et al., 1989). In another study, decision time on a visual choice reaction time measure significantly discriminated between neuropsychologically-impaired subjects and controls, although results did not significantly correlate with pass or fail outcome on a practical driving test measure (van Zomeren et al., 1988). Using the same choice reaction time measure, however, van Wolffelaar et al. (1988) found a significant correlation between decision time and a practical traffic merging task.

Complex reaction time. Complex reaction time measures show a strong relationship with measures of practical driving. For example, Stokx & Gaillard (1986) specifically investigated whether car driving could be predicted on the basis of reaction time measured in the laboratory. A range of complex reaction time tasks were used in which stimulus degradation, set size, stimulus-response compatibility, and time uncertainty conditions were varied. On all tasks, neuropsychologically-impaired subjects showed consistently longer reaction times than controls. Results showed that slalom driving was significantly correlated with mean reaction time in the four laboratory conditions. Interestingly, this correlation was found for the neuropsychologically-impaired group and not the controls.

In another study, complex reaction time was measured in the form of a driving simulator across a small sample of subjects with Parkinson's disease and controls (Madeley et al., 1990). Results showed a significant positive correlation between complex reaction time and number of correct responses made by all subjects. Complex reaction time results also significantly differentiated subjects with Parkinson's disease who were still driving, and the control drivers. Both simple and complex reaction time was significantly slowed for subjects with Parkinson's disease who no longer drove, as opposed to those who were still driving. Similarly, Galski et al. (1993) reported highly significant correlations between reaction time measures and a behind-the-wheel driving evaluation for a fairly large sample of neuropsychologically-impaired subjects.

Hartje et al. (1991) measured simple and choice reaction time using visual and auditory cues, and complex reaction time incorporating both hand and foot responding. The apparatus was similar to that used in the present study, with the exception of the auditory cue. Here, neuropsychologically-impaired subjects were divided according to whether they showed aphasic symptoms. Number of correct responses and errors were recorded for subjects over a five minute testing session. Significant differences were found in the mean number of errors recorded for the complex reaction time trials, and pass or fail on a driver licencing test.

Executive functions.

While executive functions are considered "part and parcel of everything we do" (Lezak, 1982, p. 283), there are difficulties with definition and measurement since they represent actual processes more so than specific abilities. Various interpretations of executive functions may be found in the literature. For example, Lezak (1982) defines executive functions as comprising "those mental capacities necessary for formulating goals, planning how to achieve them, and carrying out the plans effectively" (p.281). Uomoto (1990) includes ability for abstraction, problem solving, and new learning as an integral part in the definition and measurement of executive function. Further, Walsh (1994) acknowledges that both complexity, in terms of number of lower level functions involved, and an abstract quality of behaviour, may contribute to the concept of executive functioning.

Lezak (1982, 1995) also identifies four principal components, volition, planning, purposive action, and effective performance, which are probably the most useful for conceptualising executive functions. However, these components are not mutually exclusive, which adds to the difficulty with which each is assessed. Together, they rely heavily on intact frontal lobe functioning, especially the left hemisphere (Banich et al., 1989).

Volition. Volition is the capacity for intentional behaviour, which requires both motivation and awareness of one's own level of ability. This concept relates closely to an awareness of the environment and situations, which is an integral part of driving behaviour. For example, a deficiency in this area of executive functioning may translate as the inability to recognise and act on a critical driving situation. In the neuropsychologically-impaired driver literature, it is commonly reported that subjects have most difficultly recognising and acting on situations of potential hazard, particularly when the situation is complicated by several things happening at once (Hopewell & Price, 1985; van Zomeren et al., 1987). There are no neuropsychological tests which specifically measure volition, although aspects of the concept may be tested as part of mental status examinations, and may be inferred from observation of performance on a range of other tests. In this context it is difficult to interpret findings objectively, and naturalistic observations of behaviour in are often preferred (Lezak, 1982).

Lezak (1995) also states that self-awareness may be impaired, especially an appreciation of one's abilities following neurological damage. Volition is therefore also tied in with psychosocial aspects, such as social awareness in the individual. As documented earlier in this chapter, these aspects are important in the resumption of driving following neurological damage (Gurgold & Harden, 1978; Jones et al., 1983; Simms, 1987; van Zomeren et al., 1988).

Planning. Planning requires the ability to "conceptualise changes from present circumstances (i.e. look ahead), deal objectively with oneself in relation to the environment, and view the environment objectively" (Lezak, 1995, p.654). Here, an individual must be able to conceive of, and make choices while entertaining "both sequential and hierarchical ideas necessary for the development of a conceptual framework that will give direction to the carrying out of a plan" (Lezak, 1995, p.654). Hierarchical models of driving encompass this idea, where operational, tactical and strategic levels of function reflect preparatory and executionary stages of the driving task (Michon, 1985; van Zomeren et al., 1987). Thus, in order to reach a specific destination, an individual must have the ability to plan a trip and to deal with possible events such as what happens when certain obstacles (e.g. poor driving conditions, traffic congestion, fatigue) get in the way.

A range of neuropsychological measures incorporate aspects of planning and foresight, including the various well known maze tests and the Trailmaking A and B test. A series of tower tasks and other puzzles are also available, which require forward planning to meet a goal in the fewest moves (Lezak, 1995). In all of these tests, sustained attention is also an important component. Few neuropsychologically-impaired driver studies have utilised maze tests in their assessments. One study, which used the Porteus Maze, found that the test just reached a level of significance discriminating neuropsychologically-impaired subjects from controls (Sivak et al., 1981). Another recent study found that the Porteus Maze test significantly predicted success on a practical driving evaluation (Galski et al., 1993).

In other studies, the Trailmaking A and B test consistently differentiates neuropsychologically-impaired subjects from controls (Gouvier et al., 1989; Katz et al., 1990; van Wolffelaar et al., 1988). Compared with controls, greater differences in completion times for part A and B of the Trailmaking test reflect neuropsychologically-impaired subjects' difficulty with anticipating a mental sequence when more than one stimulus set is presented at a time (van Zomeren et al., 1988). However, in relation to a practical measure of in-car lateral position control, both Trailmaking A and B scores were significant, which adds emphasis to visuomotor and timed components of the test. Interestingly, van Wolffelaar et al. (1988) used the Tower of London test to measure executive functions and found that it did not distinguish neuropsychologically-impaired subjects from controls, nor did it relate to driving test outcome. The fact that this was not a timed test was thought to contribute to this unexpected finding.

Purposive action. Plans have to be translated into purposive action, which is the third component of executive functioning according to Lezak (1995). Here, the ability to programme activities, or to initiate, maintain, and alter behaviour according to demands, such as an ever changing traffic environment, is necessary. The distinction is made between impulsive and consciously deliberate actions, and routine and non-routine task performance, which has important implications for individuals who are neuropsychologically-impaired. Typically, "overlearned, familiar, routine tasks and automatic behaviours can be expected to be much less vulnerable to brain damage than are non-routine or novel activities, particularly when the damage involves the frontal lobes" (Lezak, 1995, p.659). Thus, aspects which have become automated in the experienced driver, such as manual control of a vehicle, are less likely to show the effects of impairment than responses to actual traffic scenarios. This is clearly supported in a review of neuropsychologically-impaired driver research (van Zomeren et al., 1988). In a driving situation, behaviour which is not automated may be particularly affected by a subject's inability to pull attention away from current thoughts.

A number of neuropsychological tests, such as the Stroop test and Trailmaking A and B, may be used to examine the concept of purposive action. Here, evidence for performance deficits, such as erratic behaviour, reduced capacity to shift or alter behaviour, and ability to verbalise but not carry out intentions, are typical examples from qualitative reports of subjects' responding on these tests (Walsh, 1994). Unfortunately, this type of information regarding subjects' performance is not reported in studies assessing neuropsychologically-impaired drivers. Evidence from actual test scores, however, shows that both tests have good discriminative ability for groups of neuropsychologically-impaired subjects versus controls (Friedland et al., 1988, van Zomeren et al., 1988). In relation to real driving criteria, only the Trailmaking A and B test has shown significant results (van Zomeren et al., 1988).

Effective performance. Effective performance involves monitoring, self-correction and regulation of tasks. Again, this component is difficult to measure, and is only indirectly associated with traditional neuropsychological tests scores. Nevertheless, elements of effective performance can be qualitatively measured from the ways subjects go about tests such as the Category Test, Trailmaking B, the Tactual Performance Test, and the Wisconsin Card Sorting Test (Lezak, 1995).

Lezak (1995) states that effective performance is often better assessed by giving a subject a set of instructions, such as locating an object or place, and observing procedure. In the same way, information can be obtained from subjects in their execution of a driving task. For instance, many driving tests begin by giving the candidate a set of directions for a course they must follow, which would seem a practical and direct method for assessing effective performance.

Overall, there are problems with measurement of executive functioning (Lezak, 1982, 1995). Initially, the different aspects of executive function are difficult to separate, whether they be assessed through neuropsychological tests or naturalistic observation in a specific setting (e.g. driving). For example, route finding tasks, whether formal (such as standardised maze or map tests) or informal (such as direction given to follow a specific sector of a driving test), involve all components of executive functioning from planning through to completion of the task. Further, Lezak (1995) states that deficit in executive functioning "typically involves a cluster of deficiencies of which one or two may be especially prominent" (p. 650). Thus, individuals rarely show impairments in one aspect of executive functioning without other areas also being affected. In addition, Lezak (1982) stresses that existing measurement offers no guidelines for graduations in impairment or improvement of executive functions. This greatly limits the amount of intra- and inter-individual comparison possible. All of these issues are a threat to the validity and reliability of any measures of executive function.

Screening tests and batteries for assessment of neuropsychological impairment.

According to Lezak (1995) predictive validity and an understanding of the nature of organic disabilities have been the goals which have guided the development of screening tests and batteries for neuropsychological assessment. In current practice, however, selection of test batteries is "based more on usefulness in eliciting different kinds of behaviour that are relevant to a patient's condition and needs than on predictive efficiency" (Lezak, 1995, p.686). Lezak (1995) also states that there are no test batteries which altogether encompass suitability to a subjects needs, practicality of administration and cost, and usefulness in terms of the information the examiner wants. Nevertheless, these criteria are central to the selection and evaluation of testing materials for whatever purpose they are required to serve.

Several well known screening tests and batteries have been used in the context of assessing neuropsychologically-impaired drivers. For this purpose, existing formal batteries have not been found to be particularly useful in explaining driving behaviour, although many do serve to differentiate neuropsychologically-impaired subjects from controls, thereby confirming the presence and nature of disability in the experimental groups. Most importantly, specific subtests have shown significant correlations with practical driving criteria. It is generally agreed, however, that simpler measures, or the subtests alone, should be used to supply this information (Katz et al., 1990; Rothke, 1990).

From the range of screening tests available, the Mini Mental State Examination (MMSE) has been used in several neuropsychologically-impaired driver studies. Here, overall MMSE scores discriminate between driving and non-driving subjects, particularly in studies of dementia (Gilley et al., 1991; Lucas-Blaustein et al., 1988). On the other hand, research has found no significant relationships between MMSE scores and actual driving behaviour against accident criteria (Friedland et al., 1988; Gilley et al., 1991). Unfortunately, other practical criteria, such as driving test outcome, has not been investigated as a correlate of performance on the MMSE. Similar trends using MMSE data were found for a study on the neuropsychological screening of pilots (Banich et al., 1991). While scores are low enough to set a cutoff for an acceptable level of impairment (Gouvier et al., 1989), they are unlikely to be sensitive or adequate for differentiating aspects of the driving task (Banich et al., 1991).

Use of formal test batteries in the assessment of neuropsychologically-impaired drivers has been limited. Two popular measures have been investigated: the Wechsler Adult Intelligence Scale (WAIS-R) as a measure of ability and achievement; and, the Halstead-Reitan Battery which is used in general neuropsychological assessment. While both measures tend to differentiate neuropsychologically-impaired subjects from normal controls, the relationship with driving is less clear. Overall scores are generally not significant in driver assessment, as these can be affected by impairments which have no apparent relationship to driving (Katz et al., 1990; Rothke, 1990). In this respect, analysis of individual subtests is interesting. Using various driving criteria, significant results have been inconsistently found for a range of subtests, including Picture Completion, Picture Arrangement, and Digit Symbol, from the WAIS-R (Brooke et al., 1992; Galski et al., 1993; Gouvier et al., 1989; Katz et al., 1990; Priddy et al., 1990; Rothke, 1989; Sivak et al., 1981). For the Halstead-Reitan battery, consistent relationships have been found between specific subtest scores, namely, Tactual Performance and Trail Making, and driving outcome (Brooke et al., 1992; Katz et al., 1990; Rothke, 1989; Sivak et al., 1981).

With the WAIS-R, there is controversy over the suggestion that IQ scores are higher in neuropsychologically-impaired subjects who are driving compared to those who are not (Hartje et al., 1991; Hopewell & Price, 1985; van Zomeren et al., 1987). It has been proposed that IQ is important when it lies at the lower end of the normal range, where this measure may, for instance, "have consequences for insight on the strategic and tactical levels of driving" (van Zomeren et al., 1987, p.702). However, lower IQ scores may also be a consequence of the slowed performance typical of neurological damage. Without measures of neither premorbid IQ or driving status, there is insufficient evidence to support these claims. How IQ relates to driving performance in the general population has not been established, partly because numerous other variables, such as socioeconomic status, are known confounds.

Test selections developed specifically for neuropsychologically-impaired driver assessment. Most neuropsychologically-impaired driver studies use their own informal collections of assessment tests. These generally comprise pre-existing tests, which are considered representative of the categories of abilities most relevant to the driving task. For example, the majority of test selections include measures of visual perception and visuomotor abilities, attention and speed of information processing, executive functioning, and sometimes, orientation and memory.

There are a number of considerations with research designs based of neuropsychological test selections. First, individual studies use neuropsychological tests in different ways which may affect instrument selection and result interpretation. Second, single factor approaches may vary from other research designs which incorporate multivariate techniques, in which test results are examined simultaneously. Multiple regression analyses have the advantage that while individual test correlations may be low, the combined effect of two or more tests can significantly account for the overall variance (Engum et al., 1988a, 1988b, 1990; Galski et al., 1990, 1993). Naturally, however, significant correlations for large numbers of selected tests are rare. On the other hand, many single factor studies find one or two tests independently reach a level of significance in relation to driving outcome (Priddy et al., 1990; Rothke, 1989; Simms, 1985a, 1985b; Sivak et al., 1981; van Zomeren et al., 1988).

Although neuropsychological tests may differentiate neuropsychologically-impaired drivers performance levels from controls, many studies do not examine whether there is a direct relationship between neuropsychological test performance and any driving outcome criteria. Consequently, results may be misleading as various links with actual driving performance are only inferred. By contrast, other studies do use neuropsychological tests in the context of predicting driving outcome (Brooke et al., 1992; Priddy et al., 1990; Rothke, 1989; van Wolffelaar et al., 1988; van Zomeren et al., 1988). However, many studies are limited by an absence of control subjects (Katz et al., 1990). In these cases, there may be an inappropriate reliance on testing information from previous clinical records (Hopewell & Price, 1985; Priddy et al., 1990). Frequently, driving criteria and subject selection may vary considerably between studies, which makes comparison difficult.

Despite these limitations, neuropsychological test performances as predictors of practical driving performance represents an important, if not ambitious, development in the assessment of the neuropsychologically-impaired driver. Within this context, two notable studies are the driving assessment research designs used by van Zomeren et al. (1988) and van Wolffelaar et al. (1987). Overall, the general driving quality of neuropsychologically-impaired subjects from these two studies were not related to neuropsychological tests of higher mental functioning, suggesting the practical driving tests could not explain driving performance within a cognitive framework (van Wolffelaar et al., 1987). However, there was a relationship to visuo-motoric performance, as demonstrated by significant correlations with the lateral control and adaptive tracking tasks. That is, poor lateral position control was significantly correlated with poor performance on the Benton Visual Retention Test, Trails A, and the Minnesota Rate of Manipulation Test (van Zomeren et al., 1988). In addition, simple speed relationships could also be identified between the psychological and driving tasks.

A number of other studies have also shown limited relationships between practical driving test measures and neuropsychological test assessment. For instance, Rothke (1989) exposed subjects to an unspecified open-road driving test and an extensive neuropsychological test battery. Here, the presence of neuropsychological impairment did not differentiate between subjects who passed or failed the practical driving test. Importantly, however, psychometric test results involving delayed memory and psychomotor planning/problem solving were correlated with pass/fail using a practical driving criterion. A similar relationship between driving performance and psychological test assessment was also observed by Sivak et al. (1981). Here, neuropsychologically-impaired subjects made more errors than controls on an unspecified driving task. In another study, Hartje et al. (1991) found that subjects who passed the driving test showed better mean performance on the neuropsychological tests. The limited nature of these available findings, however, underline the need for a practical on-road driving examination when a decision has to be made concerning the driving ability of a neuropsychologically-impaired subject (Hartje et al., 1991).

Selections of neuropsychological tests have been included with a range of driving measures in the small number of multivariate studies available. Compared with studies which use open-road practical driving tests, some studies have found interesting results using closed-road and other driving measures. For example, studies of neuropsychologically-impaired subjects have found high numbers of correlations among test measures and small-scale or full-scale vehicle driving criteria on a closed course (Galski et al., 1993; Gouvier et al., 1990). In the study by Gouvier et al. (1990), for example, correlations ranged .206 to .759 and all but two were significant. Tests included Digit Symbol, Trails A and B, reaction time, the Motor Free Visual Perception Test, and individual subtests of the WAIS-R. Here, 70 % of the variance in full scale driving score outcome was explained by the Oral Digit Symbol subtest of the WAIS-R. The relationship between neuropsychological tests and simple driving indicators, which both focus on more isolated and specific abilities, poses some important questions for the value of comparison of the various measures used in assessment for driving again.

A lack of follow through of the same selections of neuropsychological test variables, through replication and rigorous testing procedures, has constrained progress toward developing reliable test selections for the assessment of neuropsychologically-impaired drivers. There are only a few exceptions where the same group of researchers have attempted to validate their own test selections on various samples (Engum et al., 1988a, 1988b, 1990; Galski et al., 1990, 1993; Simms, 1985a, 1985b). For example, Galski et al. (1990) used an extensive 21 item predriver evaluation comprising neuropsychological test and observational measures. Regression analyses found that only four items, including the overall score on the Benton Visual Retention Test and the Letter Cancellation Test, significantly predicted outcome on the overall predriver evaluation. Overall, none of the items on the predriver evaluation, nor a behind-the-wheel examination, explained a significant proportion of variance in driving test outcome. However, a follow-up study, using a much larger sample, found that several neuropsychological tests significantly discriminated pass from fail on the behind-the-wheel-examination with overall 71% sensitivity and 87% specificity (Galski et al., 1993). Combined with behavioural indices, the ability of these tests to predict failure on the behind-the-wheel evaluation was increased further to 82% sensitivity and 91% specificity.

The group of studies by Engum and colleagues examined the inclusion of neuropsychological tests as part of a Cognitive Behavioural Driver's Inventory (Engum et al., 1988a, 1988b, 1990; Engum & Lambert, 1990; Lambert & Engum, 1990). Neuropsychological test items included here were the Digit Symbol and Picture Completion subtests of the WAIS-R, Trailmaking A and B, and a measure of reaction time (Engum et al., 1988a,b). Individual test scores were highly correlated with a composite score for the Cognitive Behavioural Driver's Inventory, particularly the Digit Symbol subtest, and Trailmaking A and B. Subjects passing a practical driving test performed significantly better on individual items and summary scores for the Cognitive Behavioural Driver's Inventory (Engum et al., 1990). Further studies to standardise the measure support these findings (Engum & Lambert, 1990; Lambert & Engum, 1990).

Chapter Six

THE PRESENT RESEARCH

This Chapter presents the general aim and specific research objectives for the present study. For the sake of clarity, these objectives are justified in the context of the preceding review chapter headings. Overall, the present research took a systematic, quasi-experimental approach to measure practical driving performance, driver personal characteristics, and neuropsychological assessment variables within an integrated model framework.

While the literature has a short history, interest in the assessment of neuropsychologically-impaired drivers is underscored by a growing number of publications over the last decade, including an important review (van Zomeren et al., 1987). As reviewed in the preceding Chapters, driving is a highly complex process which is defined by a wide range of social and cognitive factors. Thus, driving in the general population is affected by numerous social demographic factors such as age, education, previous experience, motivation and personality, and by psychosocial components such as use of compensatory behaviours. For all drivers, efficient cognitive function is also critical to successful driving performance given that a driver must constantly receive, process, and respond to information derived from an everchanging driving environment.

The relative contributions of all these diverse factors differ significantly between individuals. Consequently, successful driving assessments which predict driving performance and behaviour are ideally integrative in nature, and flexible enough in design to accommodate the continually changing interplay of driving-related variables. In this context, the inclusion of neuropsychological tests in a driving assessment scheme is an important component, aimed at identifying aspects of cognitive function as an integral part of the driving process. Naturally, the ability to detect impaired cognitive function that is linked to driving performance has important implications for the assessment of neuropsychologically-impaired individuals for driving again.

Currently, there is a lack of integrated theory which accounts for the special characteristics of individual drivers within the context of the driving environment. Interestingly, studies of neuropsychologically-impaired drivers, in particular, appear to place an added emphasis on a range of individual characteristics and their role in driving performance. Two current models (Galski et al., 1992; van Zomeren et al., 1987), provide conceptual frameworks for research into the assessment of drivers with acquired neurological damage, however, neither of these take a truly integrative approach.

OVERALL AIMS AND RESEARCH OBJECTIVES

The overall aim of the present research is to provide an integrated approach describing the driving performance and behaviour of neuropsychologically-impaired drivers. With this research design, the researcher hopes to identify social or neuropsychological factors which may be correlated with practical driving ability, as measured by current New Zealand driving test criteria. Isolation of significant driver-related factors may provide an important insight, furthering our understanding into social and cognitive aspects of the driving task. Importantly, correlates of practical driving ability may have practical relevance as predictors of driving performance for use in neuropsychologically-impaired driver assessment.

The present research undertakes a detailed analysis of two subject groups with acquired neurological damage: those who were presenting for assessment for driving again; and those who had returned to driving following a successful assessment outcome. These groups with neuropsychological impairment are compared with independent samples of professional drivers and control drivers. Within this context, five specific research objectives are proposed.

Objective 1. To describe and compare the four driving groups using a range of sociodemographics, driving-related variables, practical driving measures, and neuropsychological assessment measures.

Objective 2. To identify any changes and adjustments in the neuropsychologically-impaired groups through comparison of retrospective (pre-injury) and current (post-injury) subject reports, and also by comparison with the neuropsychologically-intact subjects.

Objective 3. To explore the relationship of selected subject variables and neuropsychological test measures to practical driving test outcome.

Objective 4. To consider theoretical and methodological and practical implications of the research.

Objective 5. To identify relevant outcomes and to suggest avenues for future neuropsychologically-impaired driver assessment research within New Zealand.

A DRIVING MODEL FOR THE PRESENT RESEARCH

Impaired higher level cognitive functioning almost invariably follows severe head injury, particularly when there is damage to the frontal lobe region. Interestingly, frontal lobe damage is typical of neurological damage incurred as a result of road accidents, and these cases make up the majority of individuals who present for driver reassessment (van Zomeren et al., 1987). Resulting impairments include general slowness, poor concentration, memory problems, attentional deficits (including a reduction in readiness to respond and ability to sustain attention), rigidity of response styles, and an overall reduced cognitive processing capacity.

Severe head injury, particularly frontal lobe damage, impairs higher level cognitive processes. Thus, unless physical damage has also occurred, performance of previously learned operational level skills tend to be less pronounced (Hopewell & Price, 1985; van Woffelaar, van Zomeren, Brouwer & Rothengatter, 1987). The consequences of impaired higher level cognitive processes are a reduction in information processing capacity. When challenged by complex or new situations which affect the ability to select, prioritise, and respond to the immediate demands of the driving task, the neuropsychologically-impaired driver is therefore likely to make more errors. There is growing evidence for this reduced ability to integrate existing knowledge with changing situational demands (Ponsford & Kinsella, 1988; van Zomeren, Brouwer & Deelman, 1984). Such evidence underscores the importance of higher cognitive processes when it comes to the assessment of driving ability.

A fundamental consideration in the assessment of neuropsychologically-impaired drivers is the distinction between cognitive processes involved for subjects learning to drive versus those who wish to resume driving. The initial need to view these two groups as separate is not well documented, although cognitive models of skill acquisition (e.g. Anderson, 1982) would suggest that this distinction is important. For the learner driver, the effect of neurological damage on the ability to learn a new skill is a primary concern. For experienced drivers who have sustained neurological damage, assessment and retraining issues are centred around ability to actively retrieve information from memory and respond appropriately to the demands of a dynamic driving environment. Within this context, consideration needs to be given specifically to a subject's ability to cope successfully in situations of high cognitive load, as exemplified by the strategic level in van Zomeren et al.'s (1987) driver decision making hierarchy.

There are distinct advantages for using an integrated driving approach (Chapter Two) in relation to the assessment of neuropsychologically-impaired drivers. In particular, integrated approaches which contain cognitive elements are strengthened by an emphasis on higher level executive processes. These processes govern the learning of complex driving skills, and the ability to react to dynamic traffic situations. Understanding and measuring these processes has added importance when driving abilities are compromised through neurological damage.

For the above reasons, the present research adopts the integrated systems model (Willumeit et al., 1981) in the assessment of neuropsychologically-impaired drivers. This particular integrated approach emphasises the driver in combination with aspects of the vehicle and environment, and therefore allows a holistic view of driving. Most importantly, the systems model can accommodate cognitive components relevant to complex skill acquisition. In this context, the present research also incorporates cognitive explanations such as Anderson's (1982) skill acquisition model and van Zomeren and colleagues' (1987) decision making hierarchy within the 'systems' model framework. This key feature is considered central to the assessment of the neuropsychologically-impaired driver, where higher cognitive function is likely to have a major influence on driving performance.

PRACTICAL DRIVING MEASURES

There are clear advantages for using an actual measure of driving in the assessment of neuropsychologically-impaired persons (Kaufert, 1988). Although practical driving tests may be costly in terms of time and money, problems with the ecological validity of alternative assessment measures disappear. For neuropsychologically-impaired driver assessment, parity with driver evaluations in the general population has important implications. Thus, the individual is not confronted with the possibility of unfair discrimination through being assessed with different practical driving measures.

A small number of practical driving tests are standardised, providing norms for the general driving population. Unfortunately, however, many other on-road driver evaluations are not sufficiently standardised. This lack of standardisation is particularly prevalent in the area of neuropsychologically-impaired driver assessment, where documented norms are generally unavailable for any standard practical tests. Instead of establishing norms for existing tests, many studies have focused on developing their own driving assessment measures (Croft & Jones, 1987; Galski, Ehle & Bruno, 1989). Consequently, many of these measures are not adequately documented and a number lack detail of actual procedures (Gregory, 1990). Another problem is that these more informal driving measures may lack objectivity due to rater bias. Here, different expectations and levels of expertise may be apparent depending on whether qualified driving assessors or various rehabilitation team members are responsible for a driving evaluation. Despite these problems, it is obvious that a reliable method of driver assessment is fundamental to making appropriate recommendations concerning driving fitness.

Driving tests adopted from the general population are designed mainly as licensing tests for learner drivers (Wright et al., 1984). However, the literature clearly differentiates learner drivers from experienced drivers in terms of driving performance and behaviour (Spolander, 1983). In this respect, driver tests designed specifically to evaluate the skills expected of learner drivers may be inappropriate in the practical driving assessment of neuropsychologically-impaired drivers (Nouri & Tinson, 1988). This point is emphasised by Forbes et al. (1975) who state that driving test validity should be clearly related to the objectives of the user.

The use of single measures of driving performance has been criticised (Gregory, 1990). In the present research, two complementary tests of practical driving are included within the study. One of these, the New Road Test, was introduced into New Zealand in July 1983 to replace former licensing tests used by the Ministry of Transport. The test was developed from the Michigan Test which is recognised for its high content validity and reliability, compared with other tests of its type (Michigan State University, 1973; Forbes et al., 1975; Wright et al., 1984). The New Road Test was used in the present study as it is the standard measure of driving fitness currently used in New Zealand.

The other driving test is the Advanced Driver Assessment which is currently employed in New Zealand as an alternative driving test for use when an individual needs to be reassessed. The Advanced Driver Assessment is included in the present research for several reasons. Here, unlike other driving tests currently in use, driver evaluation is continuous throughout the assessment period, thereby increasing the validity of this driving test as a dynamic measure of driving behaviour. The functional nature of the data collected has a potential for generating material for future research into driving related behaviours, particularly for impaired driver samples. The Advanced Driver Assessment may be of practical use, therefore, in the capacity of assessing neuropsychologically-impaired persons for driving again.

Concurrent validity of the Advanced Driver Assessment has not previously been investigated against other driving measures, as the test is typically administered to licensed drivers (Harwood, 1992). Previous neuropsychologically-impaired studies have been criticised for their dependence on learner driver measures. In the present study, inclusion of these two practical driving tests therefore enables an important comparison between a driving test which assesses experienced drivers and a driving test designed for learner drivers.

Efforts are made to standardise all practical driving administrations within the present study. Qualified Land Transport driving assessors administered all practical driving tests for the four subject groups. Consistency between same test administrations is optimised by the use of test scores from one assessor. A lack of standardisation of the Advanced Driver Assessment is compensated for by the inclusion of two independent assessors (one of which administered all Advanced Driver Assessments) to provide some inter-rater reliability data for this measure. Furthermore, the entire practical driving assessment is completed with an independent global rating comprising a seven point scoring scale on driver performance. This driver instructor rating is included to provide an additional measure of subjects' driving performance that would not be constrained by existing practical driving test criteria. Its purpose is to act as a check on other possible factors missed by the practical driving tests, which an experienced driving assessor would subjectively regard as important.

USE OF THE COMPARATIVE DRIVER SCALES

Few self-report evaluation studies have adequately investigated the basis of an individual's decision to resume driving following neurological damage. Despite the lack of research, ability or inability to make a reasonable self-judgement of one's own driving proficiency has important implications for the assessment of neuropsychologically-impaired subjects for driving again (Golper et al., 1980; Hartje et al., 1991; van Zomeren et al., 1987). While little is known about peoples' implicit theories of driving, the practical significance of self-report is recognised, particularly as it enables insight into decision making and driving styles of individuals (French et al., 1993). If driving is influenced by perceptions of driving skills, then the need to study the accuracy of perceptions and judgement is important. In particular, van Zomeren et al. (1987) point to awareness of limitations and use of compensatory strategies as implications in the driving safety of neuropsychologically-impaired persons. Inconsistent findings in the literature suggest the need for further research in this area.

The present research addresses the issue of driver self perception through the use of comparative driver self-ratings (McCormick et al., 1986). This measure has been employed in a previous New Zealand study which involved a general driver population sample. Using a seven point rating scale, subjects compare their perceived driving ability against perceptions of average and very good drivers across a number of driving dimensions. To gain insight into perceived changes of neurological damage, neuropsychologically-impaired subjects complete these comparative ratings retrospectively (pre-injury) and currently (post-injury).

PERSONAL CHARACTERISTICS

Personal characteristics such as driver attitudes, experience, and age, all influence practical driving ability. For neuropsychologically-impaired subjects, the relative importance of driver characteristics has not been firmly established, in part due to measurement difficulties. Whether certain personal characteristics have a differential effect on driving of neuropsychologically-impaired subjects is presently unknown. Nevertheless, personal characteristics are clearly relevant in the few research designs which have incorporated an integrated approach. Identification of personal characteristics which influence driving outcome has practical implications for the development of driver education and rehabilitation programmes (Lourens, 1992).

In the present research, quantifiable personal characteristics, such as age, are incorporated into the multivariate analysis to identify variables pertinent to the driver assessment process. Complementary to this multivariate approach, a descriptive analysis of other personal characteristics which are less quantifiable, are incorporated into the overall integrated driving model. Here, emphasis is on describing these other personal characteristics at the group level using simple description. Rather than focussing on personal characteristics as correlates or predictors of driving behaviour, the present study instead explores the potential role personal characteristics may play in the broader context of the driving process. Thus, identification of personal change and adjustment to the effects of neurological damage may have important social and practical bearing on driving performance (Hartje et al., 1991; van Zomeren et al., 1988). For example, a subject's awareness and self-perceptions may modify driving behaviour through the use of compensatory driving techniques. Practically, changes in domestic and employment circumstances may also affect individual driving patterns.

Important personal characteristics are incorporated into the overall design of the present study as initial parameters for defining groups. Thus, all subjects satisfy visual and medical criteria for driving as set out by Road User Safety Standards (Land Transport publication "*Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners*", 1990). Neuropsychologically-impaired subjects are defined by moderate to severe head injury within the last seven years. Control drivers are matched with the neuropsychologically-impaired presenters on the basis of age, gender, and number of years licensed. Within the study, information is also collected on sociodemographic variables, namely, educational background, employment and current work status, and domestic arrangements. Measurement of other driver-related characteristics include numerous factors pertaining to driving experience: driving licence data; return to driving following neuropsychological damage; typical driving patterns; driving incidents; medical conditions, medication and drugs; and alcohol. Given the extensive array of variables that are to be examined, traditional personality measures were excluded from the present study. Traditional personality measures are particularly difficult to interpret and are a relatively unknown research area in relation to neuropsychological impairment. Instead, the present research focuses on more tangible psychosocial measures, such as driver self-perceptions.

NEUROPSYCHOLOGICAL ASSESSMENT

Neuropsychological tests do not soley predict driving performance (van Zomeren et al., 1987), but they may give "a measure of potential to obtain driving ability" (Jones et al., 1983, p.754). Evidence suggests that neuropsychological tests are a valuable component in the assessment of drivers with neurological damage, which complements information taken from practical driving evaluation (Priddy et al., 1990). In particular, neuropsychological tests are clearly useful for describing individual deficits when used in a functional sense (Gregory, 1990; Ponsford, 1990). However, assessment of neuropsychologically-impaired drivers must also take into account a wider range of variables which affect driver performance and ability (Korner-Bitensky et al., 1990)

In research on neuropsychologically-impaired drivers, neuropsychological test assessment is important for two reasons. In the conventional sense, neuropsychological tests differentiate neuropsychologically-impaired drivers from controls. This information confirms the presence, and supplies information on the nature and severity, of neuropsychological impairment in research samples. Hence, neuropsychologically-impaired subjects perform less well on most perceptual and cognitive tests (van Zomeren et al., 1988). Considerable variation within neuropsychologically-impaired samples, however, highlights the complexity of impairment and the interplay of an array of individual variables.

A consensus that perceptual motor and cognitive problems are important to driving relates to the second function of tests in the neuropsychologically-impaired driver literature (Banich et al., 1989; Bardach, 1970; Galski et al., 1990, 1993; Gouvier et al., 1989; Sivak et al., 1981; van Zomeren et al., 1987). Since neuropsychologically-impaired subjects, on average, also perform less well than controls on measures of closed and open road driving, the relationship between neuropsychological test outcome and measures of practical driving is typically investigated for its predictive validity. From the range of abilities tested, the categories which have shown the highest correlations with driving include visual perceptual and visuomotor skills, attention and orientation, executive functions (including processing flexibility, planning and sequencing), as well as aspects of working memory (Brooke et al., 1992; Sivak et al., 1981; van Zomeren et al., 1987). In many cases, aspects of executive functioning involving specific information processing skills have been identified as important to the driving process (Brooke et al., 1992; Hopewell & Price, 1985; van Zomeren et al., 1987, 1988).

In the present study, a selection of neuropsychological tests are administered to all driving groups, the purpose of which was twofold. First, to describe broadly the neuropsychologically-impaired groups in terms of deficit of function. Second, at the exploratory level, to investigate potential predictors of practical driving outcome. Selection of neuropsychological tests is based on several criteria which included representativeness of driving related skills, empirical support for use in an applied setting, and practicalities of administration. The need to focus on tapping executive functions (Lezak, 1982, 1995) and complementarity of the tests was considered at length. Important practical considerations also include time and ease of administration of tests, both individually and as part of the overall combined assessment package. The background and rationale for inclusion of each individual neuropsychological test is described in detail in Chapter Seven.

DESIGN CONSIDERATIONS

Most neuropsychologically-impaired driver research continues to be based on impressionistic approaches. From those working in the field, driving data tends to be summarised post hoc from numerous case assessments within a clinical practice. While this is not necessarily a poor method, there is often a lack of systematic study and an absence of control measures. Reliance on documented clinical evidence is partly due to difficulties obtaining sufficient research subjects for time sampling, which is a limitation of most neuropsychologically-impaired driver research. The present study uses a quasi experimental approach which involves four subject groups. While exploratory, such small-n group designs are fundamental in the development of a global assessment screen, where it is important that each individual is initially seen in the context of others.

Composition of subject groups used in experimental investigations is another design feature which raises important methodological and theoretical implications. For neuropsychologically-impaired drivers, the issue of defining an appropriate control driving group has not been addressed in actual practice. Nevertheless, a number of research reports, from those working in the neuropsychologically-impaired rehabilitation field, suggest that standards for comparative driver groups may be unrealistically high or focused on inappropriate criteria (Gouvier et al., 1989; Simms, 1986, 1989). A wide range of variables for matching control groups have also been reported in the literature, limiting how much comparison can be made between independent research studies (e.g. Friedland et al., 1988; Katz et al., 1990; van Zomeren et al., 1988; Wilson & Smith, 1983).

A unique strength of the present study, therefore, is the use of both control and professional driver groups as a point of comparison for the neuropsychologically-impaired samples. The use of these two groups is advantageous because it enables comparison with driving criterion for subjects whose driving performance represents an achievable ideal (professional drivers) and for subjects from the general driving population, who are comparable in terms of age, gender, driving experience (control drivers). Further, distinction between subjects with neurological damage who are presenting for a driving assessment again (neuropsychologically-impaired presenters) and those who have undergone a successful assessment outcome (neuropsychologically-impaired drivers) may provide a benchmark for the development of assessment schemes. Here, it may be possible to gain insight into factors which contribute to judgements regarding ongoing competence and safety of neuropsychologically-impaired driver applicants.

Within the integrated model framework, the present study uses general descriptive and comparative analyses of a wide range of subject variables, including those with a psychological focus. For example, perceived changes following neurological damage and use of individual compensatory strategies have novel implications for all aspects of neuropsychologically-impaired driver research. Other more quantifiable data, such as driver self-ratings, practical driving, and neuropsychological test measures are analysed using one way ANOVA and simple multiple linear regression methods. Here, incorporation of a multivariate approach is considered an important step in the neuropsychologically-impaired driver research.

Chapter Seven

METHOD

The present study adopted a quasi-experimental design and detailed descriptive analysis of the effects of neurological damage on a range of neuropsychological and practical driving assessments. This Chapter presents the methodology, including documentation of subject groups, measures and protocols used. Detailed description of the questionnaires and practical driving assessment measures is given. Background to the neuropsychological tests includes justification for inclusion into the present study. Procedural details are given for the setting up and piloting of the research, along with administration of all assessment measures used, ethical considerations, and the analyses of results.

SUBJECTS

The present research involved four groups of licensed drivers. Each group comprised ten subjects. There were two groups of subjects who were neuropsychologically-impaired, one group of control drivers and one group of professional drivers (see Table 7.1). Since the characteristics of the four subject groups were a focal point for study, description of each sample in terms of age, gender and other personal variables is postponed until Chapter Eight. The process of setting up and recruiting subject groups is documented below.

Subjects in the neuropsychologically-impaired groups

The two groups of subjects who were neuropsychologically-impaired were differentiated by whether or not individuals had been given formal approval to return to driving following head injury. For these subjects, criteria for inclusion into the study was otherwise the same. Thus, all neuropsychologically-impaired subjects were involved as part of a hospital or Disability Resource Centre rehabilitation programme. Individual records had to indicate a moderate to severe head injury within the last seven years. Potential subjects were required to have had a valid New Zealand driver's licence. At the time they were recruited into the present study, subjects had to legally satisfy visual and medical criteria for driving as set out in the Land Transport publication "*Medical Aspects of Fitness to Drive : A Guide for Medical Practitioners*" (1990). Subjects who satisfied the above criteria were eligible for either the neuropsychologically-impaired presenters or neuropsychologically-impaired drivers groups (Table 7.1).

Table 7.1. Subject groups used in the present study.

SUBJECT GROUPS	GROUP CHARACTERISTIC
Neuropsychologically-impaired presenters	Subjects who were deemed ready, but were yet to undergo driving assessment in a professional capacity.
Neuropsychologically-impaired drivers	Subjects who had already been assessed and were given formal approval to resume driving again.
Control drivers	Subjects from the general driving population, similar age, gender and driving experience (years licensed) to the neuropsychologically-impaired presenters group.
Professional drivers	Subjects from an army transport squadron, providing a criterion for a high driving standard

In the process of recruiting subjects, the researcher made initial contact with a clinical psychologist and an occupational therapist involved in neuropsychologically-impaired driver assessment. These professionals identified potential subjects who satisfied the agreed criteria. All potential subjects were considered able enough to drive, therefore, a positive selection from the total population of neuropsychologically-impaired persons in rehabilitation was likely. Professionals sought whether each potential subject would be agreeable to having his or her name forwarded to the researcher so they could be given further information. This procedure was repeated until 10 subjects had been recruited for each of the two neuropsychologically-impaired groups. Some attrition occurred through individuals deciding not to participate or through the researcher's inability to make contact within a limited time frame.

Subjects in the control group

Subjects in the control group comprised drivers from the general population who were similar to the neuropsychologically-impaired presenters group in terms of age, gender and driving experience (years licensed). Potential subjects for the control drivers group were identified using a snowballing technique. Once identified, individuals were asked by the researcher if they would be willing to take part in the study. In the process of obtaining 10 subjects, three of the individuals contacted declined to participate.

Subjects in the professional group

Subjects in the professional group comprised drivers from a transport squadron based at a local regional army camp. These subjects were included to provide a criterion for driving at a high level. Formal approval was obtained from the New Zealand Army to recruit subjects. Army personnel from the transport squadron were briefed and recruited on a random basis by a senior officer.

MATERIALS

A variety of materials were involved in the assessment of each of the four subjects groups. These included questionnaires, practical driving evaluations, and a series of neuropsychological tests. These measures are outlined below.

Questionnaires

Table 7.2 presents an overview of the questionnaire measures which were used in the present study. These measures are documented in more detail below.

Table 7.2. Summary of questionnaires used in the present study.

QUESTIONNAIRE TYPE	PURPOSE
Demographic Questionnaire	Description of subjects, and exploration of demographic factors with possible driving relevance, e.g. : age. Where variables are likely to have been affected by neurological damage (e.g. employment situation), then questions were designed to elicit these changes. The demographic questionnaire also included a checklist for a comparative record of subject's ongoing symptoms.
Driving Questionnaires	Description of subject driving histories, including driving frequency, patterns and incidents. Measurement of comparative driver self perceptions (after McCormick et al., 1986). Neuropsychologically-impaired groups completed a retrospective (before neurological damage) and current versions of the driving questionnaires.

Demographic questionnaire. A demographic questionnaire was compiled with the assumption that certain demographic factors may be important to driving. Questions were asked concerning age, gender, marital status, living arrangements, education, employment, medical events, medication and alcohol intake. For age, gender, marital status, living arrangements, and education, the style of questioning was consistent with previous driver studies (Gouvier et al., 1989; Hopewell & Price, 1985; Katz et al., 1990; Stokx & Gaillard, 1986; van Zomeren et al., 1988). Questions about a subject's employment, medical events, medication, and alcohol intake were specific to the present study.

The structure of these questions followed literature recommendations (Bennett & Ritchie, 1975; Findley, 1989; Karoly, 1985; Baddeley, Meade & Newcombe, 1980; Rust & Golombok, 1989). Employment questions focused on occupational history and current work status. Separation of occupational history from current status was a means of identifying change, which was particularly relevant for subjects who had experienced neurological damage. Questions on medical history concerned significant or major injury, accident or illness, as well as details of when events occurred. This history of events also included questions concerning subject's self-perceptions, such as perceived individual change. In the case of neurological damage, these self-perceptions have important implications for assessment and compliance with assessment decisions (McLean et al., 1993). A symptom checklist was amalgamated from items on the Head Injury Symptom Checklist (HISC) (Dikmen, McLean & Temkin, 1986a, 1986b) and reviews from the literature (e.g. Ben-Yishay & Diller, 1983; Kolb & Whishaw, 1985; Newcombe, 1982; Prigatano, 1991; Uomoto, 1990).

Information on medication, with documented harmful effects on driving, was also sought from a checklist which included specific medical conditions. This list was generated from the Land Transport publication "*Medical Aspects of Fitness to Drive : A Guide for Medical Practitioners*" (1990). Questions concerning alcohol consumption were developed with specific reference to driving.

The demographic questionnaire comprised alternate-choice and multiple-response items. Some open-ended questions were used to elaborate on a yes/no response where qualitative description would assist interpretation of the data. A full copy of the Demographic Questionnaire is presented in Appendix A.

Driver questionnaire. A basic questionnaire was developed to record individual driving histories along with subject's experiences and perceptions of driving. Questions were predominantly multiple-response format. Subjects were asked how long they had possessed a driver's licence and for what class of vehicle the licence was applicable. A measure of driving frequency was adapted from a study by Priddy et al. (1990). Questions concerning major patterns of driving (purpose, place and traffic density) and history of traffic incidents were adapted from Cox et al. (1989) and Simms (1985a). Construction of items concerning traffic offending were guided by specifications of offences as laid out by the Land Transport Safety Authority.

The driving questionnaire also contained a self report measure of comparative driving ability previously used in New Zealand (McCormick et al., 1986) (see Appendix B for relevant statistical data). The following dichotomies are rated: foolish-wise; unpredictable-predictable; unreliable-reliable, inconsiderate-considerate; dangerous-safe; tense-relaxed; worthless-valuable and, irresponsible-responsible. Subjects were required to rate "me as a driver" and hypothetical constructs of "an average driver"; and, "a very good driver" on each of the dimensions. A seven-point rating scale was used along with standardised instructions. For the present study, subjects were asked to complete a written description of "an average driver" and "a very good driver" after completing their ratings. This addition to the methodology of McCormick et al. (1986) was made to increase objectivity in the interpretation of individual ratings, particularly when making between subject comparisons.

Three versions of the driving questionnaire were developed for the different subject groups. Control drivers and professional drivers received one copy of the questionnaire (see Appendix C). The two neuropsychologically-impaired groups each received two versions of the questionnaire designed to separately record pre- and post-injury driving (see Appendices D and E respectively). The post-injury questionnaire included additional questions to ascertain the extent subjects had driven since their head injury. Other questions were not appropriate to repeat in both 'pre' and 'post' versions of the questionnaire. Aside from these minor adjustments, the overall questionnaire format was consistent across the two forms. Time elapsed between administrations of the pre- and post- questionnaire measures was approximately 15 minutes .

Piloting of demographic and driving questionnaires. Before inclusion into the main study, the demographic and driving questionnaires were piloted on six neuropsychologically-impaired persons who were undergoing driving evaluation in another New Zealand city. Six drivers from the general driving population, who were acquaintances of the researcher, also completed the questionnaire. Time to complete each questionnaire ranged between five and ten minutes but was partly dependent on individual differences in interpretation of questions, discussion of the questionnaires and ease of administration.

Additional input on the structure and content of the pilot questionnaire was received from various professionals in driving, rehabilitation and neuropsychological fields. Careful deliberation of subjects' responses and feedback from professionals, resulted in adjustments to wording and order of presentation of some of the items included in the questionnaires. Page layout was improved for clarity of responding. In the **demographic questionnaire**, education and employment questions were clarified and the number of possible choices extended. Several minor changes were implemented in the **driving questionnaires**, including allowance for subjects to elaborate on some multiple-choice items. Examples were included for the three questions concerning traffic incidents, and a question inquiring into subjects' completion of a defensive driving course was added. The dimension "worthless-valuable" was removed from McCormick et al's (1986) comparative driver scales on the suggestion that it could be detrimental to the self-worth of some subjects. It is notable that this dimension was the least salient in the study by McCormick et al. (1986). With the above changes made, all questionnaire items were considered appropriate for inclusion into the main study.

Practical driving measures

Table 7.3 presents an overview of the practical driving measures which were used in the present study. These measures are documented in more detail below.

Table 7.3. Summary of practical driving measures used in the present study.

PRACTICAL DRIVING MEASURE	APPLICATION
New Road Test	Licensing test for NZ drivers, based on an American model. Standardised route rated in specific behavioural units and scored in pattern format. Some validity and reliability data available.
Advanced Driver Assessment	Independent driving evaluation to identify areas for improvement of licensed drivers. Based on 40 minutes continuous driving. Error patterns are scored on broadly defined general behaviours. Lack of standardisation.
Driver Instructor Rating	Global subjective rating on seven-point likert scale of how comfortable the instructor feels being driven by the subject.

New Road Test. The New Road Test was introduced into New Zealand in July 1983 to replace former licensing tests used by the Ministry of Transport. The test was developed from the Michigan Test which is recognised for its high content validity and reliability compared with other tests of its type (Michigan State University, 1975; Forbes et al., 1975; Wright et al., 1984). Practical driving, written and oral testing, and an eyesight examination are included as outlined in the *New Road Test Manual* (Nr 51). Testing is carried out by qualified Land Transport officers.

The New Road Test "is based on the requirements for testing a persons ability to perceive and cope with road hazards, both potential and real, while driving in the environment that the applicant would drive once licensed" (Sect. 10.10A.1, *New Road Test Manual*, Nr 51) and where situations encountered are "a sample of those that drivers encounter from day to day" (Wright et al., 1984, p.10). The practical component involves rating performance in the normal functions of controlling the vehicle and using the road in traffic to determine an individuals ability as a driver. In addition the prospective driver must be seen to have the physical qualifications necessary for safe driving and knowledge of road rules and safe driving principles (Sect. 10:4.6, *New Road Test Manual*, Nr 51).

Administration and scoring. The New Road Test practical driving component takes 15-20 minutes and uses one testing officer for scoring. The practical test component is set out over a route standardised for each test region and is a sample of behaviour viewed in relation to the total traffic environment (Wright et al., 1984). The written questionnaire is available in five alternate forms, comprising 25 multiple choice questions. No more than two errors are permitted if the candidate is to pass. Four out of five standardised oral questions must also be correctly answered.

Principles for conducting the practical test, including fitness of the driver and vehicle, explanation of the test to subjects, instructions during the test, and, termination of testing, are outlined in the *New Road Test Manual* (NR 51). The test route is divided into 12-15 segments each scored in terms of the principle components of search, speed, and direction. Clear guidelines are presented for constitutes a fault on any of the nineteen practical test items which may be contained within a segment. In addition, the test route is divided by observation and recording zones. Observation zones are those areas where driving behaviour is observed and recording zones refer to areas where driver performance for previous test segments is recorded and scored. Scoring is done on the New Road Test Rating Form (see Appendix F) and performance is recorded as 'satisfactory' or 'unsatisfactory' (safe or unsafe). Guidelines for what constitutes unsatisfactory performance are also given in the test manual. Where a subject does not accrue errors under the three principle components (search, speed and direction) for a segment, then a 'satisfactory' pattern score is awarded. Thus, an unsatisfactory pattern score requires that one or more of the principle components are also scored as unsatisfactory. Passing the New Road Test requires that no more than three pattern scores marked 'unsatisfactory' when the test comprises 12 or 13 segments or no more than four unsatisfactory pattern scores if the test route is 14 or 15 segments long. Immediate failure of the test is inevitable in the cases of an accident wholly or partly caused by the subject, reckless or dangerous driving, or, inability to carry out any instruction given by the testing officer.

Test norms. The only normative data available for the New Road Test relates to the fact that the majority of applicants pass on their first attempt to sit the test. The initial pass rate is slightly higher for females and slightly higher for those aged between 15 and 20, although neither of these findings reach a level of statistical significance (Wright et al., 1984).

Reliability and validity. Inter-rater reliability of the New Road Test has been determined by comparing simultaneous ratings of two examiners, one seated in the front and the other in the rear seat of a testing vehicle. Using this method, average agreement between 28 rater pairs, established after eight months of operation, was 88.6 % (Wright et al., 1984). Agreement on a pass/fail judgement was 92%. Wright et al. (1984) found that, after a minimum of 50 test assessments over the same standardised route, individual pass rates for examiners ranged from 63% to 92%.

Various forms of validity of the New Road Test have been investigated. Wright et al. (1984) state that the New Road Test's "validity rests upon the logic that a pass or fail depends on observed driver behaviours that are known to decrease or increase road hazards" (p.185). Criterion-related validity of the New Road Test is established through attention to the factors identified as most important in causing road accidents in New Zealand. In relation to construct validity, it is noted that standardised routes are developed by experts who identify road hazards and observable driver behaviours that increase or decrease the potential for accident. Subsequently these are validated and checked for representativeness by assessors observing novice and experienced drivers who pilot the course. Content validity has been investigated through analysis of the proportion of subjects failing certain segments of the course. Segments of the test which are more often failed correspond with major contributing factors of accident causation, namely, turning and giving way to other traffic at intersections. Overall route failure rate for the New Road Test compares well with similar routes set out for the Michigan Test in the United States (Wright et al., 1984).

Advanced Driver Assessment. The Land Transport Advanced Driver Assessment was designed as a means to "assist driving instructors to show competence in: (a) identifying training needs; and (b) selecting the appropriate training objectives from the approved syllabus" (Advanced Driver Assessment Manual, 1990, Purpose Statement). The Advanced Driver Assessment is used in a wide range of circumstances where an independent driving evaluation is required. Assessment must be carried out by certified Land Transport testing officers or driving instructors who have undergone the approved training modules.

Administration and scoring. Administration of the Advanced Driver Assessment requires the candidate to be observed over 40 minutes or 40 kilometres of on-road driving. At least 20 minutes of this period is spent in medium to heavy traffic conditions. A standard route is typically, but not always, followed. Drivers are required to demonstrate they are skilled in four areas: hazard identification; judgement; manipulating controls; and, observing traffic regulations. These four components are operationally defined in Appendix G. The four components or skill areas are examined over seven different driving situations. The seven driving situations for which assessment decisions are made comprise - (1) Moving into the Traffic, (2) Moving on the road, (3) Moving with the traffic flow, (4) Moving through traffic, (5) Moving past other traffic, (6) Moving back in traffic, and (7) Moving out of the traffic (see Appendix H for definition of terms). Drivers are "considered competent when they can consistently apply the skills identified to all seven driving situations" (*Advanced Driver Assessment Manual*, 1990, p.1). Errors must be repeated across situations to infer consistency and a need for training in any one of the four areas.

The assessment form (see Appendix I) records numbers of errors detected for the four skill areas and across the seven driving situations in grid fashion. On the form, these skill areas are further subdivided so that a more accurate and informative assessment is made. An emphasis on qualitative data is also a large component of the assessment. Assessment decisions are assisted by addressing specific questions specified in the assessment manual - (1) Why do I think there is a performance problem?, (2) What is the difference between what is being done and what is supposed to be done?, (3) What is the event that causes me to say that things are not right?, and, (4) What am I dissatisfied with?.

Analysis of the form is based on the identification of patterns of driver behaviour which would suggest training needs. Frequency of errors noted for any of the skill areas and across each of the seven driving situations. The manual states "it is difficult when designing the assessment report to establish a cutoff figure to determine a pass or fail, therefore it was decided that consistency in the demonstration over a period of 40 minutes was a reasonable and acceptable method of identifying patterns in the driver's performance" (*Advanced Driver Assessment Manual*, 1990, p.1). To assist in making evaluation decisions however, an assessor is drawn to consider another set of questions from the assessment manual. Technically, a candidate should pass or fail on the basis of these questions, namely - (1) What is the discrepancy and is it important?, (2) What could happen if I left the discrepancy alone?, (3) Could doing something resolve the discrepancy and have any worthwhile result?, and (4) How could this be rectified?. In conjunction with the present research, steps were taken to operationally define patterns of errors to assist a more reliable outcome decision (Harwood, 1992). Patterns were thus analysed for each column and row of the assessment form. A pattern constituted a total of six or more errors marked in three or more boxes in any one column or row.

Test norms. The Advanced Driver Assessment measure is not well standardised despite its wide application. In conjunction with the present research, some data was compiled for an initial sample over a standardised route (Harwood, 1992).

Reliability and validity. Analysis of 400 Advanced Driver Assessment forms submitted from a range of examiners suggests considerable variability in recorded errors between instructors. This was reflected by different error criteria and individual tendencies to favour different parts of the assessment form for scoring (Harwood, 1992). For the present study, inter-rater correlation coefficients ranged between .47 and .88 for errors, and .14 and .97, for patterns, for five of the assessors. However, error ratings of the sixth assessor were negatively correlated at -.46 for errors and -.35 for patterns. The average inter-rater reliability coefficient was .62 for errors and .53 for patterns.

Formal investigation into the validity of the Advanced Driver Assessment is limited. It is known however, that criterion-related validity was established by basing assessment criteria on the principles taught in New Zealand Defensive Driving Courses. A breakdown of the assessment content and structure (skill areas over situations) was generated from overseas training models (*Farhlehrer-Briefe : Circular for Driving Instructors No. 3*, 1978).

Driver instructor rating. A informal driver rating was made by the senior officer who undertook the Advanced Driver Assessments. The officer was required to rate the drivers on a seven-point Likert scale (1 being extremely comfortable and 7 being extremely uncomfortable) in response to the question "How comfortable would I feel being driven to Wellington by this driver?". This rating was included with the view that it would be interesting to obtain a global rating of each subject by an experienced professional, as well as to compare this with outcome and patterns of performance on the formal tests.

Neuropsychological tests

The neuropsychological testing component comprised seven tests administered in the following order: Mini Mental State Examination (MMSE) (Folstein, Folstein & McHugh, 1975); Benton Visual Retention Test - Revised (Benton, 1974); Standardised Money Road Map Test (Money, 1965) ; Southern California Figure Ground Test (Ayres, 1960, 1980); Stroop Colour Word Test (Stroop, 1935a, 1935b); Trail Making A and B Test (United States Army, 1947); and, a reaction time measure[1]. Background information for the individual tests, including standardisation, reliability and validity data, use in clinical and neuropsychologically-impaired driver assessment settings, and justification for inclusion into the present study, is given below. An overview of these neuropsychological test measures is presented in Table 7.4.

[1] Dr David Mellor developed this measure in the early 1970's for use with driver neuropsychological assessments at the Palmerston North Hospital Rehabilitation Unit. Dr Mellor is currently associated with the Clinical Psychological services at the University of Otago.

Table 7.4. Summary of neuropsychological tests used in the present study.

NEUROPSYCHOLOGICAL TEST.	COGNITIVE FUNCTION MEASURED
Mini Mental State Examination (MMSE)	General screen of cognitive function.
Benton Visual Retention Test- Revised (BVRT-R)	Visual perception and memory, visuo-constructive ability.
Standardised Money Road Map Test	Spatial ability, specifically topographical orientation and left/right discrimination
Southern California Figure Ground Test (SCFG)	Figure-ground discrimination.
Stroop Colour Word Test	Executive flexibility to changing demands.
Trail Making A and B Test	Executive level visual-motor integration, problem solving and attention.
Reaction time	Response speed and information processing ability.

Mini Mental State Examination (MMSE). The Mini Mental State Examination (Folstein, Folstein & McHugh, 1975) comprises a series of questions measuring orientation, registration, attention, calculation, recall and language in a simple and practical test of cognitive functioning (Lezak, 1995). The test has gained wide acceptance in clinical and epidemiological settings (Malloy, Alomayehu & Roberts, 1991), where "brevity and ease of administration makes the MMSE an attractive screening instrument for ascertaining disturbances of cognition among patients" (Anthony et al., 1982, p.397). Recent validation of a telephone version of the MMSE is tribute to its simplicity and ease of administration (Roccaforte, Burke, Bayer & Wengal, 1992). However, to ensure the validity of the MMSE as a screening instrument, it is recommended that it should only be used as part of a comprehensive assessment (Tombaugh & McIntyre, 1992; Rutman & Silberfeld, 1992).

Administration and scoring. Administration of the MMSE takes approximately five to ten minutes. Each subtest is verbally administered and timed according to standardised instructions. Scoring of MMSE test items is straightforward and recorded on a standard form (Lezak, 1995). From a possible total of 30, a score of 23-24 or below suggests an impairment in cognitive functioning. Most authors acknowledge that standardised cutoff points in the middle range should be interpreted with caution (Faustman et al., 1990; Giordiani et al., 1990).

Test norms. Normative data is available for a wide range of subject groups (Tombaugh & McIntyre, 1992) including lifetime psychiatric disorders (Lindal & Stefansson, 1993) and different European cultures (Measso, Cavarzeran, Zappala & Lebowitz, 1993; Ylikoski, Erkinjunitti, Sulkava & Juva, 1992).

A comprehensive review of the MMSE found that age, education, and cultural factors are seen to influence test performance which is comparable with effects found on other similar types of tests (Tombaugh & McIntyre, 1992). Numerous studies have shown diminished sensitivity of the test in discriminating cognitive deficit due to increased age (Anthony et al., 1982; Grut, Fratiglioni, Viitanen & Winblad, 1993; Measso et al., 1993; Ylikoski et al., 1992) and lower education levels (Anthony et al., 1982; Dick et al., 1984; Measso et al., 1993; O'Connor et al., 1989; Tsai & Tsuang, 1979; Ylikoski et al., 1992). Several authors have also noted an interaction between MMSE scores and gender depending on whether the "serial sevens" or "spell world backwards" task is administered (Lindal & Stefansson, 1993; O'Connor et al., 1989). Females perform better when the spelling backwards subtest used while males typically perform better with the serial sevens subtest. In the present study, the serial sevens subtest was used.

Use in clinical settings. The MMSE is the most widely used instrument to measure cognitive impairment in older populations (Carr, Jackson & Alquire, 1990; O'Connor et al., 1989; Tombaugh & McIntyre, 1992; Ylikoski et al., 1992). The test is also considered useful in identifying organic dementias (Friedland et al., 1988; Grut et al., 1993). Other studies have demonstrated the utility of the MMSE for differential diagnosis of patients with known neurologic pathology from normal controls (Folstein et al., 1975; Dick et al., 1984; Tsai & Tsuang, 1979). However, the utility of the MMSE in predicting neuropsychological functioning in subjects with a psychiatric history has been questioned (Faustman et al., 1990).

Reliability and validity Good inter-rater reliability coefficients within the range .63 to .95 have been reported for the MMSE (Dick et al., 1984; Folstein et al., 1975; Malloy et al., 1991: O'Connor et al., 1989). Test-retest reliability is also fairly high and within the .63 to .99 range (Anthony et al., 1982; Davous et al., 1983; Dick et al., 1984; Folstein et al., 1975; Malloy et al., 1991) .

Giordiani et al. (1990) state that the MMSE is "well validated and used in medical settings for research and clinical assessments" (p.1894) Comparisons between performance on the MMSE and other neuropsychological tests have been well documented in the literature (Tombaugh & McIntyre, 1992). Folstein et al. (1975) and Dick et al. (1984) reported good concurrent validity with the WAIS, while Faustman et al. (1990) established a modest correlation between the MMSE and corresponding subtests of the WAIS-R for subjects with psychiatric diagnoses. Significant correlations between the MMSE and the WAIS-R (overall and subtest scores), Weschler Memory Scale (WMS) (corresponding subtests), reaction time and the Rey-Osterreith Complex Figure test have been reported (Giordani et al., 1990). The MMSE also correlates highly with other cognitive screens (Davous et al., 1987; Kokmen et al., 1991; Schwamm et al., 1987). Content analysis of the MMSE reveals a high verbal content and has shown that not all items are equally affected by impairment (Tombaugh & McIntyre, 1992).

Use in neuropsychologically-impaired driver assessment. The MMSE has been a useful component of test batteries used in the evaluation of neuropsychologically-impaired drivers (Carr et al., 1990; Friedland et al., 1988; Lucas-Blaustein et al., 1988). Friedland et al. (1988) classified dementia severity using the MMSE and found a significant difference in MMSE test scores between neuropsychologically-impaired drivers and age-matched controls. Similar findings were reported in a large scale survey of dementia patients where those still driving had significantly higher MMSE scores (x=20.2, s.d.=4.6) than those who no longer drove (x=16.4, s.d.=6.7) (Lucas-Blaustein et al., 1988). In this study there were no differences among demographic variables or in caregivers' reports of accident rates between the two groups. Further, a retrospective case-control study recorded the characteristics of 182 elderly drivers referred to an outpatient geriatric assessment centre and 23% of subjects were still driving (Carr et al., 1990). Subjects still driving scored a mean of 23.7 on the MMSE which was significantly higher than a mean of 18.9 scored by subjects who had elected to discontinue driving. Age was a factor between the two groups, and those still driving were also likely to be more independent and male. By contrast, Retchin et al. (1988) examined frequency of driving in the elderly and found no significant differences between frequent drivers, occasional drivers, and non-drivers on the basis age, formal cognitive testing (including the MMSE) or prevalence of CVA history. Mean scores on the MMSE for these groups (25, 25 and 24 respectively) however, were higher than the other studies and above the arbitrary cutoff point recommended by Folstein et al. (1975) and may be suggestive of no significant impairment.

The driver assessment literature proposes that the MMSE should be evaluated against a standardised driving criterion to investigate further utility of the test. Investigation of a wider range of impaired driver populations is also warranted.

Justification for the present study. The MMSE was included in the present study as a well known screen for neurological impairment, designed to test orientation and cognitive functions simply and quickly. Research shows that the measure has good validity and reliability, and that it is easy to administer and score. It is expected that the measure will discriminate neuropsychologically-impaired from normal subjects and will give added information on the actual composition of the subject groups in the present study. Subjects' performance on the MMSE will also be investigated in relation to practical driving outcomes.

Benton Visual Retention Test (BVRT) - Revised. The Benton Visual Retention Test in its revised form (BVRT-R) is a well documented test for assessing visual perception, visual memory and visuo-constructive abilities used in the clinical diagnosis of brain damage and dysfunction (Benton, 1974; Lezak, 1995; Wellman, 1987). Due to the specificity of the visuospatial synthesis skills measured, the BVRT is viewed as a functional test having "more value to detect specific dysfunction than diagnose brain injury" (Wellman, 1987, p.46). The test is a common component of extensive neuropsychological test batteries (Lezak, 1995) and is often regarded as better than its visuoperceptual test counterparts (Wellman, 1987). Marsh & Hirch (1982) found that the BVRT was a better screen for neurological damage than other similar tests, particularly in distinguishing subjects with cerebral brain damage from those with psychiatric diagnoses.

Administration and scoring. The BVRT-R comprises three alternate forms each comprising 10 designs which are presented in a spiral-bound booklet. Subjects are required to reproduce each of the 10 given individual design trials. Four standardised modes of administration are available, which introduce different exposure times and delay periods before reproduction of the design trials. The present study used Administration A, which involved a 10 second exposure time and reproduction drawing by immediate recall. Completion time for the test is approximately 5-10 minutes. Scoring is on an all or none basis (i.e. a 0 or 1 is allocated for each design) with a maximum final score of 10 correct designs. Individual errors may also be rated and summarised by error type. There are six error categories: omission; distortion; perseveration; rotation; misplacement; and, errors of size. To provide a more detailed analysis, emphasis is placed on both number of correct responses and separate error scores.

<u>Test norms.</u> The Benton Visual Retention Test is well standardised. Norms are available for children and for adults. Benton's (1974) normative population of 200 adults also provided data for intelligence and age levels. Persons of average or better intelligence are expected to make no more than two errors while low-average to borderline individuals may incur three to four errors according to general adult norms (Lezak, 1995). In a comprehensive study of 1128 subjects, a significant positive relationship between test performance and education and a significant negative relationship between performance and age was demonstrated (Youngjohn, Larrabee & Crook, 1993). Numerous other studies have demonstrated consistent age effects particularly into late adulthood (Arenberg, 1981; Prakash & Bhogle, 1992; Robinson-Whelen, 1992). It is notable that a longitudinal study, Arenberg (1981) found that a drop in performance between two administrations of the test paralleled a steady rate of age-related decline. There have been no apparent effects for gender on BVRT-R test performance (Youngjohn et al., 1993).

Faking on the BVRT has been investigated in an interesting study where normal subjects were asked to simulate 'feeble mindedness' and consequences of brain damage. Compared with actual controls the simulators exaggerated the imagined impairment, making more errors and fewer correct responses. Subjects faking brain damage made more distortion and less omission errors than did the neuropsychologically-impaired controls (Benton & Spreen, 1961; Spreen & Benton, 1963).

Use in clinical settings. Lezak (1995) states that error type is an important indicator of specific problems of function. Simplification, substitution or omission errors suggest impaired immediate recall or an attention deficit. More errors of this type are made by neuropsychologically-impaired subjects over controls. Unilateral spatial neglect is characteristically indicated by omission errors corresponding to the side of lesion. Difficulties with execution and organisation of designs are indicative of visuospatial and constructional deficits while perceptual problems are more likely to present as rotational errors and design distortion. Perseveration, typically represented by simplification of designs and a disregard for size and placement, is common in neuropsychologically-impaired subjects and may be specific to a visuoperceptual or memory impairment.

Lezak (1995) suggested differences in test results for frontal lobe injury by side of lesion. Bilateral damaged subjects made the most errors followed by right-sided damage subjects, with marginal differences found between left-sided damage subjects and normal controls. Vakil et al. (1989) found a differential effect with time delay, when measured by correct scores, for subjects with right versus left cerebral hemisphere damage. Performance of the right hemisphere group declined with time while the left hemisphere groups showed improved performance, suggesting retention of figures for a short delay period is mediated by visual images, rather than by verbal codes.

BVRT-R summary scores are a useful indicator of general status. Summary scores are also useful for tracking disease progression, such as dementias of the Alzheimer's type (Robinson-Whelen, 1992).

Reliability and validity. Many studies have examined the reliability and validity of the BVRT-R (Lezak, 1995; Wahler, 1956). Swan et al. (1990) reported intraclass correlations of .96 and .97 for total number of correct reproductions and total number of errors respectively Individual categories of errors produced correlation ranging from .78 to .93, with misplacement and size errors being rated with least consistency. Both of these studies used Administration A of the test. High split-half (r=.76) and alternate-form (r=.85) reliability coefficients have been reported by Benton (1974).

Criterion-related validity studies of the BVRT are plentiful (Wellman, 1987). Predominantly, these are studies of concurrent validity against numerous other tests including WAIS Block Design and Digit Span subtests (Wellman, 1987; Moses, 1989), the Memory For Designs Test (Marsh and Hirsh, 1982), and the Rey Osterrieth Complex Figure (Moses, 1989). It is notable that low correlations are found between verbally mediated tests and the BVRT while those reliant on visual imagery as well as graphomotor constructional tasks are highly correlated. Moses (1989) highlights this as a limitation in using the multiple-choice administration of the BVRT.

Use in neuropsychologically-impaired driver assessment. The role of the BVRT-R test in neuropsychologically-impaired driver assessment needs to be clarified. Van Zomeren et al. (1988) found that a small sample of subjects with brain injury scored no differently from their matched controls on the BVRT. It is notable that in this study, residual deficits identified by other tests were not found to be related to any of the driving criterion measures. Priddy et al. (1990) conducted a study of 50 head-injured subjects six months or more post discharge. Prior to injury all but one of the 50 subjects had drivers' licences, while at the time of the study only 21 were still drivers. Comparison of drivers versus non-drivers yielded significant differences on the BVRT along with other measures of spatial and perceptual deficit. A mean error score of 6.0 (s.d.=2.0) was recorded for non-drivers versus a mean of 3.9 (s.d.=1.8) for drivers. Further research is required to ascertain the relationship between BVRT-R performance and outcome on driving assessment.

Justification for the present study. The BVRT-R was included in the present study as a measure of visual perception, visual memory and visuo-constructive ability. Research shows that the BVRT-R is an objectively scored and well standardised test, highly sensitive to aspects of neurological damage. Evidence also suggests that assessment of visual components is important in assessment of neuropsychologically-impaired individuals for driving again.

Standardised Road Map Test of Direction Sense. The Standardised Road Map Test of Direction Sense (Money, 1976) is one of very few neuropsychological tests devoted to the analysis of abilities necessary to adequate route finding (Walsh, 1984), particularly right-left orientation (Lezak, 1995). The test requires a subject to spatially rotate him/herself in imagery or on an abstract level, hence emphasising the importance of topographical orientation as a component of spatial ability.

Administration and scoring. With a standardised map in a fixed position in front of the subject, the subject has to describe two drawn routes taken on a hypothetical journey as the examiner traces a pathway with a pencil. A short route comprising four turns is administered first as a practice item. A long route (32 turns) is then presented and scored according to the number of correctly identified turns the subject makes (maximum score is 32). Completion time for the test is also recorded.

Test norms. Normative data on the Standardised Road Map Test of Direction Sense is available for young adults. For example, normative data for a sample of female nurses yielded a mean error score of 1.92 (s.d. = 2.08) (Money, 1976). Regardless of age, a recommended cutoff point of ten errors is suggested for evaluating impaired performance on the test (Lezak, 1995; Money, 1976). Here, it is maintained that "since it is unlikely that persons who make fewer than ten errors are guessing, their sense of direction is probably well-developed and intact" (Lezak, 1995, p.344).

Use in clinical settings. Early research used the Standardised Road Map Test of Direction Sense to validate parietal-extrapersonal and frontal-personal dichotomies, supporting the hypothesis that the frontal and parietal regions mediate qualitatively different spatial capacities (Butters, Soeldner & Fedio, 1972). Left frontal patients were significantly more impaired than parietal patients on the Standardised Road Map Test of Direction Sense because it required rotation of their own body in space. Lezak (1995) reports that most neuropsychologically-impaired subjects who are capable of following simple instructions pass this test so that failure is a clear sign of right-left orientation problems. These may result from the inability to shift right-left orientation, which will show up "particularly at those choice points involving a conceptual reorientation of 90-180 degrees" (Lezak, 1995, p. 344). Boyd & Sauffer (1993) emphasise the increasing popularity of the Standardised Road Map Test of Direction Sense and other route finding tests in the clinical setting.

Reliability and validity. Criterion-related validity of the Standardised Road Map Test of Direction Sense has been threatened by early criticism of how much of the asymmetry of function effect is due to purely right-left confusion, memory disturbance, unawareness and inattention (Butters et al., 1972). In a functional sense, however, any disturbance in completing the task is of importance. Walsh (1984) emphasises that the Standardised Road Map Test of Direction Sense Test has more predictive validity than other maze tests, which lack the subject's continuous operation within a set of spatial coordinates. In the case of the Standardised Road Map Test of Direction Sense these must be internalised and referenced in order to successfully complete the task.

Use in neuropsychologically-impaired driver assessment. The practical utility of the Standardised Road Map Test of Direction Sense in driver assessment has been demonstrated by Simms (1985a, 1985b, 1986, 1987, 1989). In these studies, the test was part of a comprehensive test battery chosen to sample skills considered fundamental to driving in a range of neuropsychologically-impaired samples.

Research on subjects with CVA (54 right CVA and 50 left CVA) established that Standardised Road Map Test of Direction Sense scores indicated spatial-perceptual deficit in 8% of right CVA and 25% of left CVA subjects. Left CVA subjects showed increased difficulty with following instructions and with left-right orientation. Importantly, the degree of deficit borne out by testing was highly consistent with in-car assessment ratings (Simms, 1985b). Similarly, the Standardised Road Map Test of Direction Sense was significantly correlated with driving performance, as measured by straight tracking speed on a closed driving course, for a mixed group of subjects with spina bifida and hydrocephalus (Simms, 1986). A mean score of 14.3 (s.d.=1.8) on the Standardised Road Map Test of Direction Sense was reported in this study.

A more recent study (Simms, 1989) found no significant differences for drivers versus non-drivers in a sample of individuals with myelomeningocele or hydrocephalus. Here. Standardised Road Map Test of Direction Sense scores were low for both groups, with a mean 13.13 errors for the drivers versus a mean of 13.42 errors for the non drivers. Simms (1989) suggested that previous screening of subjects as well as personal decisions on driving may have had a confounding effect on the selection of subjects into groups.

Justification for the present study. The Standardised Road Map Test of Direction Sense was included in the present study as a specific measure of topographical orientation and topographical memory. The test specifically involves the ability to follow directions, planning, spatial and visual searching skills which are a critical part of the driving process. Although the Standardised Road Map Test of Direction Sense is not well known in general neuropsychological batteries its use in the present study can be justified. Promising results have been shown in the neuropsychologically-impaired driver literature and the test also has good face validity as a route following test appropriate to driving.

Southern California Figure Ground Test. A component of the Southern California Sensory Integration series, the Southern California Figure Ground Test (Ayres, 1966; 1989) is sensitive to deviations in perceptual function relating to figure-ground discrimination. The suggestion has been made that the test also measures more general central nervous system integration relating to sensory modalities other than vision (Ayers, 1966).

Lezak (1995) points out that like other tests involving visual interference, the Southern California Figure Ground Test is essentially a visual recognition task complicated by distracting embellishments. A distinction is made from tests of visual organisation in that a subject is required to analyse the figure ground relationship in order to identify the figure from the hidden elements.

Administration and scoring. The Southern California Figure Ground Test is advantaged by simplicity of administration and inclusion of both common-item and geometric-design figure ground problems in the one test. The test is comprised of 18 pairs of trial cards which range in degree of difficulty. The cards progress from familiar item shapes through to complex geometric designs. Each template card contains six figures, three of which must be selected by the subject to correspond with three of six which are embedded figures on a test card. Subjects respond by either pointing, naming the item(s), or reading the response number(s) from the template card. Individual trials are of 60 seconds duration and administration of the test usually takes 10 minutes or less. Testing may be discontinued after five errors and scoring is based on the total number of correct trials. If testing is continued past five errors then a cutoff score, or number of correct responses regardless of errors, is also recorded.

The test manual notes that administration can be altered to accommodate any known perceptual difficulties in the case of an individual subject (Ayers, 1966, 1989). For example, the horizontal presentation of the test booklet may be realigned so that all response choices are set in a column presented to a subject's midline, or to the right side if left-sided inattention is pronounced (Lezak, 1983).

Test norms. Original norms for the Southern California Figure Ground Test were established for children under 10 years, however the test is now considered highly suitable for use in identifying perceptual disorders in normal and neuropsychologically-impaired populations as well as detecting developmental problems. Ayers (1980) provides normative increases in the mean cutoff score on the Southern California Figure Ground Test from 9.5 at age 4.0 years, to 18.9 at age 10.11 years. There is a lack of normative data for neuropsychologically-impaired populations. However, Bieliauskas, Newberry & Gerstenberger (1988) developed some adult norms based on a sample of 167 male and female university students ranging in age from 17-38. A mean test score of 38.04 (s.d.=4.88) was calculated, resulting in a suggested cutoff score of 30 correct responses. In this extensive study, Bieliauskas et al. (1988) found no significant main effects for age or handedness. Gender differences were significant with males scoring an average three points higher than females on both cutoff and total test scores. Overall results demonstrated a maturational effect when compared with norms for younger age groups and other embedded figures tests.

Use in clinical settings. Studies of Southern California Figure Ground Test performance of subjects with neurological impairment are reported by Lezak (1995). Poor performance has been associated with right-sided versus left-sided and posterior versus anterior cerebral lesions. Gaines (1972) reports that for children, results of the Southern California Figure Ground and similar tests correlate well for subjects with dysfunction but not for controls. Use of the test as a measure of function as part of a more comprehensive test battery is highlighted.

Reliability and validity. Test-retest reliabilities as established in the original manual (Ayers, 1960) are moderate, ranging from .37 to .52. This data was based on a small sample tested at weekly intervals, with the likelihood of practice effects. Other reliability data is unavailable (Gaines, 1972). In a number of studies, criterion-related validity for the Southern California Figure Ground Test has been established against other similar tests such as Embedded Figures (Bieliauskas et al., 1988; Gaines, 1972).

Use in neuropsychologically-impaired driver assessment. Sivak et al. (1981) incorporated the Southern California Figure Ground Test as part of an assessment of perceptual and cognitive skills in neuropsychologically-impaired drivers. Southern California Figure Ground Test performance was compared with outcome on a series of open- and closed-road driving measures. Neuropsychologically-impaired subjects performed poorly on perceptual/cognitive tasks and driving tasks. However, within the neuropsychologically-impaired group, individual subjects who scored well on the Southern California Figure Ground Test demonstrated good driving performance as well. Results for the Southern California Figure Ground Test showed significant differences in mean scores for neuropsychologically-impaired subjects versus controls and for neuropsychologically-impaired versus all other subjects combined. The mean score for the neuropsychologically-impaired group was 21.6 (s.d.=10.5) compared with a mean of 28.4 (s.d.=8.3) for the spinal cord damage group and 33.9 (s.d.=10.1) for controls.

Justification for the present study The Southern California Figure Ground Test was included to complement other measures of visual ability in the present study. As a test of sensory integration focusing specifically on visuo-constructive and visuo-perceptual abilities, the Southern California Figure Ground Test examines how an individual distinguishes figure-ground relationships. The test has important practical implications for functional tasks such as driving where an individual must be tuned to rapidly distinguish critical environmental features as they enter the visual field. The relationship between test outcome and related components of the practical driving measures (e.g. search) will be examined.

Stroop Colour Word Test. The Stroop Colour Word Test (Stroop, 1935a, 1935b) measures cognitive flexibility, or the ease with which a subject can shift perceptual set to conform to changing demands (Lezak, 1995). It can be viewed as a test of concentration which, if impaired, may contribute to problems in shifting responsively. In this respect, the Stroop interference effect has been extensively researched in the experimental literature (MacLeod, 1991). The Stroop test may also give data on reading fluency (Rush, Panek & Russell, 1990) and has been widely used in testing both adults and children (Lezak, 1995).

Administration and scoring. Numerous variations of the original Stroop Colour Word Test are available, although Golden's (1978) revised form is one of the most well known (Shum, McFarland & Bain, 1990; Wolff, Radecke, Kammerer & Gardner, 1989). In this version, the test has three conditions, although the first condition is often omitted from the testing procedure, as it was in the present study. The three conditions comprise rapid reading of (1) colour names, (2) ink colour of a series of printed Xs, and (3) the incongruent ink colour of colour names. The colour names in condition one are printed in black ink. Conventionally the ink colours and colour names used in the other conditions are blue, red and green. Three cards comprising 100 items presented in 5 X 20 matrices are used and subjects are instructed to read vertically down the columns. During the procedure the subject is stopped and required to correct each error made. The interference effect is created in condition (3) which requires suppression of a natural tendency to read linguistic text rather than identify the colour of the ink the word is printed in. The test may be scored as completion time or number of correct responses. While completion time is a common method, the present study utilised absolute scores across a timed 45 second administration of each test condition (e.g. Connor et al., 1988; Wolff et al., 1989). This latter method has the advantage of definite time limit, which lessens the possibility of subjects becoming frustrated and refusing to continue. With many impaired subjects, the completion time for the 100 item trials can otherwise be arduous, without yielding any additional information that is of use to the examiner. Error scores are not counted, although they result in a lower overall score since the subject is made to repeat the item.

Test norms. Individual differences in performance on the Stroop Colour Word Test have been identified and some norms have been established (MacLeod, 1991). For example, Wolff et al. (1989) developed norms for both general and hearing-impaired population samples, using the word count method for scoring the test. For the general population sample, number of correct words over 45 seconds completion time were 113.52 (s.d = 14.72), 81.22 (s.d =9.38). and 49.75 (s.d =7.53), for the word, colour, and colour-word pages, respectively.

Age effects on performance have been consistently found for the Stroop effect. A pattern occurs in which interference begins early in the school years, rises to its highest level as reading skill develops, declines over adulthood and then increases again with old age (MacLeod, 1991). Houx, Jolles & Vreeling (1993) found that biological life events were a significant factor in relation to Stroop Colour Word Test performance and suggested that these may reduce many of the performance deficits usually ascribed to aging. Other studies suggest that performance on the Stroop Colour Word Test is multi-dimensional with significant variation among older adults (e.g. Rush et al., 1990; von Kluge, 1992). Rush et al. (1990) identified four distinct response patterns on the Stroop Colour Word Test which were significantly and uniquely related to age, level of cautiousness, and verbal intelligence, respectively.

Most studies have found no gender differences in performance on the Stroop Colour Word Test at any age (Connor et al., 1988; Houx et al., 1993; MacLeod, 1991). An interesting study by von Kluge (1992) however, found gender differences when trading accuracy for speed of performance on the test.

Use in clinical settings. The use of the Stroop Colour Word Test in clinical settings has been well documented in several extensive review articles (e.g. MacLeod, 1991). Essentially, the test has been recommended for evaluating brain dysfunction and psychopathology, and can be used as a screening test or as part of a general test battery for making differential diagnoses (Killian, 1985). Greatest susceptibility to the Stroop interference effect is typically found in individuals with frontal syndromes (Golden, 1978). With brain injury, a larger interference effect is shown with damage to the left compared to the right hemisphere (MacLeod, 1991).

Reliability and validity. An early comprehensive study by Jensen (1965) concluded that with multiple administrations, the Stroop Colour Word Test was probably more reliable than any other psychometric test. Subsequent studies have found the Stroop Colour Word Test to be a reliable and generally stable measure, although repeated testing is found to lessen the interference effect and transfer of training to other related tasks will also occur (MacLeod, 1991). Connor, Franzen & Sharp (1988) examined the effects of practice, type of instructions, and repeated testing occasions. Results were recorded as the number of correct responses made within 45 seconds. No significant effects were found from practice either over a period of days or a single block of trials, nor from when instructions were given either directly from the test manual or with additional suggestions. Repeated testing occasions resulted in significant differences in performance. Consistent with other findings in the literature, Connor et al. (1988) concluded that differences in timed scores between conditions 1 and 2 were more important than actual completion times.

Construct validity of the Stroop Colour Word Test has been investigated against many other well-known tests of attention using both neuropsychologically-impaired and neuropsychologically-intact samples (Shum et al., 1990). Results of a principal component analysis indicated that the interference score loaded on the same construct as tests such as serial 7's and 13's (i.e. selective processing) and suggested that the Stroop Colour Word Test might be a better measure of sustained selective processing and one less prone to subject anxiety. Construct validity of the Stroop interference effect has also been demonstrated by a number of analogues to the original test including picture-word, auditory, geometric shape, and multi-lingual language interferences (MacLeod, 1991). Furthermore, differential effects may be created by stimulus set size, sequential effects for order of trials, pre-trial cues, response modality and whether the interference effect can be increased or minimised (e.g. Bohnen, Jolles & Twijnstra, 1992).

Use in neuropsychologically-impaired driver assessment. The Stroop Colour Word Test has been utilised in the assessment of neuropsychologically-impaired individuals for driving again (Friedland et al., 1988; van Zomeren et al., 1988). Friedland et al. (1988) found significant differences between subjects with Alzheimer's dementia and controls on all Stroop Colour Word Test scores, although these bore no relation to incidence of reported motor vehicle accidents. Van Zomeren et al. (1988) included the Stroop Colour Word Test as one of a group of neuropsychological tests in an evaluation which also included interview, neurologic examination, a tracking task in an instrumented car and an advanced driving test. Stroop Colour Word Test completion times were significantly higher for neuropsychologically-impaired subjects over controls for speed of reading (with a mean 53.4 and 40.8 respectively) and colour naming (with a mean 68.8 and 56.6 respectively).

Justification for the present study. The Stroop Colour Word Test was included in the present research to measure the ease with which an individual can shift perceptual set to conform to changing demands. The test is extensively used and is well validated. The increasingly difficult task requirements of the Stroop Colour Word Test are well documented as potential indicators of neurological impairment, especially as it affects information processing abilities. In relation to the present research, the Stroop Colour Word Test's practical application is demonstrated by the ever changing demands of the driving task and the need for the individual to respond by assessing the situation quickly and accurately.

The Trailmaking Test (Trails A and Trails B). The Trailmaking Test (United States Army, 1947) was added to the Halstead-Reitan neuropsychological test battery as a measure of rapid visual-motor integration and problem solving (Lynch, 1983). Specifically, the Trailmaking Test measures visual-motor speed, scanning and searching, ability to deal with numeric and linguistic symbols, execution of sequential sensory motor activity, and the ability to maintain and alternate smoothly between parallel mental sets (Lynch, 1983). It is also seen as a test of visual, conceptual and visuomotor tracking (Whitworth, 1984; Dean, 1985). The Trailmaking Test has been been repeatedly used as a measure sensitive to impairment as a result of traumatic brain injury (e.g. Eson, Yen & Bourke, 1978; Hom & Reitan, 1990; Levin, Benton & Grossmann, 1982; Rimel, Giordani, Barth, Boll & Jane, 1983; Stuss, Stethem, Hugenholtz & Richard, 1989; Whitworth, 1984). The test is universally one of the most popular inclusions in a neuropsychological test assessment (Kolb & Whishaw, 1985; Dean, 1985; Lezak, 1995; Walsh, 1994).

Administration and scoring. The Trailmaking Test comprises a timed pen and paper test which requires the subject to rapidly draw a line between 25 sequentially connecting circles which are randomly dispersed on an A4 page. On Trails A, the circles are numbered 1-25, requiring a simple operation to connect the numbers. The circles in Trails B incorporate number (1-13) and letter (A-L) sequences which the subject has to connect in an alternate fashion (i.e. 1-A-2-B-3-C). Scores are given as the number of seconds required to complete Trails A and Trails B; while errors, in the form of incorrect sequences, are sometimes recorded (Lezak, 1993). Successive modifications to the administration of the test have been made (Armitage, 1946; Reitan, 1979). The present form requires the examiner to indicate errors to subjects, so that the whole test can be timed and adequately completed. However, this method introduces further dependence on the examiners reaction time (in noticing and communicating errors) as part of the overall timed score and this may have a diminished effect on reliability of the test.

Test norms. Normative data for the Trailmaking Test is available. In the original standardisation study, Reitan (1979) administered the test to 200 subjects with organic brain damage (of mixed etiology and severity) and 84 controls. Based on this sample, Reitan (1979) recommended tentative cutoff scores of 39-40 seconds for Trails A and 91-92 seconds for Trails B. Snow (1987) is critical of these simple scoring and cutoff procedures and considers a shortcoming of the test is its inattention to differing degrees of impairment. Further, Snow (1987) emphasises a need for more standardised instructions for administration of the test.

Age-related data for the Trailmaking Test finds, as might be expected, that performance time increases with age (Jarvis & Barth, 1984; Lezak, 1993). Some age-related norms are available (Lezak, 1993). The need for ability-based norms for the Trailmaking Test has been suggested, although none have been established. Evidence suggests that fast completion times are related to intellectual ability as measured by Wechsler-Bellevue and WAIS scores (Reitan, 1959; Jarvis & Barth, 1984).

Reliability and validity. Test-retest reliability, as measured by the coefficient of concordance, has been found to be good (W=0.78) over three administrations of Trails A at six month and yearly intervals (Lezak, 1995). A cumulative practice effect on Trails A reached a significant level on the third administration, although average time scores on Trails B did not significantly decrease. This finding was supported by Bornstein, Baker & Douglass (1987) who examined short term test-retest reliability over three weeks. Here, significant practice effects were demonstrated on Trails A but not on Trails B. Charter, Alekoumbides & Seacat (1987) reported very high test-retest reliabilities within the range (.80 to .95) for Trails A and B for a neuropsychologically-impaired group, a control group, and a sample adjusted for age and education. Goldstein and Watson (1989) found modest reliabilities for a heterogenous neuropsychiatric sample over an average test-retest period of two years. Apparent sensitivity of the test was indicated with outcome being dependent on recovery among head trauma subjects, while highest reliabilities were indicated in subjects with cerebrovascular disorders. Least reliability was shown for subjects who were diagnosed schizophrenic.

The Trailmaking Test has been validated against an alternate form as well as other tests of visuospatial sequencing and rapid visual search (DesRosiers & Kavanagh, 1987). In the new version Trails A replaced number with letter sequences and Trails B used an inverted label sequence (i.e. A-1-B-2-C-3). Correlations between corresponding old and new forms were significantly high across samples of different ages (r=.89). While significant practice effects were evident for both new and old versions, the alternate forms possessed enough discriminative sensitivity to distinguish a clinical sample from a control group on follow-up one year post injury (DesRosiers & Kavanagh, 1987).

Construct validity of the Trailmaking Test has been evaluated against other tests of attention including Letter Cancellation, serial subtraction, Digit Span and Symbol, Stroop, Symbol Digit Modality and the Knox Cube (Shum et al., 1990). In these examples the Trailmaking Test was found to be measuring the same underlying constructs. Results from two separate principal analyses from normal and closed head injury samples yielded two very similar patterns. The Trailmaking Test loaded highly on visuomotor and sustained selective processing components of the analysis. The test identified subjects selectively impaired on these abilities, with performance related to severity of injury and stage of recovery. Other factor analytic studies have found significant relationships with measures of visual sustained attention and concentration (e.g. Corrigan & Hinkeldey, 1988; Leonberger, Nicks, Goldfader & Munz, 1991).

Use in clinical settings. Individual patterns of performance on the Trailmaking test can give specific information into the nature of neuropsychological impairment, particularly observation of how the subject gets off the track and the types of errors made. When completion time for Trails A is much less than Trails B, difficulties in complex double or multiple conceptual tracking are indicated. An overall slowed performance is a sign of likely brain damage, where the impairment may be one of motor slowing, poor coordination, visual scanning, motivation or conceptual confusion (Lezak, 1995).

Reitan (1979) found that the test effectively identified subjects who were misclassified (on the basis of very mild impairment) within his standardisation sample. Other studies however, have found lessened test sensitivity in samples of subjects with mild head injury or concussion. For example, Dikmen, McLean, Temkin & Wyler (1986) examined 102 acute head-injured subjects and controls. The Trailmaking Test distinguished those with head injury from controls with significant differences in performance found in all but the least severe group of subjects. The test best demonstrated performance changes according to levels of severity. Several studies have found insignificant differences for minor head-injured groups versus controls when matched for variables such as age, gender, handedness, education, language, and IQ (Corrigan & Hinkeldey, 1988; Leninger, Gramling, Farrell, Kreutzer & Peck, 1990; Stuss et al., 1985)

Lezak (1995) claims that the clinical value of the Trailmaking Test goes beyond what it may contribute to diagnostic decisions to having considerable functional utility. Specifically, visual scanning and tracking problems that show up on the Trailmaking Test can indicate how effectively the subject responds to a visual array of any complexity, and, when following a sequence mentally or dealing with more than one stimulus or thought at one time (Eson at al., 1978). Acker & Davis (1989) examined the predictive validity of the Trailmaking Test, among others, in relation to current functional status using the Social Status Outcome (SSO) survey. Data was collected from 148 head-injured subjects (with a mean 6.2 years since injury) who were heterogenous as to locus of injury, age of onset, educational background, and, severity. Results showed that there was a significant relationship between high scores on Trails A and Trails B and, good Social Status Outcome measures. The Trailmaking Test has also been found to be a useful predictor of vocational rehabilitation among brain damaged subjects (Lewinson, 1973, cited in Lezak, 1995).

<u>Use in neuropsychologically-impaired driver assessment.</u> The Trailmaking Test is frequently employed in the screening and assessment of neuropsychologically-impaired persons for driving again. In these studies the Trailmaking Test significantly differentiated between neuropsychologically-impaired subjects and controls (Gouvier et al., 1989; Katz et al., 1990; Quigley & DeLisa, 1983; Sivak et al., 1984; van Wolffelaar et al., 1988; van Zomeren et al., 1988). In particular, a relationship to driving-related abilities can be seen in the Trailmaking Test's measurement of complex visual searching skills (Quigley & DeLisa, 1983; van Wolffelaar et al., 1988).

Furthermore, the Trailmaking Test is one of a few tests to have demonstrated a significant relationship to any measures of practical driving ability (van Zomeren et al., 1988). In this study, neuropsychologically-impaired subjects took significantly longer to complete Trails A and B (a mean 39.3 and 94.0 seconds respectively) than controls (with respective mean scores of 35.4 and 74.9 seconds). Mean differences between Trails A and B were 54.7 for the neuropsychologically-impaired subjects and 39.5 for the controls. In another study, Trailmaking Test scores for neuropsychologically-impaired subjects correlated significantly with performance on small- and full-sized vehicle scores over a closed road course (Gouvier et al., 1989). Sivak et al. (1984) found that 55% of the variance in driver improvement was accounted for by perceptual improvement (as a result of training) as measured by Trailmaking and other tests.

Justification for the present study. The Trailmaking Test was included as an easily administered test of visual conceptual visuomotor tracking complementing other tests used in the present study. The Trailmaking Test is useful for investigating motor speed and attention functions, and is reputed for being highly vulnerable to the effects of neurological impairment. It is a popular and well standardised test. Application of the Trailmaking Test to studies of neuropsychologically-impaired drivers has shown some interesting results which pertain to the test's predictive validity in relation to practical driving.

Reaction time. Choice and complex reaction time data was recorded using a standard apparatus currently used in a rehabilitation setting in the assessment of neuropsychologically-impaired persons for driving again. The apparatus was based on early information processing theory (Dr. David Mellor, Department of Psychology, University of Otago, personal communication, 5 August, 1996). The original apparatus was constructed in 1976, and was later modified with the addition of an in-built electronic timer and a carry-case surround, so that it could be easily transported. In its modified form, the present apparatus comprised a box panel with digital timer, eight stimuli lights with corresponding push buttons, and supplementary foot pedal control. Measurement of choice reaction time requires the subject to respond to light cues, randomly presented from all eight stimuli, for preferred hand, non-preferred hand and preferred foot conditions. Complex reaction time is measured in a series which requires a hand response to stimuli lights three, four and six and a foot response to light five.

Administration and scoring. Standardised instructions are given to subjects (see Appendix J). Testing procedure requires that the same random order of trials (using all eight stimuli lights) are presented to subjects in blocks of ten for preferred hand and non-preferred hand, allowing an initial three practice trials. A block of five trials is then presented for the preferred foot only. This sequence is followed by blocks of ten trials (using four stimuli lights only) for preferred hand: preferred foot and, non-preferred hand: preferred foot combinations. Reaction times for each trial are recorded on a standard form and mean scores are calculated for each block of ten trials.

Test norms. Some norms are available for the present reaction time apparatus, based on a heterogenous sample of 180 adults, comprising patients and controls from the local area. This data is standardised for males and females and across different age groups. Consistent with other reaction time measures, significant gender and age effects are noted (Braun et al., 1989; Crook, West & Larrabee, 1993; Lezak, 1995; Sivak, 1981). Normative data applicable to the present samples is presented in Appendix K.

Reliability and validity. No formal reliability or validity data is available for the present reaction time apparatus, although anecdotal evidence suggests a practice effect across repeated administrations. Test-retest reliabilities for other reaction time procedures commonly find evidence for practice, motivation and fatigue effects (Schweinberger, Buse & Sommer, 1993; Sturm & Willmes, 1991; Stuss et al., 1989). Interestingly, there is some debate over differential practice effects for neuropsychologically-impaired subjects versus controls. In an important study, Schweinberger et al. (1993) found that reaction times for neuropsychologically-impaired subjects decreased at a significantly faster rate than controls over repeated testings. This evidence works against the assumption that individuals with neurological damage show smaller practice effects and instead suggests it might be essential to provide these individuals with sufficient practice.

In numerous studies of practical driving, various measures of choice and complex reaction time have shown good predictive validity (e.g. Gouvier et al., 1989; Hartje et al., 1991; Madeley et al., 1990; van Zomeren et al., 1987). On this basis the current reaction time apparatus has been in use for driver assessment for over two decades. Importantly, the neuropsychologically-impaired driver literature notes that significant correlations have been found between driving outcome and reaction time measured both artificially in the laboratory as well as in more ecologically valid settings. Despite this, Sivak (1987) notes that in practical situations a variety of factors contribute to substantially longer, and more varied, reaction times.

Use in clinical settings. It is well established that slowed reaction time is a characteristic of neurological damage. Braun et al. (1989) emphasise that "reaction time is severely impaired as a result of closed head injury and is a quick, simple and valid tool for gauging such patients functional status" (p. 167). The relationship of reaction time data to specific sites and types of damage, however, is not fully understood. While reaction time is known to have physiological and psychological components, the neural background for the reaction time process is unclear (Elsass, 1986). Variable research results are partly a function of the different measures of reaction time used. For example, Elsass (1986) reports that continuous reaction times did not distinguish between subjects with right- or left-hemisphere lesions and were not influenced by etiology of disease. Sturm & Willmes (1991) found more pronounced impairments for sustained attention and vigilance in right-hemisphere damaged subjects whereas left-hemisphere damaged subjects performed worse in choice reaction tasks. Further, in a comprehensive study, Braun et al. (1989) found that indicators of morbidity including coma duration, post traumatic amnesia, post-onset time and symptom reports did not predict performance on reaction time tasks. However, a number of other individual factors, such as age, gender, and cognitive abilities affected reaction times in all of these studies.

Use in neuropsychologically-impaired driver assessment. Reaction time is the most common measure used in the clinical assessment of neuropsychologically-impaired drivers, with over a dozen studies cited in the available literature. As documented in Chapter Five, these studies typically show significant relationships between of choice and complex reaction time, and various driving measures.

Justification for the present research. In the present study, a measure of choice and complex reaction time was included on the basis that reaction time appears to be a significant factor in practical driving. A review of the neuropsychologically-impaired driver literature strongly suggests that this relationship be investigated further (van Zomeren et al., 1987). The reaction time apparatus used in the present study is part of the current driving assessment of neuropsychologically-impaired persons in the rehabilitation setting from which the present subjects were recruited.

PROCEDURE

Setting-up of the study and data collection

Subjects were informed of the background and aims of the present study by mail. This introductory notice included a statement of the purpose and main focus of the study, a summary of what subjects' involvement would be, and a request to participate (see Appendix L). The mailed notice was followed up approximately one week later by a telephone call. With the telephone contact, subjects were given the opportunity to ask any questions concerning the information given. Upon agreement to take part, a convenient time for data collection was set for within three weeks. All subjects were given the option that they could be telephoned again, closer to the time, to remind them of their appointment. Subjects were mailed a confirmation of their appointment time and a map for locating the research venue.

All data collection took place from the Land Transport Safety Standards premises which were unobtrusively located in a high rise building (accessible by lifts and stairs) in the centre of a provincial New Zealand city. Provision was made for subject parking, and the arrival and departure of driver testing officers and vehicles. Within the premises, a reception area and two comfortable, sound-proofed interview rooms (one for psychological testing and the other for questionnaire completion/interview) were available exclusively for subjects during data collection. On arrival, subjects were greeted at reception and after reading (or having read to them) 'Information to Subjects' (see Appendix M) were requested to sign the 'Informed Consent Form' (see Appendix N). Importantly, this provided another opportunity for the details of the study to be explained and for the chance of any further questions concerning the research (Barber, 1980).

After informed consent had been given, subjects were told the order of events for their individual assessment. At the appropriate times the researcher introduced subjects to the person who was conducting each phase of the assessment. Between the assessment stages, subjects were invited to relax and help themselves to refreshments in the reception area.

It was necessary to rotate the order of presentation of assessment stages as up to four subjects were concurrently being assessed at any one time. This procedure was to ensure the most economic and efficient use of time of the professionals and premises available. Order of presentation of assessment components was however, counterbalanced between experimental and control groups. With the exception of the researcher, the other four professionals involved in subjects' assessment of each subject were blind as to which subject group participants belonged. Assessors were nevertheless aware of the general composition of subject groups. This pre-knowledge was justified on the basis of an ethical concern raised by van Zomeren et al. (1988) regarding the safety of those conducting practical driving tests who might not be sufficiently "on guard" if told they were evaluating able drivers. It was also acknowledged that cues given by subjects would, in some cases, confound the ideal blind arrangement.

Questionnaire procedure

The questionnaire component of data collection was administered by the researcher, who remained in the room to clarify and discuss any questions which might have been raised during questionnaire completion. Standardised instructions, as written on the front of each questionnaire, were read to subjects. Subjects received the driving questionnaire(s) first (a pre and post measure in the case of neuropsychologically-impaired subjects), followed by the demographic questionnaire. In the neuropsychologically-impaired groups, a number of subjects required assistance with the questionnaires, mainly through reading and comprehension difficulties. The researcher sometimes found it necessary to assist by reading out questions and, when requested, to take down responses as they were given verbally by subjects. It was made clear to all subjects that they were not obligated to answer any questions they did not wish to. Completion time for the questionnaires ranged between 10 and 22 minutes. Any issues which might have arisen during questionnaire completion were addressed and dealt with in a short debriefing session at the conclusion of this part of the overall assessment.

Neuropsychological testing procedure

Neuropsychological testing was conducted by a colleague of the researcher who was qualified in test administration. The six tests were were administered in the same order and in accordance with standardised instructions given for each testing instrument. Subjects were allowed sufficient time between tests, and additional time was available for breaks if indicated by the subject. During testing, this time allowance was required by some subjects. Allowance also had to be made for disability in the case of some subjects. For example, two subjects were unable to complete all preferred/non-preferred hand and foot trials of the reaction time test due to left hemiplegia. Feedback to subjects was minimised during neuropsychological testing. A short debriefing was given to subjects at the conclusion of testing, which focused on positive feedback and dealt with any issues identified by subjects. In total, the neuropsychological testing component averaged 45-50 minutes duration.

Practical driving procedure

The driving component of assessment comprised two standardised on-road driving tests: the New Road Test and the Advanced Driver Assessment. Each test was conducted separately and according to standardised procedure. Initial procedure was essentially the same with subjects being introduced to the testing officer(s) and then escorted to the testing vehicle. Not all subjects had their own vehicle. A Land Transport vehicle (manual steering) was also made available to all subjects for the New Road Test. For the majority of Advanced Assessments, a dual control car was available courtesy of driving instructors involved with the subject evaluations. Army personnel were provided with use of a civilian vehicle. Two subjects required use of the NZDRC training car which could be adapted with modifications. Modifications for these subjects comprised use of a wheel spinner and column gear shift due to disability experienced as a result of left hemiplegia.

All New Road Tests were conducted by the same Land Transport (Palmerston North) senior testing officer who was very experienced in administration of the test. Standardised instructions were followed over a set driving course. The set course was the local version used for New Road Test licensing examinations and was in accordance with courses set at a national level.

Each subject underwent one Advanced Driver Assessment, but was rated concurrently by two examiners in the car. One examiner was a senior officer from Head Office of the Land Transport authority who was an expert in the development and use of the Advanced Driver Assessment, and thereby acted as a control in the administration of the measure. The second examiner was one of six independent driving instructors, each of whom were randomly assigned to assess subjects from each of the four groups. This procedure enabled some inter-rater reliability data to be generated and was part of a formal evaluation of the Advanced Assessment measure conducted by a researcher within the local Land Transport Road User Safety Standards office. For this reason, two aspects of procedure did differ from the standard administration of the test: the presence of two assessors in the vehicle at the time of testing and utilisation of assessment data which was collected by an assessor positioned in the left rear passenger seat. However, to eliminate examiner inconsistency in results, only data from the control examiner was used in the final analysis of data for the present study. All Advanced Driver Assessments were conducted over the same course and comprised urban and open road driving over a 30 minute period. The course used was the standard route employed by Land Transport officers for the Palmerston North region. Before data collection, any slight variations to the standard course were eliminated in a trial run with individual driving instructors.

Testing commenced and ended from the same location outside the Land Transport premises for both driving assessments. Subjects returned to the building with the testing officer(s) who then provided sensitive and appropriate feedback on their performance in accordance with a regular testing situation. While feedback was generally positive, safety issues were also addressed as deemed appropriate. The researcher was available to the subject for additional debriefing and support within a few minutes of this consultation.

Debriefing and feedback to subjects

At the conclusion of data collection individual subjects spent a few minutes with the researcher in an overall debriefing. The subject was asked about his or her experience as a participant and any issues raised were discussed. Each subject was informed that they would be mailed an overview of the research findings and a personal summary of their own results. The subject was also once again reminded of the confidential treatment of his or her assessment result, and was told what was going to happen to the overall anonymous data. In addition, it was reiterated that individual results were strictly relevant for research purposes only. Finally, the subject was thanked for participating and given a monetary token (NZ$30) toward investment of time and any petrol costs incurred.

An overview of the study and personal feedback to subjects was mailed to subjects within four to six weeks. Personal feedback was kept general and emphasised positive aspects of the assessment. Further opportunity was given to contact the researcher should there be a need.

ETHICAL CONSIDERATIONS

A number of ethical considerations were raised concerning subjects, professionals and the information sought. The present research was seen to adequately address relevant ethical concerns and was granted approval by the Massey University Committee on Ethics in Human Research.

Recruiting subjects

The first ethical consideration was the issue of obtaining subjects for the study. Two organisations closely linked in their assessment of neuropsychologically-impaired drivers, were approached and gave permission to recruit subjects. Following each individual giving permission (which was secured by the occupational therapist or clinical psychologist involved in the case), names, addresses and contact phone numbers of those eligible to participate were forwarded to the researcher. Release of this confidential information was discussed with the professionals involved, who were aware of the implications. On the initial contact, potential participants were informed by the researcher of the acquisition of their names strictly for the purposes of the present study.

Subjects in the professional driving group were recruited from a transport squadron at a regional New Zealand Army Camp. Release of participants' names was via their training officer, who sought subjects' participation as part of a regular training programme. Those who participated were exempted other regular work duties. It was clearly established that once recruited, army personnel would share the rights (of confidentiality and withdrawal) of all other subjects involved in the present study. Subjects were also clearly informed of this by the researcher. It was also generally understood that all of the transport squadron would be required to undergo an Advanced Driver Assessment in due course, hence participants in the present study were not being unfairly singled out in any way. Participating subjects gave permission that their completed Advanced Driver Assessment forms would be made available to their training officer.

The researcher took responsibility of directly recruiting subjects for the matched control group. Recruitment was done in a fairly random manner, using a snowballing technique in order to find sufficient subjects with the characteristics required for matching. On contact it was necessary to check that potential subjects were clear about how their names had been sourced and to ensure that they received the same sequence of information as other participants in the study.

Informed consent

Once recruited, informed consent was obtained from subjects prior to commencement of the actual study. From an ethical perspective, informed consent outlined what subjects could expect from participation in the study and subjects right of withdrawal during any stage of data collection (see Appendices L, M, and N). Special consideration was given to the potential implications of informed consent for each of the different subject groups involved in the present study (Barber, 1980). These implications are discussed in the proceeding sections, under the subheadings:

confidentiality and anonymity, treatment of data, the welfare of subjects, and wider safety issues.

Confidentiality and anonymity

Subjects were assured confidentiality and anonymity of data at all stages of the research and subsequent publication of results. Throughout the present study, special concern was given to the confidential nature of subjects' responding to questionnaires and performance on psychological and practical driving tests. The researcher was very aware of the sensitivity and potential real life implications (for driving) of subject assessment data. The commitment to confidentiality was reiterated by the researcher at several stages of the data collection. Subjects were aware that the data was identifiable only by code numbers, and that the researcher was the only person able to match codes with individual participants in the study.

Treatment of data

The researcher considered issues regarding the handling of information given by subjects at length. Apart from the emphasis on anonymity of data, regard for agencies releasing subject information and for the position of those involved in processing subjects were important ethical issues. From the outset, the position of all professionals involved was established with regard to access and use of data. A written contract made clear the researcher's ownership of data and ethical obligations to participating subjects. Where appropriate, feedback to professionals involved comprised a written report of results and conclusions in which case data was presented in a summarised and anonymous form. The researcher gave permission for Land Transport to incorporate anonymous Advanced Driver Assessment results as part of a validation study which sought inter-rater reliabilities and data for standardising results across different groups of drivers. This was also made known to subjects from the outset of data collection.

In some instances, subjects from the impaired driving groups requested that their personal results from the driving and psychological assessment be forwarded to their psychologist or occupational therapist. As subjects sought permission for this to happen, and were knowledgable of the content of the information to be given, the researcher had no problem in complying with this wish. In all cases the Occupational Therapist or Psychologist referred to was the person who had initially released the subject's details for participation. Still, when any information was passed on, the researcher saw an obligation to reiterate the circumstances under which the assessment had taken place. This precaution was taken so as not to unnecessarily constrain or advantage a subject in any way (Hermeren, 1983).

Welfare of subjects

Another important ethical concern was for a number of psychological issues which could affect subjects who participated in the present study (Hermeren, 1983). It was acknowledged that some subjects could feel vulnerable and or a certain amount of distress in completing the questionnaire and during the psychological and driving assessments. In addition, the request to participate in a study about driving may have appeared threatening to potential subjects. In response, it is stressed that there were no obligations to, no repercussions for not, participating in the research. Consenting subjects were assured of the support and supervision of the organisation from which they were recruited. The researcher also possessed the clinical skills to deal with any related issues in an appropriate and sensitive way.

Confidentiality assured subjects that there could be no professional or legal implications (e.g. suppression of a drivers licence) resulting from assessment (Capron, 1983). Nevertheless, the nature of the driver testing, especially for drivers with disabilities who are ultimately seeking driving approval, suggests that some subjects experienced apprehension. This was also anticipated for the psychological testing component. Subjects who perceived that they had performed inadequately on the tasks may have felt concern, or even anger and frustration. Further, the researcher was also aware that the questionnaire component could raise a number of personal issues for subjects. In response, subjects were assured that they should feel no pressure to complete any particular question. In addition, the researcher was present to deal with issues which arose during questionnaire completion. At all times, it was important that subjects received generally positive feedback and that any concerns expressed by subjects were allayed as part of a debriefing procedure. Therefore, extent of debriefing varied with individual subjects.

For subjects who were neuropsychologically-impaired, effects such shortened attention span and irritability, were expected and allowed for. This provision included the possibility of altering administrative procedures in the best interest of the subject, such as allowing for breaks where feasible and discontinuing to avoid unnecessary distress. Time was also allowed for discussion with the subject, or making appropriate referrals (Boverman, 1983).

Wider issues of subject and general public safety

The researcher was in a position where knowledge gained about a subject's driving safety may expose a possible risk of danger to the subject and to the general public. While the researcher was clear that she had no authority to confer with any agency on a subject's driving status it was considered appropriate, in this instance, to recommend to a subject that they be re-evaluated through an appropriate source. This was considered as an ethical obligation in the best interests of the subjects own safety (Capron, 1983; Hermeren, 1983).

ANALYTICAL PROCEDURE

The general aim of the present study was to provide an integrated approach describing the driving performance and behaviour of neuropsychologically-impaired drivers. As part of this research design, the researcher hoped to identify social and neuropsychological factors which were related to practical driving ability, as measured by current New Zealand driving tests. The integrative nature of the research, therefore, called for a number of analytical techniques which enabled both qualitative and quantitative descriptions of the data. Here, the qualitative description of a number of subject variables was used to complement the more quantifiable data, such as driver self-report, practical driving, and neuropsychological test measures. These quantitative measures were summarised using simple descriptive statistics. Further analyses of these data were conducted using conventional one-way ANOVA, Pearson product-moment correlations, and multiple linear regression methods. All numerical data were analysed using SAS 6.11 For Windows (PROC FREQ, PROC GLM, PROC CORR, PROC REG). A copy of the raw data is available on ASCII File in Appendix R.

Descriptive analyses

With the lack of existing integrated research designs, an emphasis on qualitative description has generally been neglected. Nevertheless, a qualitative approach provides an information source which is clearly relevant to "the world of daily interest and concern" (Lehman, 1991, p.517). For these reasons, qualitative data was included in the present study, for example, in the analysis of open-ended questionnaire responses. Here, emphasis on outcomes were supported by frequency of responses. Where the range of responses was varied, every attempt was made to convey the representativeness of the sample (Yin, 1984). Qualitative aspects of the research design were considered strengths by which to gain insight into subjects' experiences. These were valuable both to the researcher in identifying data trends, and to the subjects whose personal experiences were a particularly meaningful part of the assessment process (Miles & Huberman, 1984).

In addition to the questionnaire responses, informal qualitative information from assessors conducting the practical driving and neuropsychological tests added a valuable descriptive element. In particular, this information enabled some practical insight into functional ability, or the way a subject actually performed a task. This type of feedback can have important implications for driving ability. Qualitative information, therefore, provides a source of 'rich' data that is not provided by numerical scores. Furthermore, the interrelatedness of quantitative data and other measures, such as quantitative test scores, offer considerable construct validity to the variables being measured (McBurney, 1994). As such, qualitative methods were a key part of the integrated research design.

Simple descriptive statistics (means, standard deviations, ranges) were used in the present study to summarise all quantifiable data. These were the basis for further statistical procedures, allowing inferences to be drawn from the results of the present study.

Inferential Statistics

Inferential statistics were used in the present study to enable conclusions to be drawn about driving behaviour of neuropsychologically-impaired subjects, to identify potential predictors of practical driving test scores, and to assist development of general theoretical statements. Finding the appropriate methods for analysis of quasi-experimental data can be problematic (Cook & Campbell, 1979), however, the flexibility, straightforwardness and adequacy of ordinary, classical methods for most purposes is advocated by many statisticians (e.g. Lehman, 1991; Kaplan, 1987; McBurney, 1994). On these recommendations the present study employed conventional inferential statistical methods. These analyses were conducted with the proviso that the research was exploratory and based on a small sample size.

From the simple descriptive statistics, one-way analyses of variance (ANOVA) were conducted to provide support for conclusions about differences, or lack of differences, among the four subject groups. One-way ANOVA is suitable for multiple conditions; testing the null hypothesis that there is no difference in means among a number of conditions (McBurney, 1994). The logic of the analysis of variance is to derive two independent variability estimates; the variance of the differences among groups and the variance within groups. The latter determines how much measures of the dependent variable vary by chance. The ratio of these two variances is indicated by the F value (Kaplan, 1987).

In cases where the omnibus F ratio was significant, then follow-up or post-hoc comparisons were conducted to determine specifically which of the four groups actually differed from one another. An inherent feature of post-hoc tests is that they guard against increases in the experiment-wise probability of making a Type I error, or rejecting a true null hypothesis (Howell, 1992). Here, the widely used Tukey's Honestly Significant Difference (HSD) test was chosen for the present study. The Tukey procedure establishes a value for the smallest possible significant difference between two means; any mean difference greater than that value is significant at

$p < .05$. Selection of the Tukey (HSD) procedure was based on the test's ability to protect the experiment-wise (EW) error rate for all paired comparisons. The test is also useful with unequal group sizes. Although less powerful than planned tests, the Tukey (HSD) test is more powerful than other post-hoc measures (Lehman, 1991).

Correlation tables were used to examine the relationship between the practical driving test measures. Here, the purpose was to investigate the relatedness of the two driving tests and the informal driver instructor ratings. Similarly, correlation tables were obtained for the neuropsychological tests, to look at possible relationships or common links among these test measures. Here, the purpose was to identify possible common themes which could indicate certain cognitive processes in driving.

Regression analyses in the present study were used in an exploratory sense to identify relationships between independent variables and dependent measures (practical driving outcome). In the present study, regression analyses were used in conjunction with the other complementary methods of analysis, particularly qualitative description. As a statistical tool, regression is very helpful in answering practical questions by exploring the way variables interact or combine to influence the dependent variable (Howell, 1992; Tabachnick & Fidell, 1989). The result of regression analyses "is an equation that represents the best prediction of a DV from several continuous or dichotomous IV's" (Tabacnick & Fidell, 1989, p.123). In the present study, standard multiple linear regression analyses were used, in which all independent variables are entered into the model simultaneously.

The purpose of multiple regression is to find a regression equation which represents the best prediction of a dependent variable from several correlated variables. Solving the derived regression model yields a set of 'b' values, termed partial regression coefficients, which optimise the correlation between predicted and actual outcomes. The standardised form of these b_i regression coefficients are termed β_i. The relative magnitude of β_i are not necessarily the best indicators of importance, but give a rough estimate of the relative contribution of the variables in the equation (Howell, 1992). The square of the Pearson product-moment correlation coefficient gives an indication of the importance of each independent variable. Individual r^2 values, therefore, are a measure of the degree of overall variance accounted by each single independent variable.

The best combination of independent variables yields an overall correlation coefficient, R, the square of which (R-square) can be interpreted in terms of percentage of accountable variation. As in any sampling distribution the magnitude of chance fluctuations increases as the sample size decreases. Notably, the overall correlation coefficient, R, tends to be over-estimated with smaller sample sizes. The adjusted R-square is an adjustment of the R-square based on the sample size and the number of predictors.

In the present study, standard multiple linear regression analyses were conducted to assess whether practical driving outcome (the dependent variable) could be predicted from a number of pertinent subject and neuropsychological test (independent) variables. With a small sample size, a limitation of regression analysis is the relative number of independent variables. Therefore, one of the goals was to select the fewest independent variables which were able to predict practical driving test scores. Preliminary analyses were conducted to reduce the number of independent variables to pertinent subsets that were deemed realistic, given the size of the sample groups involved in the present study.

Chapter Eight

DRIVER PERSONAL CHARACTERISTICS: RESULTS AND DISCUSSION

This Chapter presents the group results and discussion of the driver personal characteristics. As an integral part of the study of neuropsychologically-impaired drivers, a number of sociodemographics and driver characteristics were identified. The purpose was twofold: (1) to describe and compare groups, and (2) to examine the potential role of personal characteristics in the broader context of the driving process, particularly to the assessment of neuropsychologically-impaired drivers. With the exception of age, analyses of these personal characteristics were descriptive. Theoretical, methodological, and the wider practical implications of the results are discussed in Chapter Twelve.

SOCIODEMOGRAPHIC VARIABLES

While sociodemographic variables have not been examined extensively on neuropsychologically-impaired drivers, evidence from the general driving population suggests that they have has implications for both driving performance and behaviour. In conjunction with these findings, the relationship of certain sociodemographics to incidence of neurological damage raises issues concerning neuropsychologically-impaired drivers as a group. As part of the description of subjects in the present research, data was collected on age, gender, education, employment and current work status, and, domestic situation. The design of the present study ensured that age and gender were comparatively similar for subjects in the neuropsychologically-impaired presenters and the control drivers groups. Overall, age was evenly distributed within the present neuropsychologically-impaired samples. The present subjects were predominantly male, which is consistent with previous research samples and head injury statistics (Heilman & Valenstein, 1993). Differences between the two neuropsychologically-impaired groups in employment and current work status appeared to be related to improvement of function following neurological damage.

Age

Table 8.1 shows age data for each of the four groups. Subjects in the two neuropsychologically-impaired groups shared a similar age range and mean age in years. Control drivers were also chosen to approximate the neuropsychologically-impaired presenters group on the basis of age. The age of the professional drivers was an artifact of these subjects being full time army personnel at similar stages in their careers. Any differences in age between the groups were statistically non significant[1], $F(3,36) = 2.31$, $p = .09$.

Table 8.1.

Group data for subject age.

	Professional drivers (n=10)	Control drivers (n=10)	Neuropsychologically -impaired presenters (n=10)	Neuropsychologically -impaired drivers (n=10)
Mean age (years)	24.8	34.6	36.9	32.2
Standard deviation	3.33	14.8	12.0	10.9
Age range	20-31	20-57	20-54	22-47

[1] For ease of language, the term non significant is used in the loose sense of a test result in which the *P-value* is sufficiently large (>.05) that it does not provide acceptable evidence against the null hypothesis. This **does not imply** the misconception that the groups are alike and the H_0 is true.

The present results for age of experimental subjects are interesting in light of other neuropsychologically-impaired driver studies. Present samples appear to have a higher proportion of middle-aged drivers than many studies comprising subjects who are neuropsychologically-impaired through head injury. On the other hand, the present results do not reflect the extreme age range characteristic of studies comprising neuropsychologically-impaired groups of mixed etiology, which often include subjects with dementias and other age-related neurological damage. As the present study selected only closed head-injured subjects, the slightly wider age range reported may be more representative of this specific group of neuropsychologically-impaired drivers. Here, while head injuries may actually occur more frequently in a younger age range (Garcia, 1993), drivers with head injury represent all ages.

Taking age as synonymous with life stage, the present research involved a group of neuropsychologically-impaired individuals who typically had some years of driving experience before neurological damage (Evans, 1991). Given the range, one would expect that any changes in psychophysical capacity would be less likely related to age than the effects of neurological damage (Ball & Rebok, 1994; Cosher & Wallace, 1993; Planek, 1981). However, according to available evidence, the range is sufficient to expect possible age-related differences in perceptions, attitudes and beliefs associated with driving behaviour (Furnham & Saipe, 1993; Hemenway & Solnick, 1993; Jung & Huguenin, 1992) or at least the stereotypes associated with them (Cooper, 1990). As a consequence of the age of subjects, there are practical considerations for development of education programmes for the neuropsychologically-impaired driver, as well as for generalisation of results.

Gender

Subjects were predominantly male. For professional drivers, this was an artifact of the armed forces population from which this sample was drawn. Nine males and one female constituted this sample. The other three groups in the present study each comprised seven males and three females. Neuropsychologically-impaired subjects were randomly drawn from hospital and clinic lists of those who met the injury and assessment requirements. Here, the predominance of male subjects is consistent with head injury statistics in the 18-30 age group (Garcia, 1993). Similarly, an imbalance of male and female subjects is consistent with previous research on assessment of neuropsychologically-impaired drivers (van Zomeren et al., 1987).

It is important to consider whether a gender imbalance in the research may have implications for the neuropsychologically-impaired driver population. Although the general literature is hard pressed to find evidence for gender differences in driver performance, data concerning driver behaviour has noted some effects. For example, Barjonet (1988) found gender differences in risk exposure and risk perception generated through both amount of exposure and social attitudes toward risk acceptance. However, self-evaluations of driving behaviour provide some of the strongest evidence for gender bias, with males making significantly more self-enhancing judgements concerning themselves as drivers (Cooper, 1990; Cutler, et al., 1993; McKenna, et al., 1991). Consideration should therefore be given to whether these results generalise to neuropsychologically-impaired driver samples. If this is the case, there may be, as part of the assessment process, practical benefits for implementing re-education programmes aimed specifically at male driving behaviour.

Educational background

Educational background has been correlated with aspects of driving performance and behaviour, however findings are limited by the confounding effects of socioeconomic status and other related variables (Hemenway & Solnick, 1993; McLellan et al., 1993; O'Toole, 1993; Peck, 1990). Cohort effects may also be responsible for differences in the level of educational achievement in some groups of subjects. In the literature, there are similar difficulties relating levels of educational achievement to incidence of head injury. Together with the variables age and gender, however, statistical data suggests that the incidence of head injuries are higher among young males in the 18 - 25 age group with lower educational backgrounds (Garcia, 1993). Consistent with these statistics, an analysis of school leaving qualifications from the present study found that subjects in the two neuropsychologically-impaired groups noted fewer educational achievements overall, despite the fact that they had all completed their schooling prior to injury.

The present research found that seven subjects in the neuropsychologically-impaired presenters group and six subjects in the neuropsychologically-impaired drivers group had left secondary school without qualifications, while the remainder had the equivalent of School Certificate or University Entrance. Two subjects from the neuropsychologically-impaired presenters group had further qualifications; one of these was a trade certificate and the other a tertiary degree. Additional qualifications for the neuropsychologically-impaired drivers group also included one trade certificate and one tertiary degree. By contrast, all subjects in the control drivers group had School Certificate and seven had Sixth Form Certificate or higher. Four subjects had further qualifications, comprising two trade certificates and two tertiary degrees. Compared with control drivers, subjects in the professional drivers group had fewer educational achievements; four subjects reported that they had left secondary school without any qualifications, while six subjects had achieved School Certificate. It is noted however, that this level of attainment has been characteristic of school leavers seeking a career in the regular armed forces. Further qualifications for this group included two trade certificates and one tertiary degree.

Educational background was difficult to quantify within a relatively narrow range of secondary school qualifications. While fewer high school achievements were noted for the neuropsychologically-impaired samples in the present research, it is difficult to judge whether these differences are substantial enough to impact on any aspect of driving. Further, while performance on some of the psychological tests used in the present assessment may be affected by education (Lezak, 1995), it is questionable whether the tests are sensitive to differences in secondary school qualifications. An interesting feature of the present data was the lower level of educational attainment (as measured by secondary schooling) among professional drivers. On the basis of educational qualifications, this group was more comparable with neuropsychologically-impaired subjects than controls.

Employment and current work status

Subjects were asked about both their current work status as well as what occupation they considered best described their work history. These questions were designed in order to identify the occupation which best represented each subject, as well as to ascertain any changes due to current circumstances (e.g. unemployment, inability to work as a result of neurological damage). With this approach, the impact of neurological damage on employment was clear, and also showed some important differences between the two neuropsychologically-impaired samples.

Three subjects in the neuropsychologically-impaired presenters group were in work (two part time and one on a work scheme) while the remaining seven were unemployed. Of these seven, two were volunteer workers, one was studying full time (but was physically unable to work), and five were currently not working as a consequence of their head injuries. In the neuropsychologically-impaired driver group, seven subjects had work (three full time, three part time, and one on contract). One of those not working was seeking a job, while the other two did not specify whether they were able to work or not. It is notable that the range of previous occupations reported by both neuropsychologically-impaired groups was wide, from unskilled labour to highly qualified work. As would be expected, for both groups, there was a marked change in career path of individuals who previously held higher status jobs, such as Senior Sergeant in the police force, teacher, marine engineer, farm manager. All reported a change in job status which involved a considerable drop in duties and responsibilities assigned to them, or unemployment. Interestingly, however, considerably more subjects in the neuropsychologically-impaired drivers group had resumed work, either returning to previous employment, or, in the case of highly qualified individuals, usually accepting a less demanding position.

Among control drivers, six subjects were currently employed (five full time and one casual) and four subjects were not working. Out of those not working, one was seeking a job, two were studying and one was retired. As army personnel, all subjects in the professional drivers group were currently employed in full time work. All belonged to the same transport squadron and were involved in a similar range of driving duties. Except for one subject, all shared a similar lower order military rank. There were no other outstanding features in this data.

Several speculations can be made from the information gathered concerning employment. For the two neuropsychologically-impaired groups, differences in employment status was probably indicative of improvement in function coupled with the extent of social and emotional adjustment following neurological damage (Dikmen et al., 1986a, 1989; McLean et al., 1993). Alternatively, these differences could suggest that the two groups were different in some other respect, such as severity of neurological damage. Whichever the case, subjects who were neuropsychologically-impaired clearly showed more changes in employment than controls or professional drivers. In most cases, these differences reflected the need to adapt following neurological damage. The fact that more subjects in the neuropsychologically-impaired driver group were currently working, however, also has implications for considering the role improvement and adjustment may have for what is an appropriate time to assess driving following neurological damage. For neuropsychologically-impaired subjects who were no longer working, there were also implications for driving. The ability to drive had been an integral part of work for many subjects. A car was also a means of getting to and from work, but was now being used for different reasons. Consistent with past research, economic issues in the use of a car were important and were related to whether or not subjects were in work (Jones et al., 1983).

Domestic arrangements

Highly similar proportions of subjects in all groups were single, married or previously married. These results were no different from what one would expect in the general population given subjects' age (Department of Statistics, 1995). On the other hand, it is noted that there is a very high incidence of relationship dissolution for individuals who have experienced severe neurological damage (Hall et al., 1994). It could be speculated that results for the present neuropsychologically-impaired samples imply something about the degree of disability, adjustment, and/or social support networks these individuals have. On the other hand, approximately half of the subjects in each of the neuropsychologically-impaired groups lived with parents or other relatives or in a boarding situation, which suggests some degree of dependency. As well as the possibility of being dependent on others for some of their care, financial issues are often central to choice of living arrangements for those who have experienced neurological damage (Rosenthal et al., 1983). For these subjects in particular, the importance of being able to drive a car for both independence and mobility is well documented (Jones et al., 1983).

DRIVER CHARACTERISTICS

There are a number of driving-related variables which affect driving performance. These variables include driving experience, medical conditions, and use of medication, drugs, and alcohol. As outlined in Chapter Seven, all subjects met the visual criteria for driving set by the Land Transport Division of the Ministry of Transport. Personal reports of transient states, namely the effects of fatigue and stress, were incorporated as part of the general symptom checklist, as discussed in Chapter Ten. Importantly, implications exist for the interaction of all these documented variables with the effects of neurological damage. Overall, the present results were particularly interesting for driving experience, where a focus on several component measures provided some meaningful data for group comparisons. Thus, driving differed between pre- and post-neurological damage. However, there were also differences between the two neuropsychologically-impaired groups, suggesting various stages exist in returning to driving following neurological damage. This finding has implications for when a driving assessment should take place.

Driving experience

Driver's licence data. Subjects were asked how long they had had their current driver's licence. Results showed some spread in the time drivers had been licensed, which was similar across all groups. In most cases, time licensed tended to reflect subject age.

The length of time that professional drivers and control drivers had been licensed is shown on Table 8.2. All control drivers drove private cars and two subjects were also licensed to ride a motorcycle. As well as being licensed for a private car, all professional drivers were licensed for heavy commercial vehicles. Five of these subjects also had a motorcycle licence.

Table 8.2.

Number of years licensed for professional and control drivers.

	FREQUENCY	
Years licensed	Professional drivers	Control drivers
less than 2 years	1	0
2-5 years	0	1
6-10 years	5	3
11-20 years	4	4
21-30 years	0	1
more than 30 years	0	1

Table 8.3 shows the time licensed before neurological damage for subjects in the two neuropsychologically-impaired groups. All neuropsychologically-impaired subjects drove private cars. Prior to injury, five subjects in the neuropsychologically-impaired presenters group also drove other vehicles (commercial vans, forklifts, trucks or farm vehicles) primarily associated with their work. Five subjects previously rode motorcyles, and two continued to do so. Notably, four subjects in the neuropsychologically-impaired drivers group had changed from manual to automatic column drive cars. As a result of the occupational therapist's evaluation, two of the automatic cars had been professionally adapted to accommodate the needs of the driver. Seven of the neuropsychologically-impaired drivers had motorcycle licences, but only two subjects continued to ride since their head injury. These restrictions were equally either voluntary or professionally advised. Prior to neurological damage, three subjects drove commercial type vehicles but no longer did so.

Table 8.3.

Time licensed prior to neurological damage for neuropsychologically-impaired subjects.

	FREQUENCY	
Years licensed	Neuropsychologically-impaired presenters (pre-injury).	Neuropsychologically-impaired drivers (pre-injury).
less than 2 years	0	0
2-5 years	1	1
6-10 years	0	3
11-20 years	6	4
21-30 years	3	1
more than 30 years	0	1

Return to driving following neurological damage. Time driving in the period since neurological damage is shown in Table 8.4. As expected, neuropsychologically-impaired drivers tended to have been driving for longer compared with neuropsychologically-impaired presenters. Still, in the neuropsychologically-impaired presenters group, several subjects had been driving again for up to twelve months before undergoing formal assessment. The one subject who had been driving again for more than three years had experienced a further head injury and was about to be assessed again.

Seven subjects from the neuropsychologically-impaired presenters group had resumed driving before any formal evaluation or recommendation. Decisions about when to resume driving were largely subjects own. There was one instance of a subject who was illegally driving at the time of head injury through licence suspension subsequent to a DIC offence. Interestingly, this situation appeared not to affect this subject's personal decision to begin driving again. Two subjects in the group reported that they had started driving again under supervision of friends and family. The remaining three subjects had awaited the opportunity for formal assessment through consultation with a psychologist and an occupational therapist before returning to driving. Data therefore reflected wide range of views on return to driving.

Table 8.4.

Time driving since neurological damage for both neuropsychologically-impaired groups.

	FREQUENCY	
Time driving since neurological damage	Neuropsychologically-impaired presenters.	Neuropsychologically-impaired drivers
Less than 1 month	4	0
Between 1-5 months	2	2
Between 6-12 months	2	1
More than 1 year	1	4
More than 3 years	1	3

All neuropsychologically-impaired driver subjects held current driver's licences and had been given formal approval to return to driving after assessment by an occupational therapist, and in most cases, a clinical psychologist. How subjects initiated driving again followed a similar pattern to those in the neuropsychologically-impaired presenters group. Three subjects made their own decision to begin driving again, two had driven with family or friends, one had lessons with a driving instructor and three awaited formal assessment.

Subjects were also asked about the time between neurological damage and resumption of driving. These periods varied considerably for both groups, and there appeared to be no common factors attributed to this. Extent of injury, personal choice, professional advice (physician, psychologist), concerns of significant others, access to a motor vehicle, and financial constraints were among some of the reasons given which influenced when subjects began driving again. A few subjects expressed concern over unclear guidelines regarding an appropriate time to resume driving.

Typical driving patterns. To ascertain typical driving patterns, subjects were given a number of multiple response questions modelled on past research (Cox et al., 1989; Priddy et al.,1990; Simms, 1985a). Initially, neuropsychologically-impaired groups were compared with control drivers and professional drivers to establish whether subjects shared similar driving patterns in the period prior to head injury (refer Appendix O). Importantly, this data suggests all neuropsychologically-impaired subjects had a more regular driving pattern compared with controls prior to head injury.

Subjects in both neuropsychologically-impaired groups drove on a regular basis and had similar driving patterns prior to head injury. For both groups, all but one subject drove at least once daily. Most subjects drove to and from work or other daily activities. Many subjects also viewed driving as an integral part of their job. Most drove short distances and local routes, although four subjects in each group regularly drove long distance. Driving covered all traffic situations (from inner city to rural) and densities (minimum to peak traffic periods).

Half of the control drivers drove daily and half drove several times a week. Three subjects drove as part of their job. Main driving for all subjects was over local routes, short trips and travel to and from work or other daily activities. Two subjects regularly drove long distance. Driving was mainly over inner city and suburban routes and took place during moderate to peak traffic periods. Half of the control drivers regularly drove out of town, primarily on main routes. By comparison, all but one of the professional drivers drove daily for their work. Driving involved regular short and long distance journeys and was equally spread over city, rural and main highway routes in all traffic densities. Overall, the control driver group drove less often and typically over shorter distances. These findings are interesting from the point of view of exposure as a component of driving experience. Although neuropsychologically-impaired presenters and control drivers were comparable on time licensed, the adequacy of this measure of driving experience is questionable.

Pre- and post-injury driving patterns. In addition to completing a current questionnaire, retrospective reports of driving prior to head injury were collected from all neuropsychologically-impaired subjects. This data clearly showed changes in driving patterns relating to neuropsychological impairment (see Figures 8.1-8.4). These results are in agreement with changes in typical driving patterns resulting from individuals attempt to compensate for the effects of neurological damage (Priddy et al., 1990; van Zomeren et al., 1987).

A shorter history of return to driving implied that subjects in the neuropsychologically-impaired presenters group may not have had established driving patterns. As already indicated, three subjects were not driving at all. However, two subjects in this group were driving more than once daily and the other five subjects were driving less than weekly (Figure 8.1). Driving was therefore much less for all but the two subjects still driving on a daily basis. Changes in subject's driving patterns were mainly attributed to aspects of neurological damage such as visual disturbances. However, one subject reported that driving was lessened because he no longer had a job and therefore did not have to drive to and from work.

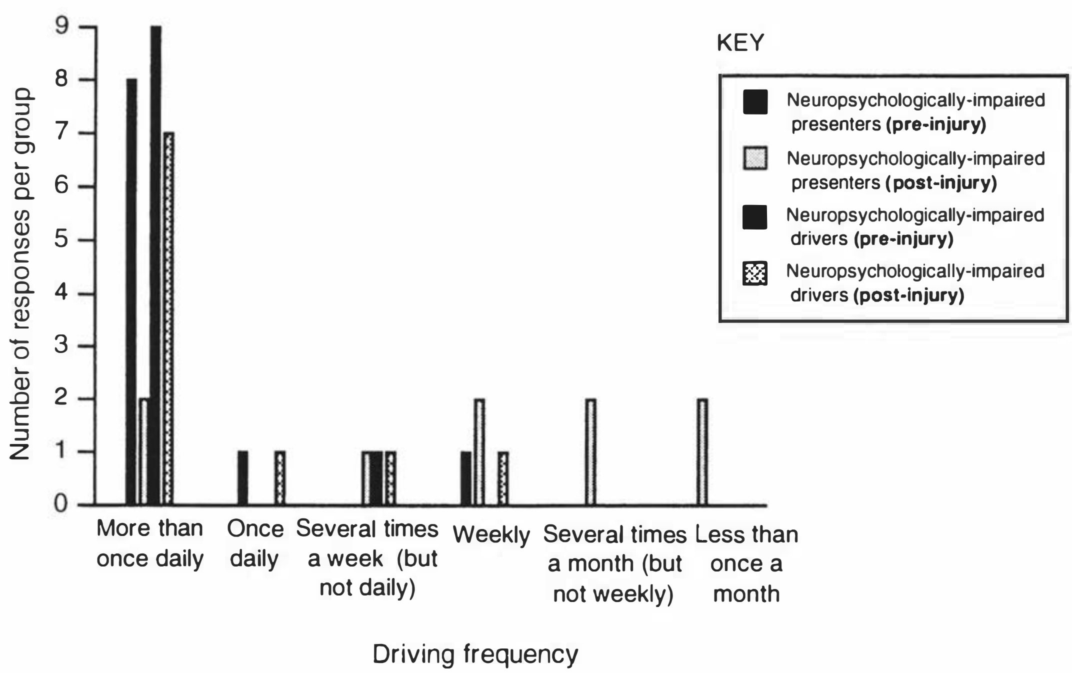

Figure 8.1. Driving frequency pre- and post-neurological damage.

Compared with neuropsychologically-impaired presenters, neuropsychologically-impaired drivers had a more regular driving pattern since neurological damage. Nevertheless, this driving pattern still differed from pre-injury status for some subjects. Eight subjects had returned to driving on a daily basis, while two drove about once weekly. Despite this, half of the sample were still driving less than before. Reasons for this reduction included no longer having to travel to work and the expense of petrol. One subject had had a medical restriction placed on driving. Remarkably, three subjects reported that they were driving more than before their injury because they were no longer working, so driving had become a means of passing the time. The remaining two subjects said that the amount of driving they did had remained the same.

For all subjects in the neuropsychologically-impaired presenters group, driving was restricted to local routes and short distance journeys, and mainly involved travelling to and from daily activities (Figure 8.2). Compared with pre-injury, there was a strong tendency to avoid driving inner city, main routes and motorways, and during busy and peak traffic periods. These findings suggest that neuropsychologically-impaired drivers may have been actively using compensatory techniques to overcome perceived deficits which result from neurological damage (van Zomeren et al., 1987).

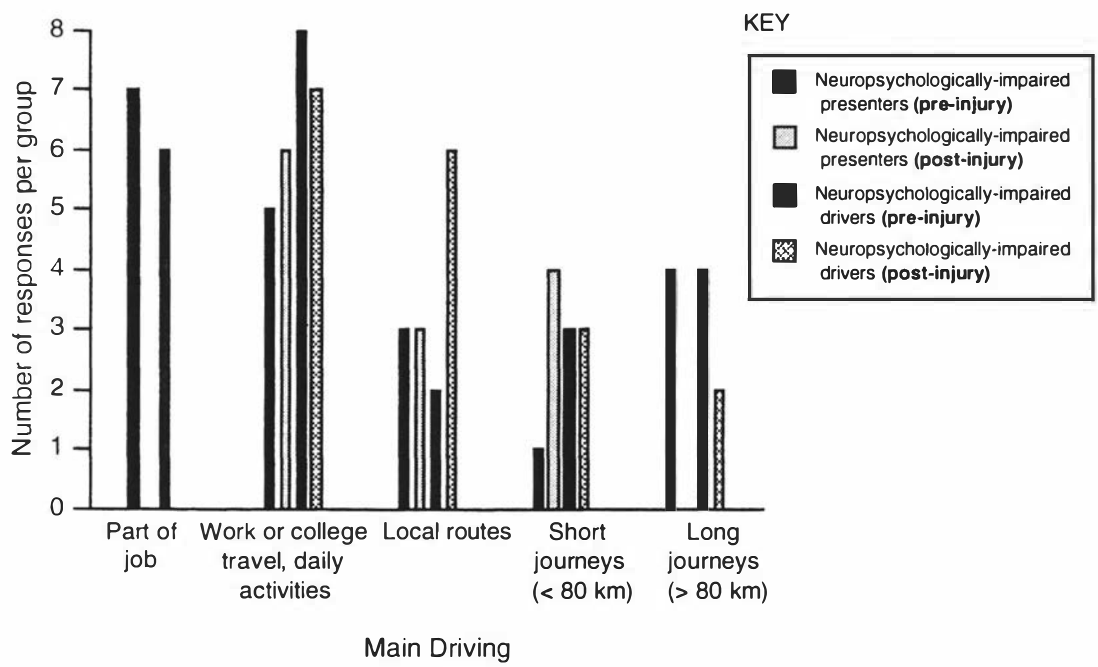

Figure 8.2. Main driving patterns pre- and post-neurological damage.

For neuropsychologically-impaired driver subjects, main driving now involved local routes, short distances and travel to and from work or daily activities (Figure 8.2). Driving was no longer a part of any subject's job, and there was a reduction in the amount of long distance journeys taken. Driving patterns across varying situations such as inner city to rural roads (Figure 8.3) and within a range of traffic densities (Figure 8.4) were generally the same as before head injury.

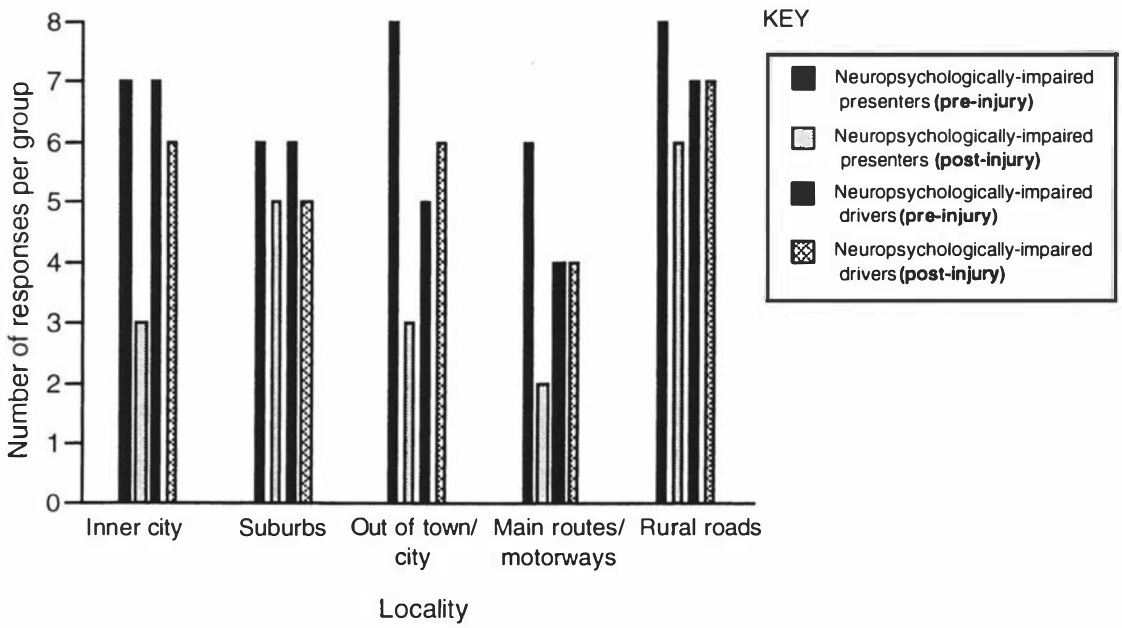

Figure 8.3. Patterns of driving locality pre- and post-neurological damage.

Overall, there were driving pattern differences between pre- and post- neurological damage. Driving patterns changed markedly for subjects in the early stages of a return to driving (neuropsychologically-impaired presenters) and results for this group were more homogeneous. While the neuropsychologically-impaired drivers group was more variable, there was not a return to formerly established driving patterns for some subjects. The heterogeneous nature of the neuropsychologically-impaired drivers group could be a function of several factors, including severity of injury, rehabilitation opportunities, and temporal factors. Possibly, these are the reasons why the two neuropsychologically-impaired groups were different for driving patterns. If so, then there are implications for the expected amount of change or improvement from the neuropsychologically-impaired driver. Consequently, there may be an optimal time for driving assessment.

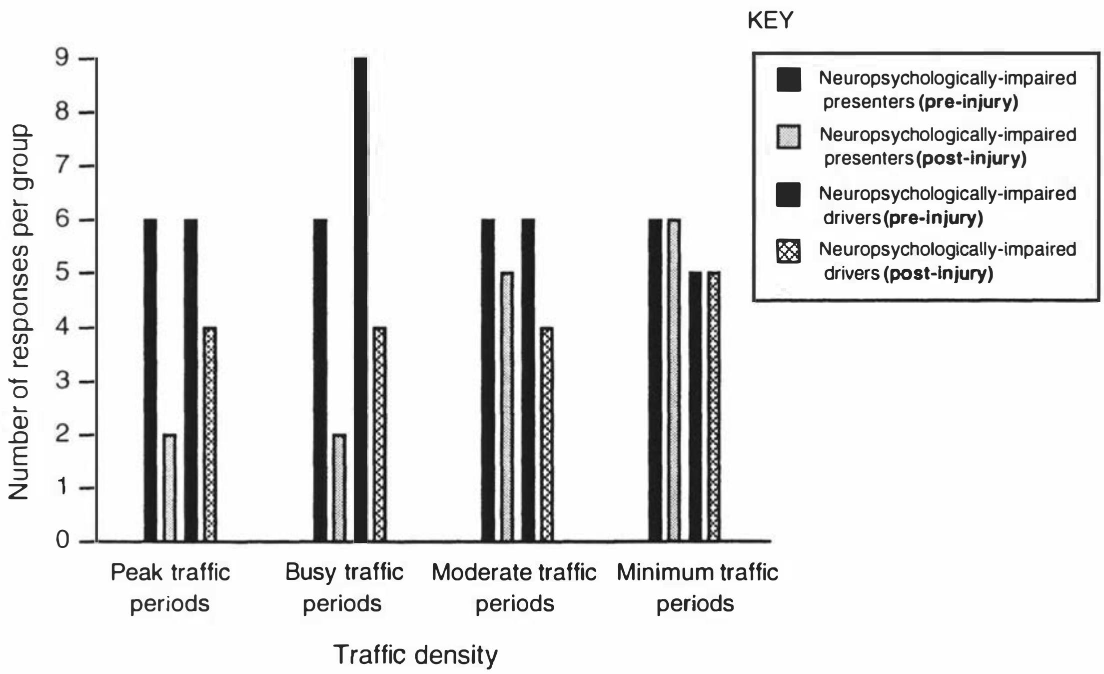

Figure 8.4. Traffic density driving patterns pre- and post-neurological damage.

Defensive driving course. The effects of defensive driver training are difficult to assess. However, there is the underlying assumption that individuals who have completed a course possess a certain knowledge base. A standard New Zealand defensive driving course was part of the training criteria for all professional drivers involved in the present research. Four subjects in the neuropsychologically-impaired presenters group had also completed the course, two before, and two following neurological damage. One subject in the neuropsychologically-impaired drivers group had undergone the course before neurological damage. Defensive driving courses had also been undertaken by three control drivers.

Previous studies have found that accident statistics for individuals who have done a defensive driving course are not reduced, although there is some evidence for fewer traffic violations (Evans, 1991; Lund & Williams, 1985). There is also the possibility that defensive driving and other advanced driver education courses attract certain types of drivers, such as the safety conscious, which is a limiting factor for the generalisation of results. With this in mind, two subjects in the neuropsychologically-impaired presenters group were compelled to do a defensive driving course as part of court action taken for driving offences. Overall, therefore, little can be said concerning the motivation behind a subject's involvement with defensive driver training.

Driving incidents. Subjects were asked a number of fixed-choice questions concerning driving incidents, modelled on questionnaires used by Cox et al. (1989) and Simms (1985a). Unfortunately, this section of the present study was characterised by incomplete data sets which limited any in-depth analysis of results. Importantly, however, most of the missing data came from the neuropsychologically-impaired groups. One explanation for this lack of response could be the potential threat of disclosing information about 'quality' of driving, particularly for neuropsychologically-impaired subjects who may have perceived the research to have implications for future assessment. Additionally, subjects may have experienced some memory difficulty in providing information about past driving incidents.

It was interesting that from the data provided, fewer subjects in the neuropsychologically-impaired groups (pre- and post-neurological damage) claimed any minor or non-reported incidents when compared with control drivers or professional drivers. In contrast, previous research has found that compared with controls, neuropsychologically-impaired subjects tend to report greater numbers of minor driving incidents (Simms, 1985a). Whether or not subjects viewed any minor incidents or unreported accidents as significant may have been a contributing factor in the present results.

Frequency of incidents reported to an insurance company were about the same for all groups. Number of traffic offences were also similar across all groups, with the exception that there were more major offences recorded for the neuropsychologically-impaired presenters group prior to neurological damage. While these results may be due to chance, there is also the interesting possibility that a higher frequency of premorbid driving offences for neuropsychologically-impaired presenters reflects real differences in driving ability.

Overall, from the data available for neuropsychologically-impaired subjects, evidence to suggest changes in frequency of any type of driving incident was unclear. Nevertheless, subjects in the neuropsychologically-impaired drivers group did have similar numbers of post injury incidents over a clearly shorter time span (i.e. since return to driving) which raises questions regarding an equitable standard of driving when compared with controls. Here, in particular, recall of events may also be a factor in explaining these results.

Medical conditions

Subjects were asked several questions to elicit information on medical conditions and/or relevant injuries they may have experienced. While the relationship between medical conditions and fitness to drive is vague, it was considered important to check for possible medical explanations which could affect performance on any of the measures used in the present research.

Separate from neurological damage, none of the subjects in the neuropsychologically-impaired groups reported any other medical conditions and/or relevant injuries. However, throughout the course of assessment it became apparent that several subjects had suffered multiple injuries (e.g. fractured bones) at the time of neurological damage, some of which continued to impede mobility and ability to function. Further, during the course of assessment, a few subjects did report that they had had subsequent accidental injuries (including further head injuries) since the initial neurological damage. Such injuries are not uncommon. A high incidence of further head injury, including accidental injury, is a known trend within neuropsychologically-impaired populations (Garcia, 1993; van Zomeren et al., 1987). More detailed information is given in Chapter Ten.

There were no relevant injuries or medical problems reported by professional drivers. In the control driver group, four subjects reported chronic medical conditions. One subject had mild cystic fibrosis, one suffered chronic back pain, and two were asthmatic. All four subjects reported some loss in physical function as a result of these conditions. However, only the subject with chronic back pain reported that the condition impeded driving, to the extent that long distance journeys were avoided.

Medication and drugs. The present questionnaire listed number of conditions for which known medications or drugs are likely to affect driving performance (*Medical Aspects of Fitness to Drive : A Guide for Medical Practitioners*, 1990). Four subjects from the neuropsychologically-impaired presenters group reported that they took regular medication for one or more of the following conditions: chronic pain, depression, motion sickness, inflammation, sleeping problems, stress/hypertension, and, neurological or psychiatric conditions. Of these, two subjects reported that they were aware of, and noticed, some effect of their medication on their ability to drive. Similarly, in the neuropsychologically-impaired driver group, there were four subjects who regularly took medication for chronic pain, depression, motion sickness, sleeping problems, and stress/hypertension. One subject reported taking marijuana for pain suppression and 'recreational use'. None of those responding in this group reported that they were aware of, or noticed, any effects of their medication on driving. One of the professional drivers regularly took medication for allergies, while two subjects in the control driver group took anti inflammatory drugs. These individuals were aware of the potential effects of their medication on driving, but did not experience any.

Overall, proportionately more medication was taken by almost half of the neuropsychologically-impaired subjects involved in the present study. Consequently, two issues can be raised. There is the increased likelihood of drug effects for the neuropsychologically-impaired groups, which may also be exacerbated by the combinations of drugs taken and the type of neurological damage present. However, due to the small numbers involved in the present study, there was no common pattern relating to whether any medications were potentially more important in the assessment picture, or could be documented as having a noticed effect.

Alcohol

Some general questions were asked about alcohol consumption. No subject reported a pattern of alcohol consumption consistent with heavy drinking. One subject in each of the neuropsychologically-impaired groups drank regularly, but this constituted less than two drinks per day. Five neuropsychologically-impaired presenters drank occasionally, while four did not drink at all. In the neuropsychologically-impaired drivers group, seven subjects drank occasionally and two did not drink any alcohol. Consistent with previous studies, a typical pattern emerged for all of the neuropsychologically-impaired subjects who abstained from alcohol (Friedland et al., 1988; Gronwall, 1989). These subjects reported that they had stopped drinking after they were made aware of the compounding effects of alcohol and neurological damage. Interestingly, decisions not to drink were largely due to personal experiences of reduced alcohol tolerance.

Table 8.5.

Decisions on alcohol consumption and driving.

	FREQUENCY OF ITEMS CHECKED			
Driving concerns checked	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Being caught by the law	2	1	1	1
Knowing my limit	4	1	2	1
Whether I feel safe to drive	4	4	3	3
Whether others feel I am safe to drive	1	2	1	1
Having to find other transport home	2	1	1	1
None, I do not mix alcohol and driving	5	4	7	4

Four subjects in the control drivers group did not drink, while the remaining six drank occasionally. In the professional driver group nine subjects reported that they drank alcohol occasionally and one subject did not drink at all.

To elicit some data on attitudes to drinking and driving, the question "if you were to drink some alcohol and then drive a car, which of the following would be your main concern?" was posed. Six categories were presented from which subjects could choose any number of responses. Table 8.5 summarises this data across groups. As shown, subjects chose a wide range of responses, although reasons of personal safety and decisions not to drink and drive were the most common across all groups. Interestingly, more neuropsychologically-impaired presenters reported that they did not mix alcohol and driving. For these subjects in particular, responses could be a function of several things including personal conviction, recent awareness of the compounded effects of alcohol and neurological damage, or demand characteristics in light of assessment for driving again.

Chapter Nine

DRIVING MEASUREMENT: RESULTS AND DISCUSSION

This Chapter presents the results and specific discussion of the practical driving measures and the self-reported comparative driver scales for each of the four groups. In the analysis of results, significant F values were followed up using Tukey's Honestly Significant Difference (HSD) Test to determine specific group differences. An alpha level of .05 was used for all statistical tests. The relationship between pertinent driving measures and the other assessment variables is explored through multiple regression analyses in Chapter Eleven. Theoretical, methodological, and practical implications of the results are discussed in Chapter Twelve.

PRACTICAL DRIVING EVALUATION

New Road Test

In accordance with standard procedure for the New Road Test, results were recorded as separate scores for **speed, search**, and **direction** errors in addition to a composite score for total **driving patterns**, which stresses the interrelationship of driving behaviours (Wright et al., 1984). Mean New Road Test scores for each of the four groups are shown in Table 9.1.

Group differences for **total patterns** were statistically significant, $F(3,32) = 5.89$, $p = .02$. Neuropsychologically-impaired drivers had more total patterns than professional drivers. A breakdown of total patterns revealed that there were statistically non significant differences between groups for numbers of **search** and **speed** errors. However, group results for **direction** errors reached a statistically significant level, $F(3,32) = 8.51$, $p = .00$. Direction errors encompass a wide range of faults including errors in tracking or maintaining position on the road, steering away from hazards, traffic interference, smooth driving, signalling and timing of driving intentions, and, directional sense. Here, neuropsychologically-impaired drivers made more errors than any of the other three groups.

Table 9.1

Group results for the New Road Test

	Mean (standard deviation)			
Error category	Professional drivers (n=10)	Control drivers (n=10)	Neuropsychologically-impaired presenters (n=7)	Neuropsychologically-impaired drivers (n=9)
Total patterns	1.70 (1.06)	3.30 (1.25)	3.14 (2.25)	4.30 (1.00)
Search	8.20 (2.15)	7.70 (1.16)	8.43 (0.79)	7.77 (0.97)
Speed	0.60 (1.0)	2.00 (2.11)	2.57 (3.59)	2.44 (2.83)
Direction	1.70 (1.16)	2.22 (1.62)	2.86 (1.95)	5.11 (1.62)

Total patterns are determined by an unsatisfactory rating for at least one of the three error types occurring within a segment of the New Road Test. As already stated, there were differences between professional drivers and neuropsychologically-impaired drivers. However, a breakdown of type of error, revealed an important comparison between the groups. Thus, the poorer performance of the neuropsychologically-impaired drivers was largely accounted by significantly more direction errors compared to any of the other three groups.

Interestingly, normative data suggests that direction control errors are most often noted as unsatisfactory in driving licence candidates. Wright et al. (1984) state that "in this relatively complex situation of control of speed, search for other traffic and related decision making may tax the inexperienced drivers capability." (p.191). Subsequently, they suggested that direction control is probably least important and the first behaviour to be neglected in a situation of information overload. Here, it may be possible to parallel the learner driver's position, where many driving manoeuvres have not reached the procedural stage of skill development, with the similar concentrated effort required by neuropsychologically-impaired subjects while attending to complex driving tasks.

Another interesting feature was that all four groups had comparatively more search errors than any other error category, despite no significant group differences for this category. Looking out for and monitoring other traffic, identification of hazards, observation of road rules and related decision making are all search components. Interestingly, normative data for the New Road Test (Wellington course) does not find more proportionally search errors marked unsatisfactory across all segments of the course. The high incidence of search errors for all groups in the present study could therefore be a function of the different regional course, independent examiner effects, or some aspect common to the present subject groups.

A limitation of the New Road Test data was that full scores were not available for all subjects. Only seven test scores were recorded for the neuropsychologically-impaired presenters group. Data was missing for various reasons. One test case was aborted, and subsequently failed, due to exceptionally poor driving skills. The other two tests could not proceed because the testing officer found one subject's car was legally unfit to drive, and believed a second subject required a specially adapted vehicle (which was unavailable at the time of testing). The status of these subjects was interesting, as in each case, the testing officer remarked on the apparent lack of insight that was shown. Exclusion of these subjects' data from the overall analysis of the New Road Test results may have introduced a positive bias for the neuropsychologically-impaired presenters group, particularly since the sample size is small. Unfortunately, one subject's data was also missing from the neuropsychologically-impaired driver group due to an administrative loss of the test form.

Pass or fail outcome on the New Road Test. The New Road Test is the standard test of driving proficiency administered to all applicants for a current New Zealand driver's licence (Harwood, 1992). According to the instruction manual, the test sets standards for determining the suitability of each applicant to hold a driving licence. Criteria for passing the New Road Test, when it is based on a 16 segment course, is a pattern score of less than four. Thus, present findings indicate that all professional drivers passed the test, while six subjects in the control driver group passed. The neuropsychologically-impaired presenters group had four passes, and the neuropsychologically-impaired drivers had two. These results reflect the higher standard of the professional driving group. However, while the pass rate for the other groups is low, this does not show up the differences in the nature of driving errors made. Interestingly, the control driver group does not have a particularly high pass rate. An important consideration is whether a low pass rate may also be attributed to the questionable ability of learner skill-based driving tests to predict latter driving (Wright et al., 1984). Here, professional drivers may be more likely adhere to a driving style consistent with the formal criteria of driving tests, and subsequently perform well by this measurement criteria.

Advanced Driver Assessment

Rather than serve as a test of driving success or failure, the Advanced Driver Assessment is recognised as a procedure for identifying driver error. This driving test provides a systematic guide for instructors on areas for retraining of test applicants (Harwood, 1992). Performance is summarised in a grid fashion to facilitate analysis of error type and the description provided is a unique feature of this driving evaluation. However, it is also acknowledged that this measure may be compromised by poor operational definition of the numerous performance areas. This lack of standardisation was reflected in the wide range of inter-rater reliability coefficients recorded between the chief assessor and driving instructors in the present study. To ensure consistency, only the data from this experienced chief assessor was used in the present results. The Advanced Driver Assessment involved continuous driving over a 40 minute town and open road course which was rated and summarised using the standard form (see Appendix I) to record total errors and error patterns (a predefined cluster of errors within a set category). Table 9.2 presents the mean data for total errors and error patterns across all four groups.

Table 9.2

Group results for the Advanced Driver Assessment.

	MEAN (STANDARD DEVIATION)			
Error category	Professional drivers (n=10)	Control drivers (n=10)	Neuropsychologically-impaired presenters (n=10)	Neuropsychologically-impaired drivers (n=10)
Total errors	25.5 (10.93)	47 4 (12.79)	42.6 (12.00)	40.1 (11.70)
Error patterns	2.3 (2.06)	5.0 (2.94)	3.8 (2.20)	3.4 (2.10)

Overall group differences for **total errors** were statistically significant $F(3,36) = 6.29$, $p = .00$. Professional drivers made fewer total errors than neuropsychologically-impaired presenters and control drivers. Differences between groups on total **error patterns** were statistically non significant.

The statistically statistically non significant finding for error patterns is interesting, given that the F-value for total errors was highly significant. An error pattern constitutes six or more errors within three or more horizontal or vertical row boxes on the assessment grid (see Appendix I). Therefore, insignificant group differences in error patterns would appear be a function of a ceiling effect created by the way patterns are scored. The lower number of errors scored by professional drivers directly corresponds with the number of error patterns for this group. On the other hand, the remaining three groups had more errors concentrated in certain areas, which were therefore less well represented by the pattern scores.

Qualitative error analysis on the advanced driver assessment. Error analysis raised some interesting qualitative data which is more pertinent to the different subject groups, although not specifically reflected in the assessment scores.

Importantly, this finding is consistent with van Zomeren et al. (1988), who used a similar practical measure of continuous driving.

A breakdown of composite skill categories indicated that all subjects made errors predominantly in the area of hazard identification. For both neuropsychologically-impaired groups, there were proportionally fewer errors associated with manipulating controls, which supports the notion that basic operational level skills are less likely to be affected by neurological damage (van Zomeren et al., 1987). Proportionally more errors relating to judgement and observation of traffic regulations were accrued by both neuropsychologically-impaired groups and controls. An important factor here is appropriate and timely decision making, typical of higher level executive functioning (Lezak, 1995). Professional drivers showed better judgement and adherence to traffic regulations, which could be expected as a function of their training and occupational status.

Analysis of driving situations showed that for all groups, predominantly more errors occurred for holding on the road or tracking ('moving on'), and going through intersection traffic ('moving thru') categories (Harwood, 1992). This high proportion of errors would seem relative to the amount of time spent in these driving situations during the course of assessment.

Overall, most errors occurred in the identification and prediction of hazards at intersections. Both neuropsychologically-impaired drivers and control drivers were less effective at making appropriate decisions in response to these errors. Interestingly, the nature of the road holding (tracking) errors was qualitatively different across the four groups. Here, professional drivers made notably fewer errors of any other type except for those relating to 'power' while holding on the road. The assessor considered that this 'over-acceleration' could be a function of professional drivers being more accustomed to driving heavy transport vehicles.

Errors identifying and predicting hazards, and determining consequent action while moving on the road, were common for both of the both neuropsychologically-impaired groups and for control drivers. Notably, steering (tracking) errors 'moving on' the road occurred relatively frequently for both neuropsychologically-impaired groups and controls. Neuropsychologically-impaired drivers were also more likely to break the speed limit during tracking phases.

Driving instructor rating

As part of the assessment of practical driving, a simple rating on a seven-point ordinal scale (1 being extremely comfortable and 7 being extremely uncomfortable) was obtained from the senior testing officer who conducted the Advanced Driver Assessments. The rating was made in response to the question "How comfortable would I feel being driven to Wellington by this driver?" Mean results for the four groups are shown on Table 9.3

Table 9.3

Group data for instructor's rating of practical driving.

	INSTRUCTOR RATING (1-7)			
	Professional drivers (n=10)	Control drivers (n=10)	Neuropsychologically-impaired presenters (n=10)	Neuropsychologically-impaired drivers (n=10)
Mean	3.1	4.8	5.3	4.8
Standard Deviation	0.99	0.92	1.15	1.13
Range	2-5	3-6	3-7	3-6

Group results for the instructor rating were statistically significant, $F(3,36) = 8.30$, p = .00. The testing officer's overall impression was that professional drivers were more comfortable to drive with compared to the three other groups. This result is consistent with the main outcomes of both formal driving test measures.

Numerous informal measures have been documented in the driving assessment of neuropsychologically-impaired subjects, and in many cases these may be the only practical indication of driving ability (Wilson & Smith, 1983). Comparison of these measures is problematic for many reasons. For example, informal driving assessments are typically conducted by an occupational therapist. Contrast this with the different skill base of the experienced traffic officer used in the present study. Each professional has their own equally valid criteria for judgement of performance.

Correlation between the practical driving measures

Table 9.4 shows Pearson product-moment correlation coefficients for the New Road Test, the Advanced Driver Assessment and the informal driver rating. These coefficients were calculated for all groups combined. Importantly, the moderately strong correlation shown between the frequency of Advanced Driving Assessment errors and the New Road total patterns provides some evidence for concurrent validity. This relationship implies that both tests utilise similar measurement criteria despite differences in how New Road total patterns were categorised, or other systematic biases, such as the conditions under which the driving tests were administered. Thus, the weaker relationship shown between Advanced Driving Assessment patterns and the New Road Total patterns may be contributed to by introducing another schemata for grouping errors into patterns.

Moderate to strong correlations were shown between the informal driver rating and both practical driving tests. Correlations were higher for the Advanced Driver Assessment measures, most probably because the testing officer who made the informal ratings also conducted the Advanced Driver Assessment. Judgements were therefore based on the same driving experience, and similar criteria may have been used.

For the Advanced Driver Assessment there was high internal consistency between errors and patterns. This correlation is expected given that these two scores are inherently linked. In the New Road test, the relationship of subtest errors (search, speed and direction) to the overall pattern score was more complex. Here, an error pattern was scored on the basis of a minimum one error, from either search, speed or direction categories, within a segment of the driving test course. Hence, a proportional relationship of errors is not necessarily conveyed by a pattern score within a defined driving segment. Table 9.4 shows that the highest correlations were found between direction errors and total errors.

Table 9.4

Pearson product-moment correlation coefficients for the practical driving measures[1]

	NRT patterns.	Search	Speed	Direction	ADA patterns	ADA errors	Informal ratings
NRT patterns	1.00	.29	.37*	.50**	.38*	.51***	.49**
Search		1.00	-.06	0	-.08	-.03	0
Speed			1.00	.23	.17	.29	.32
Direction				1.00	-.07	.12	.15
ADA patterns.					1.00	.83***	.59***
ADA errors						1.00	.72***
Informal ratings							1.00

*p< .05 **p<.01 ***p<.001

[1] New Road Test total patterns (NRT patterns); Search, Speed and Direction (subtests of the New Road Test); Advanced Driver Assessment patterns (ADA patterns); Advanced Driver Assessment errors (ADA errors); Informal ratings (driver instructor ratings).

Overview of the practical driving measures

The New Road Test and the Advanced Driver Assessment findings have some interesting features, many of which are common to both practical measures. First, the professional drivers had a higher driving standard compared to the neuropsychologically-impaired driver group, as measured by the overall scores of both driving tests. In fact, professional drivers performed significantly better than all three groups on the the Advanced Driver Assessment and the informal driver rating. These results suggest that criteria for a professional driving standard are not being met by the other sample groups.

Second, there are no significant quantitative differences in total errors between the neuropsychologically-impaired subjects and the control group. However, there are qualitative differences in the breakdown of errors made. These results are consistent with van Zomeren et al. (1988) where qualitative information suggested that the type of errors made by neuropsychologically-impaired subjects was a greater threat to traffic safety. In this previous study, differences between actual driving test scores were statistically non significant.

For the neuropsychologically-impaired subjects in the present study, there was a trend toward more errors relating to direction and tracking on the road, as well as judgement and decision making. The latter occur particularly in situations of hazard identification, which require an immediate and often modified response. Vigilance and crucial timing of responses are often compromised through neurological damage (van Zomeren et al., 1987). Previous studies have shown that tracking tasks are adversely affected (Gianutsos, 1994; Gouvier et al., 1989; van Wolffelaar et al., 1987). Neuropsychological tests have shown that directional sense, as part of general orientation, is also likely to be impaired (Brooke et al., 1992; Simms, 1989).

Differences between neuropsychologically-impaired drivers and professional drivers on both practical driving measures could also be explained by motivational factors. Professional drivers may be motivated to perform well to uphold a high occupational standard. Neuropsychologically-impaired drivers have been assured that they are able to return to driving and thus performance factors may be less important. The lack of significant results for the neuropsychologically-impaired presenters may be accounted for by the fact that these subjects are under the pressure of an awaited assessment decision and are thus more inclined to perform to their best level. Control drivers, on the other hand, probably have the least motivation to perform to any standard.

SELF REPORT EVALUATION

Driver semantic differential scales

A version of McCormick et al.'s (1986) comparative measure of driver ability was administered to all subjects. Both neuropsychologically-impaired groups received two versions of the scales, administered suitably apart and designed so they could rate their driving both pre- (retrospectively) and post-neurological damage. Results found that the values assigned to driver self-ratings were comparable across groups. However, within groups comparisons were affected by how subjects rated an average and a very good driver, and gave a more meaningful impression of how subjects viewed themselves relative to other drivers (see Appendix P for mean data). Here, overall mean results indicated that professional drivers and both neuropsychologically-impaired groups rated themselves within the league of a very good driver. This finding differed in pre- versus post-injury ratings of the neuropsychologically-impaired subjects, where predominantly lower self-appraisals were given on some dimensions. Interestingly, mean results showed that control drivers were more modest in their ratings and tended to judge themselves better than average but below a very good driver.

Between group comparison of driver self-ratings. Group comparison of ratings for "me as a driver" found statistically non significant group differences between professional drivers, control drivers and the retrospective (pre-neurological damage) reports of both neuropsychologically-impaired groups on the seven semantic differential scales, irrespective of the driver dimensions being rated. Between group comparisons using neuropsychologically-impaired groups' current status (post-injury) ratings found non-significant group differences on six of the scales. However, group differences on the scale dimension inconsiderate - considerate were significant, $F(3, 36) = 2.87$, $p = .05$. Here, neuropsychologically-impaired presenters rated themselves less considerate, while neuropsychologically-impaired drivers rated themselves more considerate, than all other groups. This result is interesting as it does not conform with the expectation that subjects in the neuropsychologically-impaired presenters group may have wanted to appear favourably in view of an impending assessment for driving again. Although not highly significant, it is possible that this only difference in ratings of the two neuropsychologically-impaired groups is due to some third factor, such as adjustment to neurological damage, and the ability to compensate for possible driving disability. Mean ratings for "me as a driver" for the four groups are presented with the other perceived driver ratings in Appendix P.

Within group comparison of self, average, and very good driver ratings. Data was analysed within each of the four groups to investigate how subjects rated themselves ("me as a driver") against (1) "an average driver", and (2) "a very good driver". Subjects were also asked to rate what an hypothetical average and very good driver would score. Individual group *t*-tests were conducted for paired samples on the seven bipolar semantic differential scales. **Differences between actual mean scores and the corresponding *t-values* are shown on Tables 9.5 - 9.8.** Positive values denote a higher rating difference compared to either an average or a very good driver. Negative values denote a lower rating compared to either an average or a very good driver.

Professional drivers rated themselves significantly more predictable, reliable, safe, and responsible than "an average driver" (Table 9.5). They also perceived themselves no different to "a very good driver" on all of the seven scale dimensions. All ratings for "a very good driver" were significantly higher than those for "an average driver".

Table 9.5

Differences between driver concepts rated on semantic differential scales for professional drivers[1]

	DIFFERENCES IN MEANS BETWEEN DRIVER CONCEPT RATINGS.					
	Very good minus an **average** driver rating		**Self** minus an **average** driver rating		**Self** minus a **very good** driver rating	
SCALES	Difference in means	t-value	Difference in means	t-value	Difference in means	t-value
Wise	+2.5	5.24***	+2.0	3.87	-0.5	1.34
Predictable	+1.8	3.38***	+2.0	5.07***	-0.4	1.08
Reliable	+2.2	5.28***	+0.8	3.50**	-0.8	2.23
Considerate	+2.5	7.32***	+0.9	3.36	-0.9	1.87
Safe	+2.5	6.23***	+0.6	3.94**	-0.6	1.62
Relaxed	+1.5.	3.50**	+0.1	1.33	-0.1	0.29
Responsible	+2.5	6.23***	+0.4	3.99**	-0.4	1.50

*** p<.001 ** p<.01

1 Positive and negative differences in means represent higher and lower comparative ratings respectively

Table 9.6 shows that self-ratings for control drivers were significantly higher than "an average driver" for wise, reliable, considerate, safe, and responsible driving dimensions. However, control drivers' self-perceptions on these dimensions did reach a level "a very good driver". Interestingly, relaxation was not a distinctive variable for control drivers, as this dimension failed to differentiate an average from a very good driver.

Table 9.6

Differences between driver concepts rated on semantic differential scales for control drivers.[1]

	DIFFERENCES IN MEANS BETWEEN DRIVER CONCEPT RATINGS					
	Very good minus an **average** driver rating		**Self** minus an **average** driver rating		**Self** minus a **very good** driver rating	
SCALES	Difference in means	t-value	Difference in means	t-value	Difference in means	t-value
Wise	+2.3	7.00***	+0.6	2.83*	-1.7	5.77***
Predictable	+2.1	8.10***	+0.9	2.23	-1.2	3.77**
Reliable	+1.7	4.47**	+1.0	2.68*	-0.7	2.31*
Considerate	+2.6	8.69***	+1.5	4.91***	-1.1	5.55***
Safe	+2.6	7.56***	+1.3	5.50***	-1.3	5.66***
Relaxed	+1.0	1.60	+0.5	0.74	-0.5	2.29
Responsible	+2.6	16.00***	+1.5	5.29***	-1.1	3.59**

***$p < .001$ **$p < .01$ *$p < .05$

[1] Positive and negative differences in means represent higher and lower comparative ratings respectively

Subjects in the neuropsychologically-impaired presenters group rated themselves more considerate, relaxed and responsible than "an average driver" both before (retrospective) and after their head injury (Table 9.7). While pre-injury ratings for the predicability scale were higher than "an average driver" this dropped to a non-significant level post-injury. The driver dimensions wise, safe and reliable were rated with some variability and did not distinguish neuropsychologically-impaired presenters from perceptions of either an average or a very good driver. However, post-injury ratings for driver safety dropped, and became significantly different from the level of a very good driver. With the exception of the reliability scale, perceived pre- and post-injury ratings for "a very good driver" were significantly higher than those for "an average driver".

Table 9.7

Differences between driver concepts rated on semantic differential scales for neuropsychologically-impaired presenters: pre- and post-neurological impairment.[1]

	DIFFERENCES IN MEANS BETWEEN DRIVER CONCEPT RATINGS					
	Very good minus an **average** driver rating		**Self** minus an **average** driver rating		**Self** minus a **very good** driver rating	
SCALES	Difference in means	t-value	Difference in means	t-value	Difference in means	t-value
Wise						
Pre	+1.4	2.73*	+1.3	2.22	-0.5	1.89
Post	+1.7	4.44**	+0.7	1.79	-1.0	2.27
Predictable						
Pre	+1.6	2.89*	+1.2	2.35*	-0.4	1.32
Post	+1.9	3.51**	+0.6	1.31	-0.8	1.67
Reliable						
Pre	+1.4	1.44	+0.5	1.51	-0.5	1.05
Post	+1.5	1.00*	+0.6	0.85	-0.9	2.29
Considerate						
Pre	+2.2	4.06**	+1.8	3.25*	-0.4	1.00
Post	+2.0	3.62**	+1.1	2.40*	-0.7	1.49
Safe						
Pre	+2.3	3.06*	+1.1	2.17	-0.3	0.89
Post	+1.7	3.11*	+1.0	1.60	-0.7	3.50**
Relaxed						
Pre	+2.2	3.16*	+1.5	3.35**	-0.2	0.37
Post	+2.8	6.01***	+1.2	3.89*	-1.0	2.27
Responsible						
Pre	+2.5	3.73**	+1.6	2.58*	-0.6	1.64
Post	+1.5	3.78**	+1.1	2.63*	-0.4	1.51

***p< .001 **p< .01 *p< 05

[1]Positive and negative differences in means represent higher and lower comparative ratings respectively

Pre- and post-injury ratings for neuropsychologically-impaired drivers were significantly higher than "an average driver" on six scale dimensions: wiseness, reliability consideration, safety, relaxation and responsibility (Table 9.8). Of these, pre- and post-injury ratings for reliability, consideration and responsibility were comparable to a very good driver. Importantly, some other dimensions showed a change in the post-injury period, with subjects' perceiving themselves wiser and safer compared to ratings which were significantly lower than a very good driver in the pre-injury period. Post-injury, neuropsychologically-impaired drivers also shifted to being more predictable than average, but still significantly lower than a very good driver. All pre- and post-ratings for "a very good driver" were significantly higher than those for "an average driver".

Qualitative descriptions of an average and a very good driver. Subjects were asked to give qualitative descriptions of both an average and very good driver at the conclusion of the comparative driver rating exercise. In each case, clearly different common themes emerged, and these themes were consistently described across subject groups. An average driver was described with some variability in terms of consideration to others on the road. Most perceived "an average driver" to be mid twenties or older, who has had a driver's licence for a few years. While average drivers have a basic knowledge, they were also seen to have limited skills with which to approach difficult driving situations. Lack of experience and a tendency to drive too fast were problems for the average driver. Qualitative descriptions of "a very good driver" emphasised consideration for other drivers and full attention to the task at hand. Very good drivers are experienced and have had their licence for a minimum of four years. These drivers are aware of their capabilities and and drive defensively, so they observe road rules and are in control of their vehicle at all times. Several descriptions included good driver reaction times. Very good drivers were also described as alert, predictable, careful and safe.

Table 9.8

Differences between driver concepts rated on semantic differential scales for neuropsychologically-impaired drivers: pre- and post-neurological impairment.[1]

	DIFFERENCES IN MEANS BETWEEN DRIVER CONCEPT RATINGS					
	Very good minus an **average** driver rating		**Self** minus an **average** driver rating		**Self** minus a **very good** driver rating	
SCALES	Difference in means	t-value	Difference in means	t-value	Difference in means	t-value
Wise						
Pre	+2.3	4.45^{*}	+1.4	2.41^{*}	-0.9	2.59^{*}
Post	+2.4	9.00^{***}	+1.6	4.31^{**}	-0.8	2.06
Predictable						
Pre	+2.1	3.28^{**}	+1.2	1.62	-0.9	3.86^{**}
Post	+2.9	5.75^{***}	+1.7	3.60^{**}	-1.2	3.34^{**}
Reliable						
Pre	+2.8	5.72^{***}	+2.2	3.93^{**}	-0.6	2.25
Post	+2.5	4.61^{***}	+2.0	3.00^{*}	-0.5	1.25
Considerate						
Pre	+2.8	5.47^{***}	+2.4	4.00^{**}	-0.4	1.18
Post	+2.8	6.00^{***}	+3.4	6.09^{***}	-0.2	0.69
Safe						
Pre	+2.2	4.30^{**}	+1.5	2.50^{*}	-0.9	2.38^{*}
Post	+2.7	4.67^{***}	+2.3	4.61^{***}	-0.2	0.69
Relaxed						
Pre	+2.2	4.49^{**}	+1.5	2.76^{*}	-0.8	2.75^{*}
Post	+2.6	5.75^{***}	+2.6	2.33^{*}	-1.2	2.88^{*}
Responsible						
Pre	+2.3	4.87^{***}	+1.7	3.29^{**}	-0.6	2.25
Post	+2.6	4.80^{***}	+2.6	5.75^{***}	0	0

$^{***}p<.001$ $^{**}p<.01$ $p<.05$

[1] Positive and negative differences in means represent higher and lower comparative ratings respectively

Group differences in comparative driver ratings. Self-ratings for the professional drivers and both neuropsychologically-impaired groups were comparable with "a very good driver". By contrast, control drivers rated themselves comparable to, or higher than, "an average driver" but not as high as "a very good driver". Taken together, these comparative driver ratings suggest varied group explanations for driver self-perception, and is interesting in light of a previous study conducted within New Zealand (McCormick et al., 1986). Here, self-ratings of New Zealand drivers were inflated (see Appendix B), but still more conservative than American driver studies. The self-rating by the control driver group in the present study showed a similar trend, as expected of a representative control group.

There are a number of possible explanations for the different comparative driver ratings across the four sample groups. As suggested from previous research, the subjects in the present study fall within an age range where self-ratings may be over estimated. An inflated self-perception may influence driving style (Guppy, 1993) and may affect driver confidence (Cutler et al., 1993). Positive self-bias in driver ratings has been found to reduce with driving experience. However, in the case of professional drivers, high confidence levels and ongoing training requirements are likely to weaken this effect (McKenna et al., 1991). The practical driving results for the professional driver group suggests that self-ratings were probably quite accurate.

Previous research has not used comparative methods for rating drivers who have sustained neurological damage. The present study shows that this method may be a useful assessment tool. For both neuropsychologically-impaired groups, a comparison of driver self-ratings with the practical driving data suggests that these subjects were probably least accurate in their judgements. These results are consistent with Hartje et al. (1991) who found that neuropsychologically-impaired subjects made poor judgements, which tended to reflect a strong desire to drive, more than their actual driving ability. Many ratings both pre-(retrospective) and post-neurological damage showed that subjects compared themselves with "a very good driver". Measured against actual driving criteria, these differences in real versus perceived driving ability suggest a genuine lack of insight, a common effect of head injury (Lezak, 1995). Alternatively, these results could be a function of demand characteristics in a situation where neuropsychologically-impaired subjects, in particular, are compelled to present a good assessment image.

It is interesting that retrospective pre-injury ratings on most scale dimensions were equated with "a very good driver". No concrete evidence can be given to substantiate the accuracy of these claims, although it is worth noting that most of these subjects actually sustained their initial head injuries through motor vehicle accidents. Further, matched control drivers did not compare themselves as highly. It is therefore possible that over-inflated driver self-ratings may be a factor in identifying a more at risk driver group.

Comparison between neuropsychologically-impaired subjects pre- and post-injury ratings on the driver scales. A comparison of pre- and post-injury ratings showed interesting differences between the two neuropsychologically-impaired groups. Overall, neuropsychologically-impaired presenters were much more variable in their ratings (Table 9.7). However, this group did show a significant drop in post-injury ratings of driver safety and predicability. Interestingly, these results do not support a positive self-bias that could be expected in subjects seeking approval to drive again. Instead, these subjects may be showing an awareness of the general effects of head-injury on driving. This awareness may be a function of the little post-injury driving experience compared to the neuropsychologically-impaired driver group.

Neuropsychologically-impaired drivers considered they were wiser, safer and more predictable drivers in the post-injury period (Table 9.8). These improved ratings suggest that these subjects may be, or believe they are, adjusting their driving to compensate for any perceived impairments.

Previous studies have implicated accurate self-judgements as important for neuropsychologically-impaired driver assessment. In particular, an awareness of one's limitations and a willingness to use compensatory strategies may be critical factors for a successful assessment outcome (Hartje et al., 1991; Priddy et al., 1990; van Zomeren et al., 1987). The present results suggest that neuropsychologically-impaired subjects have limited insight into the effects of their head injury on driving, although they still compare themselves favourably with at least an average driver. Different results for the two neuropsychologically-impaired groups suggests that the length of time since driving may contribute to driver perceptions.

Chapter Ten

NEUROPSYCHOLOGICAL ASSESSMENT: RESULTS AND DISCUSSION

This Chapter presents the results and specific discussion of the neuropsychological assessment measures used in the present study. Neurological outcome measures were reported for the two neuropsychologically-impaired groups while the neuropsychological tests were administered to all subjects. In the analysis of results, significant F values were followed up using Tukey's Honestly Significant Difference (HSD) Test to determine specific group differences. An alpha level of .05 was used for all statistical tests. The relationship between the neuropsychological assessment measures and actual driving outcome is explored through multiple regression analyses in Chapter Eleven. Theoretical, methodological, and practical implications of the results are discussed in Chapter Twelve.

NEUROLOGIC OUTCOME MEASURES

Time since injury

The mean time since injury for the two neuropsychologically-impaired groups are shown in Table 10.1. Group differences on this outcome measure were statistically non-significant. Thus, division of subjects into neuropsychologically-impaired presenters (presenting for a driving assessment), and neuropsychologically-impaired drivers (those already permitted to drive) groups found that time since injury had little bearing on when driving was resumed. These results appear interesting in light of previous studies, where specific time since injury criteria is used in the selection of neuropsychologically-impaired driver subjects (e.g. Katz et al., 1990; van Wolffelaar et al., 1988).

Table 10.1.

Time since injury.

	TIME SINCE INJURY	
	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Mean duration	2 years 8 months	4 years, 4 months
Standard deviation	2.91	4.20
Median	1 year, 7 months	2 years, 9 months
Range	5 months - 10 years	11 months - 15 years

Overall, the wide range of post-injury periods reported in the present study suggested that time since injury was a very individual factor in the return to driving. In the literature it is shown that individual factors largely contribute to difficulties predicting cognitive outcome at different periods following neurological damage, although the potential for improvement over time is well documented (Cope, 1990; Stein et al., 1993).

Perceived changes.

Subjects in both neuropsychologically-impaired groups were asked to comment freely on changes brought about by neuropsychological impairment. All of these subjects reported at least one perceived change which clearly fell into categories of cognitive, physical, or psychosocial consequences of head injury (see Table 10.2). The type of changes reported are consistent with the neuropsychological literature (Lezak, 1995; Ponsford & Kinsella, 1992; Tate et al., 1991; Walsh, 1994).

Table 10.2

Perceived changes since neurological damage

	FREQUENCY	
Perceived changes	Neuropsychologically-impaired presenters	Neuropsychologically-impaired drivers
General cognitive function	3	4
memory	3	3
concentration	1	2
reaction time	1	1
General physical function	3	3
eyesight	2	0
tiredness	1	3
sleeping problems	1	0
Psychosocial adjustment		
difficulty with social relations	0	3
anger problems	0	2
impatience	0	1
lack of self confidence	1	1

Interestingly, the neuropsychologically-impaired drivers mentioned a number of perceived changes relating to psychosocial adjustment which the neuropsychologically-impaired presenters did not. It is possible that the two groups were at different phases of psychosocial adjustment following head injury, which may be linked to the different stages of return to driving. Consent to drive again symbolises part of a subject's reintegration into the community (Jellinek et al., 1982; Eisenhandler, 1990). At such point in a subject's rehabilitation, difficulties with social relations, lack of self confidence, and overriding emotion may become important issues (see Table 10.2). Alternatively, subjects who have been given permission to drive may feel more self-assured, and less constrained about revealing information concerning adjustment to the effects of neurological damage.

Subjects were also asked to comment on consequences of the perceived changes brought about by neuropsychological impairment. A similar pattern of response was given by subjects in both neuropsychologically-impaired groups, which was consistent with the effects of moderate to severe head-injury (Brooks, 1984; McLean et al., 1993). In order of reported frequency, these effects included inability to be involved in former sports and other physical activities, inability to hold down a job, difficulties remembering, dealing with pressure, following instructions and concentrating on a task, and participating in a normal family life. Interestingly, the issue of awaiting formal approval for driving was a highly important for neuropsychologically-impaired presenters. Therefore, subjects may be inclined to make every effort to present themselves positively in the interim period.

Symptom checklist

All subjects completed a structured checklist, developed from a composite of the Head Injury Symptom Checklist (Dikmen et al., 1986a, 1986b) and reports from the literature. This checklist included a range of common symptoms and complaints, which are not necessarily specific to neurological damage, but may have implications for driving (e.g. frequent tiredness, eyesight problems, feeling depressed).

Table 10.3 shows the mean data for number of symptoms checked. Frequency data for both neuropsychologically-impaired groups reflected a wide range. Data for the control drivers was affected by one subject who checked 14 symptoms compared to all other subjects who checked less than four. This atypical subject experienced a number of symptoms due to a chronic medical condition.

Table 10.3.

Mean data for number of symptoms checked.

	NUMBER OF SYMPTOMS			
	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Mean	1.5	2.6	10.4	13.4
Standard deviation	1.58	4.17	7.29	7.32
Range	0-4	0-14	2-24	5-26

Overall, group differences for total reported symptoms were highly significant, $F(3,36) = 10.75$, $p = .00$. More symptoms were checked by both neuropsychologically-impaired groups. This result is consistent with Dikmen et al. (1986b), who found that neuropsychologically-impaired subjects reported significantly more symptoms in total, despite a small number of symptoms being shared with controls.

Raw data for frequency of symptoms checked is available in Appendix Q . Here, both neuropsychologically-impaired groups indicated the same physical and cognitive difficulties that some subjects had earlier identified when questioned about perceived changes. Using the symptom checklist as a prompt, however, there was a higher frequency of response regarding physical effects, such as tiredness and eyesight problems, and cognitive effects such as forgetfulness, being easily distracted, difficulty remembering, concentrating and learning new things. These symptoms are highly similar to those endorsed by neuropsychologically-impaired driver subjects in van Zomeren et al's (1988) study. In this, and the present study, use of a checklist approach was found to be an efficient means of eliciting subject information and, importantly, gaining insight into subject's perceived effects of neurological damage.

NEUROPSYCHOLOGICAL TESTS

Mini Mental State Examination (MMSE)

As a general screen, the Mini Mental State Examination (MMSE) is an integral part of many comprehensive neuropsychological test evaluations, and is valued for testing cognitive functions simply and quickly (Lezak, 1995). Group results for the Mini Mental State Examination are shown in Table 10.4.

Table 10.4.

Group results for the Mini Mental State Examination.

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Total Score	28.7 (1.42)	28.7 (1.16)	26.1 (1.60)	27.0 (2.71)
Subtests				
orientation	9.7 (0.48)	10 (0)	9.4 (1.07)	9.7 (0.48)
registration	3 (0)	3 (0)	3 (0)	3 (0)
attention	4.4 (1.07)	4.3 (1.25)	3.6 (1.26)	3.9 (1.79)
recall	2.7 (0.48)	2.7 (0.48)	2.4 (0.52)	2.1 (0.88)
language	8.9 (0.32)	8.7 (0.48)	8.1 (0.99)	8.3 (1.34)

Group differences for the MMSE Total Score were significant, $F(3,36) = 5.07$, $p = .01$. Here, neuropsychologically-impaired presenters scored lower than both the professional and control driver groups. Within the neuropsychologically-impaired presenters group, it was clear that the overall group mean was reduced by the poorer scores of a small number of subjects. Group means at the subtest level supported the trend toward lower scores for both neuropsychologically-impaired groups. However, no group differences for the orientation, registration, attention, recall, and language subtests were significant at the .05 level. On this basis, assessment decisions would need to incorporate more comprehensive testing of these separate abilities (Tombaugh & McIntyre, 1992; Rutman & Silberfeld, 1992).

All subject's total scores on the Mini Mental State Examination were comparable with standardised adult norms for the general population (Lezak, 1995, Tombaugh & McIntyre, 1992). Consequently, mean total scores were higher than previously reported for neuropsychologically-impaired drivers. However, these previous studies involved some subjects who were generally older or showed symptoms of dementia, which are clearly visible through MMSE scores (Carr et al., 1990; Lucas-Blaustein et al., 1988; Retchin et al., 1988).

Benton Visual Retention Test - Revised (BVRT-R)

The Benton Visual Retention Test-Revised (BVRT-R) is extensively used and generally sensitive to the effects of neurological damage on perception, memory and constructive components of the visual system (Lezak, 1995; Marsh & Hirch, 1982; Wellman, 1987). Results for the Benton Visual Retention Test-Revised are shown in Table 10.5. Here, there were non significant group differences on both total correct responses and total errors. Group differences remained at a non significant level when total number of errors were subdivided by error type. Notably, however, subjects in the neuropsychologically-impaired presenters group tended to show an increased number of 'right' peripheral errors which is consistent with spatial neglect through right hemispheric damage. Whether site of lesion is a significant determinant of performance has been extensively debated, however, recent literature supports a right-left differential in defective copying of BVRT-R designs, with subjects who have right hemisphere damage tending to score more errors (Lezak, 1995). On the other hand, performance of subjects with left hemisphere damage tends to be more comparable with controls. For the neuropsychologically-impaired groups in the present study, some of the variability in individual scores may be attributed to differences in laterality of lesion.

Table 10.5

Group results for the Benton Visual Retention Test.

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Total correct	8.3 (1.25)	8.1 (1.10)	7.2 (1.81)	7.1 (1.79)
Total errors	2.3 (1.70)	2.6 (1.60)	3.2 (2.25)	3.8 (3.08)
Error type				
Omission	0.2 (0.42)	0	0.3 (0.68)	0.5 (0.85)
Distortion	1.1 (1.20)	1.5 (1.30)	1.7 (0.95)	1.2 (0.92)
Perseveration	0.3 (0.48)	0.4 (1.30)	0	0.5 (0.85)
Rotation	0.6 (1.08)	0.5 (0.50)	0.9 (1.29)	0.8 (1.03)
Misplacement	0.1 (0.32)	0.2 (0.40)	0.2 (0.42)	0.7 (1.64)
Size	0	0	0.1 (0.32)	0.1 (0.32)
Left	1.1 (0.28)	1.1 (1.00)	1.2 (0.63)	1.0 (0.82)
Right	1.1 (1.00)	1.4 (0.84)	1.3 (1.25)	2.4 (1.96)

Interestingly, comparison with test norms indicated that mean total errors for each of the four groups were more characteristic of individuals in the low-average range (Benton, 1974; Lezak, 1995). In all groups, there were three or four subjects who made more than two errors, which is consistent with this level of performance. In both neuropsychologically-impaired groups there were two subjects who would be considered borderline.

Mean error scores for the present neuropsychologically-impaired groups are consistent with those found for drivers a similar research sample (Priddy et al., 1990). In this previous study, the BVRT-R successfully discriminated head-injured subjects who continued to drive from those who were no longer driving.

Standardised Road Map Test of Direction Sense

While there is a lack of normative data for completion times on the Standardised Road Map Test of Direction Sense, an indication of topographical orientation deficit is suggested by a cutoff score of ten errors (Lezak, 1995). In a wide application of the Standardised Road Map Test of Direction Sense, mean scores in the vicinity of fourteen errors were found for various neuropsychologically-impaired driver samples (Simms, 1986, 1987, 1989). Mean data for the Standardised Road Map Test of Direction Sense across the four subject groups are shown in Table 10.6.

Table 10.6

Group Results for the Standardised Road Map Test of Direction Sense

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Total errors	2.0 (2.90)	0.8 (1.00)	5.7 (5.50)	2.7 (4.70)
Time (seconds)	65.7 (19.30)	82.6 (25.60)	133.4 (77.80)	95.6 (32.80)

Group differences were bordering on significant for total errors, $F(3,36) = 2.83$, $p = .05$, with the neuropsychologically-impaired presenters group showing a higher error rate than controls. Statistically significant differences were also found for completion time, $F(3, 36) = 4.07$, $p = .0138$. Here, neuropsychologically-impaired presenters had slower completion times than the professional drivers. Total errors mean scores for all groups fell short of the cutoff of ten errors indicated by Lezak (1995). For the professional drivers, the mean error score was affected by one subject who made nine errors. Three individual scores within the neuropsychologically-impaired presenters group, and one of the neuropsychologically-impaired driver scores, were in excess of ten errors. Nevertheless, the mean total errors for the neuropsychologically-impaired subjects was considerably lower than the fourteen errors obtained in previous studies (Simms, 1986, 1987, 1989), suggesting a lower level of impairment in the present sample.

Southern California Figure Ground Test

The Southern California Figure Ground Test identifies perceptual deficits, particularly visual construction and recognition within the context of a figure ground relationship. Group results for the Southern Figure Ground Test (SCFG) are shown in Table 10.7.

Table 10.7

Group results for the Southern Figure Ground Test (SCFG)

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Total correct	30.1 (9.29)	26.8 (8.63)	21.9 (9.36)	25.1 (9.36)

There were statistically non significant differences between groups for total number of correct responses. Interestingly, however, mean scores for all groups were in the region of the cutoff score of 30.2 correct responses, according to available adult norms (Bieliauskas et al., 1988). This normative data originated from a university based sample, which may explain the low scores of many subjects in the present study. A breakdown of the mean scores indicated that six subjects in the professional driver group fell below the cutoff score, along with nine subjects in the neuropsychologically-impaired presenters group and eight each of the neuropsychologically-impaired and control drivers.

Compared with previous driver research there was less overall contrast between the scores of neuropsychologically-impaired subjects and controls. Mean scores in the present samples were not as low as those recorded for a sample of neuropsychologically-impaired drivers (Sivak et al., 1988). In addition, mean scores for the professional and control driver groups were respectively three and eight points lower than controls in the Sivak et al. (1988) study.

Stroop Colour Word Test

A comparison of scores on the Stroop Colour Word Test can give insight into cognitive flexibility, particularly the ability to adjust to new task demands, as indicated by the magnitude of the interference effect (difference score). This effect is apparent regardless of whether number of words correct, or completion time methods are used for scoring the Stroop Colour Word Test (MacLeod, 1991). The present study scored the test on the basis of number of correct responses over 45 second trials for each condition. Imposing this time limit is advantageous with neuropsychologically-impaired samples as it curbs the tendency for frustration and non-compliance for subjects who find the task exceedingly difficult. Using this method, a smaller difference score implies increased susceptibility to the interference effect, as shown by both neuropsychologically-impaired groups in Table 10.8. Evidence of a stronger interference effect is highly characteristic of subjects with neurological damage, particularly to the frontal lobes and with left hemisphere damage (Golden, 1978; Lezak, 1995).

Table 10.8

Group results for the Stroop Test.

TEST RESULTS (words correct over 45 second trials)	MEAN (STANDARD DEVIATION) Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Word Score	94.1 (12.94)	94.2 (16.72)	82.1 (25.59)	85.7 (26.20)
Colour Score	74.5 (9.19)	70.1 (11.92)	56.3 (19.44)	68.2 (22.78)
Colour-Word Score	40.5 (6.50)	37.5 (5.99)	35.2 (10.88)	40.0 (16.16)
Difference Score*	34 0 (6.00)	32.6 (11.30)	21.1 (10.50)	28.2 (14.94)

* Many approaches have been proposed for calculation of the interference effect, but the most common and straightforward is a simple difference score (colour-word score - colour score) used here (MacLeod, 1991).

Despite the above trend, differences between groups for the colour, word, colour-word and interference scores for the present study were statistically non significant. For all four groups, mean values for word, colour, and colour-word scores were low compared with other studies of neuropsychologically intact subjects, which rely on the word count method for scoring the test (e.g. Connor et al., 1988; Wolff et al., 1989). Based on previous research, explanations for low-average scores may encompass motivational factors, level of cautiousness, reading fluency and verbal intelligence (Rush et al., 1990).

Trailmaking Test

The Trailmaking Test is well known for its sensitivity to the effects of neurological damage, particularly as it relates to the ability to shift between corresponding mental sets. Scored as completion time, the measure also encompasses rapid visual motor speed. General slowness on both trials is recognised as a sign of likely neurological damage (Lezak, 1995). Within this context, a noticeably slower completion time for Trails B may be indicative of difficulties with visuospatial sequencing and dealing with more than one stimulus at a time. Hence, it is accepted that while both Trails A and B discriminate between neuropsychologically-impaired subjects and controls, Trails B is more discriminating (Reitan, 1986).

Table 10.9

Group results for the Trailmaking Test.

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Trails A (seconds)	25.8 (11.8)	26.2 (7.9)	36.9 (17.4)	32.6 (18.1)
Trails B (seconds)	73.1 (25.8)	58.5 (14.3)	90.7 (36.3)	93.7 (61.6)
Difference between Trails A and Trails B	47.3 (23.7)	32.3 (13.8)	53.8 (25.8)	61.1 (51.6)

For the present study, group differences in completion times for both Trails A and Trails B (see Table 10.9) were statistically non significant. A wide range of individual completion times for both Trails A and B was characteristic of all groups. Notably, however, the Trails B group mean for neuropsychologically-impaired drivers was just above Reitan's (1986) proposed cutoff score of 91-92 seconds. For the original standardisation sample this cutoff had high diagnostic prediction and was estimated to correctly classify subjects with neurological damage 85% of the time. A breakdown of individual subject scores for the present study, however, shows that the neuropsychologically-impaired drivers group mean was affected by two subjects whose completion times were well in excess of Reitan's proposed cutoff. By comparison, half of the subjects in the neuropsychologically-impaired presenters group scored above the cutoff scores proposed for both Trails A and B. Interestingly, also, were the individual scores of four subjects in the professional drivers group, who exceeded Reitan's (1986) Trails B cutoff score.

Overall, the trend toward larger mean differences in completion times between Trails A and B for both neuropsychologically-impaired groups is consistent with the literature (Lezak, 1995). The present results are also comparable with previous driver assessment studies, in which neuropsychologically-impaired subjects were found to be significantly slower than controls for both Trails A (39.3 and 35.4 seconds respectively) and Trails B (94.0 and 74.9 seconds respectively) (van Zomeren et al, 1988).

Reaction time

Mean reaction time measures (seconds) for the present study are summarised in Table 10.10. Individual scores were calculated as mean time (seconds) separately over ten trials each for preferred hand, non-preferred hand, preferred hand - preferred foot, non-preferred hand - preferred foot, and preferred foot alone conditions. Mean reaction times for the professional and control driver groups fell within one standard deviation of age adjusted means based on male samples from a variety of backgrounds. Reaction times for the neuropsychologically-impaired groups fell within two or three standard deviations of this normal range.

Numerous previous studies have shown that various measures of choice and complex reaction time are statistically and practically significant factors in driving measurement (Galski et al., 1993; Hartje et al., 1991; Madeley et al., 1990; van Wolffelaar et al., 1988). In these studies, significantly slower reaction times have been recorded for various neuropsychologically-impaired groups. Similar findings were found in the present study. Here, significant main effects were found for two of the reaction time measures: non-preferred hand, and non-preferred hand - preferred foot. For non-preferred hand, neuropsychologically-impaired drivers had slower choice reaction times than professional drivers, $F(3, 35) = 4.48$, $p = .01$. This choice reaction time task involved responding to light cues randomly presented from all eight stimuli. Neuropsychologically-impaired drivers were also slower than professional drivers over the non-preferred hand - preferred foot condition, $F(3, 35) = 3.13$, $p = .04$. This condition was a measure of complex reaction time, in which subjects responded by hand to lights three , four and six, and by compressing a foot pedal in response to light five.

Table 10.10

Group results for reaction time measures.

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	Professional drivers	Control drivers	Neuropsychologically impaired presenters	Neuropsychologically impaired drivers
Preferred hand	0.569 (0.07)	0.632 (0.07)	0.674 (0.15)	0.680 (0.10)
Non-Preferred hand	0.568 (0.06)	0.641 (0.08)	0.662 (0.10)*	0.705 (0.10)
Preferred hand-Preferred foot	0.706 (0.10)	0.809 (0.13)	0.854 (0.21)	0.789 (0.12)
Non-Preferred Hand/Preferred foot	0.685 (0.08)	0.815 (0.15)	0.772 (0.11)*	0.832 (0.13)
Preferred foot	0.538 (0.04)	0.598 (0.10)	0.631 (0.11)	0.653 (0.15)

*N=10 observations except neuropsychologically-impaired presenters where N=8 for reaction time scores involving non-preferred hand. The remaining two subjects in this group were right hemiplegic.

The two reaction time conditions which reached statistical significance were those involving the non-preferred hand. These results suggest that the neuropsychologically-impaired driver subjects had difficulty transfering the task to the non-dominant hand, or that there was damage to the contralateral hemisphere. Nine of the ten subjects in this group were right-handed, although two subjects had to prefer their left hand due to mild right hemiplegia. There was insufficient evidence to specifically indicate whether any of the remaining subjects had damage to the right hemisphere. However, trends in the literature show that subjects with right-sided lesions pose a greater threat to driving (Quigley & DeLisa, 1983; van Zomeren et al., 1987). Due to the type of deficit shown, these subjects tend to be disproportionately represented in driving reassessments.

Correlation between the neuropsychological test measures

Pearson product-moment correlations between the neuropsychological test measures were calculated for all groups combined (Table 10.11). Low to moderate correlations were found between many of the neuropsychological test measures.

Within tests, internal consistency naturally tends to be high between subscores which are inherently similar (e.g. reaction time). Further, correlations between tests which are scored on a relative time basis, such as Trails A and B, and the Stroop series, are also relatively high. Many of these tests also reflect common qualities in measurement such as elements of executive function and specific abilities such as rapid visual sequencing, which were the criteria used in their selection for driving assessment. A good example is Trails B, which appears to have concurrent validity with several other measures. Here, moderate to strong correlations were shown with the MMSE, Standardised Road Map Test of Direction Sense errors, reaction time - preferred hand trials, and the three Stroop subscores.

Overview of the neuropsychological assessment measures

Time since head-injury was highly variable within the two neuropsychologically-impaired groups, suggesting this was not a prominent factor affecting when subjects decided to resume driving. Following neuropsychological-impairment, subjects perceived cognitive, physical and psychosocial changes which resulted in a number of lifestyle adjustments. Numerous ongoing symptoms were experienced by all neuropsychologically-impaired subjects.

The neuropsychologically-impaired groups performed typically less well across all neuropsychological test measures, as indicated by mean scores. Nevertheless, mean

Table 10.11. Pearson correlation coefficients between the neuropsychological test measures[#]

	MMSE	BVRT CORR	BVRT TERR	MONEY	MONEY SEC	SCFG	STR WORD	STR COLOR	STRCW	TRAILA	TRAILB	REACT PH	REACT PHPF	REACT PF	REACT NPH	REACT NPHPF
MMSE	1.0	.29	-.16	-.61***	-.38*	.15	.32*	.28	.22	-.37*	-.50***	-.14	-.12	-.12	-.11	.008
BVRTCORR		.0	-.91***	-.35*	-.26	.36	.41**	.36*	.35*	-.35*	-.54***	-.37*	-.32*	-.59***	-.34*	-.35*
BVRTTERR			1.0	.22	.22	-.23	-.29	-.27	-.21	.13	.42**	.38*	.26	.54***	.39*	.29
MONEY				1.0	.58***	-.24	-.25	-.31	-.41**	.54***	.66***	.20	.24	.18	.16	.16
MONEYSEC					1.0	-.29	.01	-.01	-.14	.23	.22	.06	.12	.15	.12	.06
SCFG						1.0	.24	.30	.34*	-.21	-.33*	-.10	-.13	-.26	-.27	-.07
STRWORD							1.0	.78***	.67***	-.42**	.64***	-.13	-.08	-.43**	-.05	-.03
STRCOLOR								1.0	.60***	-.55***	-.64***	-.36*	-.24	-.55***	-.36*	-.31
STRCW									1.0	-.42**	-.61***	-.01	-.11	-.21	.07	-.11
TRAILA										1.0	.63***	.35*	.45**	.30	.36*	.45**
TRAILB											1.0	.25	.15	.45**	.34*	.25
REACTPH												1.0	.82***	.64***	.68***	.60***
REACTPHPF													1.0	.46**	.52***	.64***
REACTPF														1.0	.58***	.58***
REACTNPH															1.0	.55***
REACTNPHPF																1.0

***p <0.05 **p <0.01 ***p < 0.001**

[#] Mini Mental State Examination (MMSE); Benton Visual Retention Test: total correct (BVRTCORR); Benton Visual Retention Test: total errors (BVRTERR); Standardised Road Map of Direction Sense: total errors (MONEY); Standardised Road Map of Direction Sense: time in seconds (MONEYSEC); Southern California Figure Ground Test (SCFG); Stroop Colour Word Test: word score (STRWORD); Stroop Colour Word Test: colour score (STRCOLOR); Stroop Colour Word Test: colour-word score (STRCW); Trailmaking test: Trails A (TRAILA); Trailmaking test: Trails B (TRAILB); Reaction time: preferred hand (REACTPH); Reaction time: preferred hand/preferred foot (REACTPHPF); Reaction time: preferred foot (RTPF); Reaction time: non-preferred hand (REACTNPH); Reaction time: non-preferred hand/preferred foot (REACTNPHPF).

scores for the Mini Mental State Examination (Total Score), the Standardised Road Map Test of Direction Sense, and two of the reaction time conditions, were the only measures to significantly differentiate groups at the .05 alpha level. In each of these cases, the neuropsychologically-impaired presenters group had poorer test scores than the professional and/or control drivers. However, the mean neuropsychological test scores of both neuropsychologically-impaired groups did not necessarily equate with a profile for severe or even moderate neurological damage. Thus, with the exception of a few cases who achieved borderline scores, many of these subjects performed comparably with low to average norms for the general adult population. Considerable variability in performance was also characteristic of all four groups.

Mean scores for the remaining measures - BVRT-R, Southern California Figure Ground Test, Stroop Colour Word Test, and Trails B - implied that all four groups scored within a low-average range. While it is difficult to score highly on neuropsychological tests without intact cerebral functioning, many factors such as motivation, could explain these poor scores. Here, an important consideration is whether any of the subjects, particularly professional and control drivers, had less inclination to perform well. Anecdotal evidence suggested that some tests, particularly the reaction time trials, were viewed as a challenge and were enjoyed by most subjects. Other tests, such as the Stroop Colour Word Test, were generally perceived as difficult and less meaningful, especially by subjects in the professional driver group.

In a neuropsychological assessment, interpretation of individual test components should take into account the overall level of performance. For example, subjects who made three or four errors on the BVRT-R and who typically performed at below average levels on most other intellectual tasks had probably performed as expected. For them, the presence of a borderline number of errors does not necessarily signify a visuographic disability.

Overall, although a detailed neuropsychological test profile for each group is not feasible, a number of common features nevertheless emerged, including slowed performance and difficulty with complex tasks for many neuropsychologically-impaired subjects. These findings were supported by qualitative reports from these subjects who had difficulty in following instructions to some of the more complex tests.

Chapter Eleven

MULTIPLE REGRESSION ANALYSIS

This Chapter presents the results and specific discussion of multiple regression analyses between selected subject variables and practical driving test measures used in the present study. The aim was to identify variables which may predict driving performance both generically, and specifically in subjects who have sustained neurological damage. Theoretical, methodological, and practical implications of these exploratory analyses are discussed in Chapter Twelve.

BACKGROUND

In the present study, the four driving groups were subjected to a variety of assessment measures including a selection of neuropsychological tests and on-road practical driving assessments. Overall, neuropsychological tests such as the Mini Mental State Examination (MMSE) Total Score, the Standardised Road Map Test of Direction Sense, and the reaction time measures significantly distinguished between the four sample groups. Practical driving measures consistently indicated a higher driving standard amongst the professional drivers, but no significant quantitative differences in total driving errors across the control and two neuropsychologically-impaired subject groups.

Questions about whether subject variables can be used to predict driving ability is the next important step in the development of possible driving assessment schemes for neuropsychologically-impaired drivers. Statistically, however, this is not a straightforward proposition. As an analytical technique, multiple regression may be constrained by the number and type of variables selected for analysis, and the use of small subject groups. For the present study, the small clinical sample is a particular limitation. In this instance, use of multiple regression to answer questions about predictive validity must be, at best, exploratory. Therefore, the line of investigation taken was to identify variables which may be important to driving performance generically, and in a subsequent within groups analysis of neuropsychologically-impaired and neuropsychologically-intact subjects.

The present study used simple multiple linear regression analyses to explore relationships between subject variables and, practical driving test outcomes (scores). Specifically, neuropsychological tests, clinical variables, and driver self-ratings were tested in separate regression analyses against two dependent variables: New Road Test pattern scores and Advanced Driver Assessment total error scores. Through this type of analysis it was hoped that it might be possible to gain an insight into underlying factors which are linked to the driving process. Furthermore, identification of potential driving predictors may provide an assessment base for more comprehensive future research.

A combination of factors influenced decisions about the relative importance of the variables chosen for inclusion in the regression models reported in this Chapter. Following some initial regression analyses using all of the neuropsychological tests, for example, variables of lesser relative importance were omitted so that a smaller more viable subset of potential predictors could be tested. From these initial regression analyses, both regression coefficients and individual correlations were considered in assessing the importance of each independent measure. Here, it was important to bear in mind that when strong relationships exist between independent variables, there can be a misleading effect on interpretation of values in the regression model (Tabachnick & Fidell, 1989). Thus, regression coefficients can be ambiguous because other independent variables suppress some of the irrelevant variance. Similarly, individual correlations between an independent and dependent variable are a reflection of variance shared with the dependent variable. Nevertheless, some of that variance may also be predictable from other independent variables. The decision to include selected measures in the chosen subsets, therefore, was also based on whether these measures differentiated groups by significant ANOVA. Aside from statistical support, empirical evidence and the practicalities surrounding the use of specific measures were also relevant deciding factors.

MULTIPLE REGRESSION MODELS.

For the sake of conciseness and clarity, only the multiple regression models which showed the most promising results are presented here. Thus, a greater emphasis is placed on the neuropsychological test variables which showed interesting outcomes for all groups combined, as well as the separate subsets of neuropsychologically-impaired and neuropsychologically-intact subjects. With the driver self-ratings, results for the neuropsychologically-impaired subjects showed a noteworthy relationship to driving outcome. Interestingly, no clear patterns emerged for the relationship of quantifiable clinical variables to driving errors for the present neuropsychologically-impaired sample.

Neuropsychological tests and practical driving test outcome.

Standard multiple linear regression analyses were performed for all groups combined using neuropsychological test measures as the predictor variables and practical driving performance on the New Road Test or Advanced Driver Assessment as separate dependent variables (Table 11.1). Shown are the unstandardised regression coefficients (b) and the intercept, the standardised regression coefficients (ß), the individual r^2 (derived from single predictor models) and overall non-adjusted and adjusted Pearson product-moment coefficients (R-square) for the overall model.

For all groups combined, variability in driving performance could be accounted for, in part, by performance on the neuropsychological test measures. Thus, for the New Road Test and the Advanced Driver Assessment respectively 34 % (20 % adjusted) and 42 % (31 % adjusted) of the variance could be explained by performance on the selected subset of neuropsychological tests results. Notably, of all the neuropsychological tests, the visuospatial tests which had a timed component and those measures of pure reaction time, contributed most to the observed variance. In particular, three reaction time trial sets and completion time for the Standardised Road Map Test of Direction Sense (Moneysec) were prominent for both the practical driving measures.

Table 11.1

Regression models for selected neuropsychological tests and practical driving performances across all groups.

NEW ROAD PATTERNS (N=36*)

Variables***	b	Prob.> T	β	Individual r^2
Moneysec	0.01	.13	0.30	.12
RTNPH	7.86	.04	0.47	.11
TrailB	0.01	.33	0.19	.05
RTNPHPF	2.73	.29	0.21	.05
Money	-0.02	.85	-0.04	.02
RTPH	-8.73	.02	-0.59	.00
Intercept	-0.48	.80		
R-square	.34			
Adj R-square	.20			

ADVANCED DRIVER ASSESSMENT TOTAL ERRORS (N=39)**

Variables***	b	Prob.> T	β	Individual r^2
RTNPHPF	48.2	.02	0.44	.16
Moneysec	0.06	.24	0.20	.15
RTNPH	62.1	.04	0.43	.12
Money	1.21	.13	0.34	.09
RTPH	-55.0	.04	-0.42	.02
TrailB	-0.11	.13	-0.31	.01
Intercept	-3.63	.81		
R-square	.42			
Adj R-square	.31			

* Four subjects from neuropsychological groups were unable to complete this test due to practical problems or due to abortion of the driving test because of exceptionally poor performance.

** Due to left hemiplegia, one complete set of reaction time data was not possible. This subject was omitted from the regression analysis.

*** Standardised Road Map of Direction Sense: time in seconds (Moneysec); Reaction time: non-preferred hand (RTNPH); Trailmaking test: Trails B (TrailB); Reaction time: non-preferred hand/preferred foot (RTNPHPF); Standardised Road Map of Direction Sense: total errors (Money); Reaction time: preferred hand (RTPH).

To identify possible differences between the subject groups, standard multiple linear regression models were then derived from composite neuropsychologically-intact and neuropsychologically-impaired groups (Table 11.2). Within the neuropsychologically-intact subject group, selected neuropsychological test measures explained 53 % (31 % adjusted) and 81 % (71 % adjusted) of the variance in New Road Test pattern scores and the Advanced Driver Assessment scores respectively . By comparison, for the neuropsychologically-impaired groups, these same neuropsychological test measures explained 68 % (46 % adjusted) and 46 % (19 % adjusted) of the variance in New Road Test pattern scores and the Advanced Driver Assessment total errors (Table 11.3). In particular, scores for the Standardised Road Map Test of Direction Sense (Money and Moneysec) were predominant in relation to Advanced Driver Assessment Total Errors.

There are a number of limitations in the interpretation of these results; in particular, the overall small sample size and wide range of scores on all measures. In this context, individual variability was most characteristic of the neuropsychologically-impaired subjects. By contrast, professional drivers were much more uniform in all their test measurement outcomes (Chapters Nine and Ten). This factor may in part explain the greater amount of shared variance (81 %, 71% adjusted) accounted for by the neuropsychologically-intact group on Advanced Driver Assessment total errors. The reduction in the number of subjects, through division into the two composite groups, however, clearly places an additional limitation on the interpretation of the separate regression models. Nevertheless, these multiple regression analyses suggested some interesting differences between the neuropsychologically-intact and neuropsychologically-impaired groups.

Of special interest, were the relationships between the different reaction time variables and performance on the two driving tests. Within the regression equations for all groups combined (Table 11.1), two of the independent variables, reaction time with the preferred-hand (RTPH) and reaction time with the non-preferred hand (RTNPH), correlated significantly with New Road Test patterns and Advanced Driver Assessment total errors. Remarkably, for both New Road Test patterns and Advanced Driver Assessment total errors, standardised ß estimates suggested that the relationship between RTPH and driving scores was negative.

Table 11.2

Regression models for selected neuropsychological tests and practical driving performances across neuropsychologically-intact groups

NEW ROAD TEST PATTERNS (N=20)

Variables***	b	Prob.> T	β	Individual r^2
RTNPHPF	5.63	.04	0.53	.44
RTPH	-1.78	.86	-0.10	.24
RTNPH	4.43	.61	0.25	.16
Moneysec	.010	.44	0.17	.12
TrailB	.021	.28	0.32	.08
Money	-0.13	.41	-0.21	.01
Intercept	-5.25	.05		
R-square	.53			
Adj R-square	.31			

ADVANCED DRIVER ASSESSMENT TOTAL ERRORS (N=20)

Variables***	b	Prob.> T	β	Individual r^2
RTNPH	110	.11	0.53	.53
RTNPHPF	65.8	.00	0.54	.52
RTPH	-17.2	.82	-0.08	.39
Moneysec	-0.00	.97	-0.00	.03
Money	1.63	.17	0.23	.03
TrailB	-0.25	.09	-0.33	.02
Intercept	-54.9	.01		
R-square	.81			
Adj R-square	.71			

*** Standardised Road Map of Direction Sense: time in seconds (Moneysec); Reaction time: non-preferred hand (RTNPH); Trailmaking test: Trails B (TrailB); Reaction time: non-preferred hand/preferred foot (RTNPHPF); Standardised Road Map of Direction Sense: total errors (Money); Reaction time: preferred hand (RTPH).

Multiple regression models derived for the two composite groups (Tables 11.2 and 11.3) appeared to explain this unexpected inverse relationship further. For the neuropsychologically-intact group, reaction time for non-preferred hand - preferred foot (RTNPHPF) trials correlated significantly with New Road Test patterns and Advanced Driver Assessment total errors. The importance of all three reaction time measures was supported by standardised ß estimates and individual r^2 values derived from the regression model. Notably, the relationship between the significant reaction time measures and practical driving outcome was positive.

In contrast, for neuropsychologically-impaired subjects (Table 11.3), there was a significant negative correlation between reaction time using the preferred hand and New Road Test patterns. Standardised B estimates and individual r^2 values in this model suggested that some importance could be placed on all reaction times as well as completion time for the Standardised Road Map Test of Direction Sense and reaction time using the preferred hand.

These different reaction time relationships with practical driving outcome across the two composite groups were strikingly confirmed by Pearson correlation coefficients for each reaction time measure (Table 11.4). For the combined neuropsychologically-intact subjects, all the reaction time correlations which reached a level of significance on either the two driving tests (seven out of eight) were positive. Similarly, for the combined neuropsychologically-impaired subjects, all the reaction time correlations which reached a level of significance (three out of eight) were negative.

These results suggest an important difference between the two composite subject groups. For the neuropsychologically-intact subjects faster reaction times were associated with fewer driving errors, as measured by both the two practical driving tests. Thus, when complicated with a request to use the non-dominant hand for choice reaction time, or the non-dominant hand and preferred-foot for complex reaction time trials, longer response times were consistent with more driving errors. By contrast, for the combined neuropsychologically-impaired subjects, slower reaction time was associated with better driving performance; that is, fewer driving errors as measured by the New Road Test.

Table 11.3

Regression models for selected neuropsychological test and practical driving performances for combined neuropsychologically-impaired groups

NEW ROAD TEST PATTERNS (N=16)*

Variables***	b	Prob.> T	β	Individual r^2
RTPH	-8.53	.04	-0.64	.42
RTNPHPF	-6.02	.17	-0.41	.27
Moneysec	0.00	.45	0.23	.03
RTNPH	8.35	.10	0.51	.00
Money	0.02	.88	0.05	.00
TrailB	-0.00	.68	-0.11	.00
Intercept	8.42	.01		
R-square	.68			
Adj R-square	.46			

ADVANCED DRIVING ASSESSMENT TOTAL ERRORS (N=19)**

Variables***	b	Prob.> T	β	Individual r^2
Moneysec	0.10	.13	0.48	.33
Money	0.23	.81	0.10	.15
RTPH	-41.0	.16	-0.43	.14
RTNPHPF	17.1	.58	0.17	.03
TrailB	0.02	.78	0.10	.02
RTNPH	-0.33	.99	0.00	.02
Intercept	41.8	.07		
R-square	.47			
Adj R-square	.20			

* Four subjects from neuropsychological groups were unable to complete this test due to practical problems or due to abortion of the driving test because of exceptionally poor performance.

** Due to left hemiplegia, one complete set of reaction time was not possible. This subject omitted from the regression analysis.

*** Standardised Road Map of Direction Sense: time in seconds (Moneysec); Reaction time: non-preferred hand (RTNPH); Trailmaking test: Trails B (TrailB); Reaction time: non-preferred hand/preferred foot (RTNPHPF); Standardised Road Map of Direction Sense: total errors (Money); Reaction time: preferred hand (RTPH).

Table 11.4

Pearson correlation coefficients for reaction time tests[1] and practical driving performances for the two composite subject groups.

NEUROPSYCHOLOGICALLY-INTACT GROUPS (N=20)

DRIVING TEST	RTPH	RTNPH	RTPHPF	RTNPHPF	RTPF
New Road Test total error patterns	.49*	.40	.46*	.66***	.57**
Advanced Driver Assessment Total Errors	.62**	.72***	.53*	.72***	.56*

NEUROPSYCHOLOGICALLY-IMPAIRED GROUPS (N=20)

DRIVING TEST	RTPH	RTNPH	RTPHPF	RTNPHPF	RTPF
New Road Test total error patterns	-.65**	.01	-.56*	-.52*	-.36
Advanced Driver Assessment Total Errors	-.39	-.13	-.17	-.16	-.19

* $p < .05$ ** $p < .01$ *** $p < .001$

[1] Reaction time: preferred hand (RTPH); Reaction time: non-preferred hand (RTNPH); Reaction time: preferred hand/preferred foot (RTPHPF); Reaction time: non-preferred hand/preferred foot (RTNPHPF); Reaction time: preferred foot (RTPF)

Use of different driving test outcomes as dependent variables

Criterion-related validity of the practical driving measures was implied by the fact that the selected neuropsychological test measures tended to predict outcome on both New Road Test patterns and Advanced Driver Assessment total errors. Importantly, these moderate to strong correlations were found despite the differing methods used by these two driving tests for scoring and categorising erroneous driving performance. Notably, however, in regression models for separate subtest errors within the New Road Test, the amount of shared variance accounted for by selected neuropsychological test measures was relatively small. For example, the overall non-adjusted and adjusted Pearson product-moment coefficients for Search errors were 29 % and 17 % respectively (Table 11.5). Most individual variance within this model was accounted for by the two Benton Visual Retention Test - Revised scores. This result is interesting in light of the strong visual component which is common to both the New Road Test Search errors and this neuropsychological test.

Table 11.5

Regression model for selected neuropsychological tests and New Road Pattern search subtest

ALL GROUPS COMBINED (N=36)

Variables***	b	Prob.> T	β	Individual r^2
BVRTcorrect	0.67	.09	0.72	.09
BVRTerrors	0.11	.65	0.18	.07
Trails B	0.02	.04	0.45	.04
Moneyerrors	0.05	.48	0.13	.03
RT-PH	-0.74	.74	-0.06	.00
Intercept	1.21	.76		
R-square	.29			
Adj R-square	.17			

*** Benton Visual Retention Test: total correct (BVRTcorrect); Benton Visual Retention Test: total errors (BVRTerrors); Trailmaking test: Trails B (TrailB); Standardised Road Map of Direction Sense: total errors (Moneyerrors); Reaction time: preferred hand (RTPH).

Comparative self-rating driver scales and practical driving test outcome

Standard multiple regression analyses were performed between self-ratings from the comparative driver scales and the two practical driving test measures used in the above regression analyses Thus, current ratings of "me as a driver" on the seven driver dimensions served as the predictor variables and New Road Test patterns and Advanced Driver Assessment total errors were separate criterion variables.

Table 11.6

Regression model for self-ratings from the comparative driver scales and Advanced Driver Assessment total errors.

COMBINED NEUROPSYCHOLOGICALLY-IMPAIRED GROUPS (N=20)

Driver dimensions	b	Prob.> T	β	Individual r^2
wise	7.22	.05	0.68	.23
predictable	-7.25	.18	-0.68	.05
reliable	10.8	.07	1.10	.07
considerate	1.70	.70	0.10	.00
safe	-6.35	.35	-0.51	.00
relaxed	0.85	.76	0.10	.17
responsible	-4.67	.50	-0.32	.00
Intercept	32.0	.17		
R-square	.50			
Adj R-square	.20			

Table 11.6 shows the regression model for neuropsychologically-impaired subjects' current self-ratings on the comparative driver scales and Advanced Driver Assessment total errors. Interestingly, for this group alone, some variability (50 %, 20 % adjusted) in Advanced Driver Assessment total errors could be accounted for by the

driver self-ratings. Although the limitations outlined above still apply, these results highlight some interesting possible relationships between driver self-perceptions and an actual driving performance measure. In particular, the driver dimension 'wise - unwise' was significant, and explained most of the individual variance for driving test outcome. Here, higher ratings on driver 'wiseness' tended to be associated with increased driving error scores.

DISCUSSION OF OVERALL TRENDS

Driver self-report ratings in relation to practical driving test outcome

Previous research has not used comparative methods for rating drivers who have sustained neurological damage. In the present study, a comparison of driver self-ratings with the practical driving data suggests that neuropsychologically-impaired subjects were inconsistently accurate in their self-ratings on the seven driver dimensions. In particular, the driver dimension 'wise - unwise' suggested that driver 'wiseness' was associated with increased driving error scores. This finding can be explained by a number of factors, including lack of insight through neuropsychological impairment (Cicone et al., 1980; Lezak, 1995), the driver self-bias phenomenon (Cutler et al., 1993; Guppy, 1993) or the desire to present a good assessment image.

These results support Hartje et al. (1991) who found that neuropsychologically-impaired drivers made some poor self-judgements, possibly reflecting a strong desire to drive more than actual driving ability. The social importance of driving emphasised in this previous study, was also supported by the present results. Thus, it appears that self-rating measures may have merit in driving assessments for detecting whether driver perceptions are utilised in any functional sense. In particular, they could provide insight into the use of compensatory strategies which are otherwise difficult to measure through existing methods (McLean et al., 1993; Priddy et al., 1990; van Zomeren et al., 1987).

Neuropsychological tests as potential predictors of driving test outcome.

Overall, the multiple regression models presented here suggest that reaction time and driver directional sense are predictive of driving ability, and may have validity in a driver assessment context. The prominence of the Standardised Road Map Test of Direction Sense (Money and Moneysec) in the regression models is consistent with a directional sense component of driving (Evans, 1991). Poor performance for this test is considered a clear sign of right left orientation problems (Lezak, 1995). Although the neurological basis for such topographical loss is unclear, the literature suggests that left/right hemisphere or bilateral posterior damage may play an important role (Walsh, 1994). In a broader sense, Standardised Road Map Test of Direction Sense performance also implicates memory problems, inattention ability to follow directions, planning, spatial and visual searching skills. Consistent with previous studies (Simms, 1985a, 1985b, 1986, 1987, 1989), the present results suggested that the Standardised Road Map Test of Direction Sense may identify a specific driving-related deficit in neuropsychologically-impaired subjects.

The prominence of the reaction time measures is consistent with previous studies which show that reaction time is an important element in driving assessment for both neuropsychologically-impaired and neuropsychologically-intact drivers (Tate et al., 1991; van Zomeren & van den Burg, 1985). Choice and complex reaction time measures relate to efficient decision making and response speed, both of which are unquestionably important to driving at the executive or strategic level (Lezak, 1995; van Zomeren et al., 1987). It is also well established that slowed reaction time is a characteristic of neurological impairment. In this regard, numerous studies have successfully incorporated reaction time measures as valid predictors of actual driving performance in neuropsychologically-impaired subjects (e.g., Gouvier et al., 1989; Hartje et al., 1991; Madeley et al., 1990; van Zomeren et al., 1987). These studies all suggested that slowed reaction time was correlated with poorer driving test scores.

In the present study, a similar trend for reaction time was also globally supported for some of the reaction time measures for all combined driving groups. Interestingly, however, some other reaction time measures also exhibited an inverse relationship to driving test scores. A breakdown of the regression analysis into the two main groups indicated that these unexpected correlations could be attributed exclusively to the neuropsychologically-impaired subjects. These results raise the intriguing possibility that the neuropsychologically-impaired drivers were incorporating compensatory techniques in their driving performance. Consequently, in some circumstances, impaired reaction time may not necessarily indicate potentially poor driving performance, particularly if drivers have some insight into their neuropsychological-impairment.

Chapter Twelve

SUMMARY AND CONCLUSIONS

This Chapter summarises the results of the present study in terms of the overall aim and the specific research objectives proposed in Chapter Six. Thus, theoretical and methodological implications of these results are addressed, and recommendations are made for practical application of the present findings and for future research directives.

OVERALL DESCRIPTION OF SUBJECT GROUPS

The first objective of the present study was to describe and compare the four driving groups using a range of sociodemographics, driving-related variables, practical driving measures, and neuropsychological assessment measures. The following points were highlighted from these findings.

Sociodemographics

All subject groups were predominantly male and of similar mean age. Description of educational background suggested that professional drivers and neuropsychologically-impaired subjects did not have a high level of secondary school qualifications. For neuropsychologically impaired subjects, the impact of neurological damage on employment was clear. A comparison between previous employment and current work status revealed some important differences between the two neuropsychologically-impaired groups, which may be related to improvement of function following neurological damage.

Driving-related variables

Despite similar number of years driving experience, there were differences in driving frequency and driving patterns between control drivers and the neuropsychologically-impaired presenters prior to injury. On a par with the professional drivers, subjects in both neuropsychologically-impaired groups previously drove on a very regular basis, encompassing all types of driving situations and traffic loads. These driving patterns clearly changed following neuropsychological impairment. Changes were most marked for neuropsychologically-impaired subjects who were in the early stages of a return to driving. In later stages, there were various reasons why few subjects actually returned to formerly established driving patterns. For both neuropsychologically-impaired groups post-injury, modifications to driving frequency and patterns typically included a reduction in amount of driving and restriction to driving short distances in low density traffic situations.

Data concerning driving incidents was complicated by a number of factors, however, similar numbers of more major traffic incidents were reported by all groups. Compared to the other groups, neuropsychologically-impaired presenters and drivers reported fewer minor incidents both pre- and post- head injury. The meaning of post-injury incidents was difficult to assess relative to wide variations in timeframes for driving again.

Practical driving assessment

Overall, results for the practical driving measures (New Road Test and Advanced Driver Assessment) showed that professional drivers set a high standard for driving which was not generally met by the other three sample groups. Subjects in both neuropsychologically-impaired groups were qualitatively distinguished by type of driving errors made, although this did not necessarily mean that their total driving scores were quantitatively different from controls. For all groups combined, modest to strong correlations were found between the practical driving tests and the informal driving instructor rating.

Self-reported driver ratings showed some interesting findings in the way subjects compared themselves with hypothetical average and very good drivers. Here, the actual values assigned to self-driver ratings were generally comparable across groups. However, within groups comparisons were affected by how subjects rated an average and a very good driver, and gave an impression of how subjects viewed themselves relative to other drivers. Here, professional drivers rated themselves equivalent to a very good driver, while control drivers perceived that they were generally somewhere between an average and a very good driver. There were some differences in how the two neuropsychologically-impaired groups perceived their current driving status. Here, neuropsychologically-impaired presenters typically rated themselves between an average and a very good driver. By comparison, neuropsychologically-impaired drivers generally perceived that they were comparable to a very good driver.

Neuropsychological assessment measures

Time since head-injury was variable across both neuropsychologically-impaired groups, with all subjects reporting some ongoing effects of neurological damage. For these groups, variability in performance was also reflected by neuropsychological test outcomes. However, with the exception of a few cases who achieved borderline scores, neuropsychological test scores were comparable with low-average adult norms for the general population. Importantly, slowed responding and difficulty with complex tasks were characteristic of many neuropsychologically-impaired subject's test performance.

The present results showed that mean scores for the Mini Mental State Examination (Total Score), the Standardised Road Map Test of Direction Sense, and two of the reaction time conditions were significantly lower for neuropsychologically-impaired groups. Importantly, average performances on the remaining four neuropsychological tests indicated that all four subject groups scored within a low-average range.

ADJUSTMENT TO NEUROLOGICAL DAMAGE

The second objective of the present study was to identify any changes and adjustments made by neuropsychologically-impaired subjects. This was achieved through direct questioning, comparison of retrospective (pre-injury) and current (post-injury) reported driver self-rating scales, driving frequency and patterns, and also by comparison with the neuropsychologically-intact subjects.

As expected, the present results indicated that neuropsychologically-impaired subjects had undergone changes and made numerous physical, social, emotional and cognitive adjustments following head injury. Importantly, these results also suggested that individuals were at different stages in a process of adjustment, mediated by a wide range of individual variables. Subsequently, time between neurological damage and resumption of driving varied considerably within the neuropsychologically-impaired groups.

Neuropsychologically-impaired subjects had also made adjustments to their driving as a function of neurological damage. These adjustments were indicated by reported changes in driving frequency and driving patterns, as summarised above. Here, it was interesting that most change was observed for neuropsychologically-impaired presenters, while some neuropsychologically-impaired drivers were driving with similar regularity and degree as before injury.

Retrospective and current driver self ratings showed some overall differences between neuropsychologically-impaired presenters and neuropsychologically-impaired drivers groups. Neuropsychologically-impaired subjects' post-injury ratings indicated a drop from pre-injury ratings, with slightly lower self appraisals given on safety and predictive driving behaviour. In contrast, neuropsychologically-impaired drivers either increased or maintained their self ratings from pre-injury status on some driver dimensions, namely driver safety, wiseness and predictive behaviour. Thus, neuropsychologically-impaired drivers currently perceived that they were comparable to a very good driver.

RELATIONSHIP OF SELECTED VARIABLES TO PRACTICAL DRIVING TEST OUTCOME

The third research objective for the present study involved an exploration of relationships between selected subject variables and neuropsychological test measures to practical driving test outcome.

Multiple regression analyses suggested that reaction time and driver directional sense were important components of driving ability, as measured by the practical driving tests. The Standardised Road Map Test of Direction Sense appeared to identify specific driving-related deficits in the neuropsychologically-impaired subjects. Reaction time measures were an important element in driving assessment for all subject groups. However, for the neuropsychologically-impaired subjects, there was evidence for an inverse relationship between some reaction time trials and outcome on both the New Road Test and the Advanced Driver Assessment. One possible explanation for these results was that the neuropsychologically-impaired subjects were compensating for slowed performance by adjusting their driving and allowing more time to react in some driving situations.

The relationship between driver self-rating scales and practical driving outcome for all groups together was not strong. However, for the combined group of neuropsychologically-impaired subjects, ratings on the driver 'wiseness' dimension was related to increased Advanced Driver Assessment errors.

RESEARCH IMPLICATIONS

The overall aim of the present research was to explore an integrated model of driving which describes driving performance and behaviour of neuropsychologically-impaired drivers. As part of this aim, the fourth

research objective was to consider theoretical and methodological and practical implications of the research. A fifth objective was to identify relevant outcomes and to suggest avenues for future neuropsychologically-impaired driver assessment research within New Zealand.

Integrated theoretical approach

As justified in previous chapters, an integrated approach was taken by the present study in order to identify possible trends in the data not possible from a single measurement research design. Currently, there is a lack of integrated theory which accounts for the special characteristics of individual drivers within the context of the driving environment. Previous research on drivers with acquired neurological damage has not taken a truly integrative approach, even though these studies emphasise a range of individual characteristics and their role in assessing driving performance. The results of the present study underscore the complexity of the driving process which is influenced by a wide range of social and cognitive factors. Although exploratory, some interesting themes emerged, which have important theoretical implications. One important trend was a link between an awareness of neurological deficit and compensatory driving strategies shown by subjects in both neuropsychologically-impaired groups. Here, a number of observations, when taken together, suggest that neuropsychological impairment may not necessarily impede driving performance. These findings also suggest that it may be prudent to investigate further the effectiveness of individual compensatory strategies in relation to actual driving proficiency.

• Driving frequency and patterns underwent a pattern of change following neuropsychological impairment. All subjects reported some reduction in driving frequency and limitation of aspects of their driving environment. These limitations included choice of opportune times for driving, avoidance of high density routes and long distance driving. Such strategic decisions suggested that subjects had some awareness of neurological deficit and were compensating for these effects in a practical way. This finding was also supported by the self-rating driving scales for the neuropsychologically-impaired presenter who rated themselves as less safe and less predictable compared to self-ratings pre-injury.

- Evidence suggested that some subjects in the neuropsychologically-impaired driver group returned to a driving pattern similar to pre-injury. Neuropsychologically-impaired drivers, on average, also tended to perform less well on the practical driving tests compared to the neuropsychologically-impaired presenters. Although, a number of explanations may account for these observations, it is possible that some of these subject's driver self-perceptions reflected over-confidence and self-assurance, as a consequence of driving longer. This proposition could be supported by the self-rating scales for the neuropsychologically-impaired drivers who rated themselves as safer, more predictable, and more wise compared to pre-injury self-ratings. Consequently, some subjects may not have been aware or possibly ignored the extent of their neurological deficit. This self perception may have contributed to a poorer driving performance, given that social aspects of driving are known to play an important role in driving behaviour.

- There was a significant inverse relationship between some of the reaction time data and practical driving test outcome for the combined neuropsychologically-impaired subject groups. These results highlight the possibility that the neuropsychologically-impaired drivers were incorporating compensatory techniques in their driving performance. Here, subjects with impaired reaction time may have been aware of their neurological deficit and compensate driving performance accordingly, either by driving slower or by allowing a greater margin for error. This type of driving behaviour was also supported by the self-rating multiple regression models which suggested that over-estimated self-perceptions by the neuropsychologically-impaired subjects correlated with higher driving error scores.

Methodological considerations

A number of methodological considerations concerning the research design, as well as the measurement and analysis of variables, are important when interpreting the results of the present study.

Considerations in the basic research design. Quasi-experimental research designs are often the only way of gaining insight into practical or theoretical problems. By necessity, the present study adopted a quasi-experimental approach to study the effects of neurological damage on a range of neuropsychological and practical driving assessments. Here, the four non-equivalent subject groups were obviously selected, rather than obtained by specific manipulation. Thus, although all other aspects of the present design were controlled in an experimental manner, the researcher could not assert control over a random assignment to subject groups. Inherently, such a design is exposed to unknown biases in group assignment, whereby any number of uncontrolled factors may intrude on the independent variable. In the selection of neuropsychologically-impaired subjects, for example, the various reasons for neurological damage and the treatment of subjects in rehabilitation, are unqualified extraneous variables. Another limitation in the use of quasi-experimental designs are logistical difficulties in maintaining similar experimental conditions for data collection across non-equivalent groups. Lehman (1991) identifies this as a likely threat to internal validity. Possible causality between neuropsychological impairment and neuropsychological or driving performance, needs to be carefully qualified under these circumstances.

As an example, motivation may in part explain the practical driving performances of the four groups. Thus, the professional drivers may have been motivated to perform well within their occupational role. Similarly, the neuropsychologically-impaired presenters may have been highly motivated to perform well as they were awaiting a driving assessment. The neuropsychologically-impaired drivers and control drivers, on the other hand, may have had the least motivation to perform to their best as they were already driving successfully.

Despite these limitations, quasi-experimental studies have the advantage of both group measurement and relative control of experimental conditions over alternative possibilities using survey, archival, and single case designs. For the present study there were several in-built experimental controls. For example, control drivers were chosen for similarity in age, gender and years of driving experience when compared to the neuropsychologically-impaired presenters group. Division of the neuropsychologically-impaired subject groups into presenters and drivers was also an endeavour to introduce control within a temporal framework. A further positive feature was that all subjects were tested by the same group of examiners under highly similar, controlled conditions, and data was collected within an efficient timeframe. This approach ensured a high degree of internal validity.

The present study attempted to gain some insight into changes in subjects perceptions resulting from neurological damage. As a longitudinal design was not feasible the research design involved questioning on experiences and the process of change, as well as relating subjects' retrospective and current ratings on the comparative driver scales. Additionally, the relationship of time with different stages in the assessment process was examined through the inclusion of the two neuropsychologically-impaired subject groups.

This method of data collection has the limitation that all data was collected from neuropsychologically-impaired groups after head injury. Here, for example, neuropsychologically-impaired subjects' retrospective reports may have been affected by aspects of the neurological damage (Cicone et al., 1980), or by selective remembering. The latter is a feature common also to the non-impaired population. Given this limitation, the present results nevertheless suggested that time since head injury and time subjects had been driving again may have influenced individual perceptions of change. This finding highlights a potentially important area of research which has been neglected by previous studies. On this basis, a case for longitudinal research, which maps the return to driving after neurological damage, can be justified for future research.

Considerations within the measurement procedure. The present study ran a tight procedure to ensure that the order of assessment components was counterbalanced between the subject groups. Thus, variables such as fatigue had an equal chance of affecting all measures within a group. This design factor was particularly important for neuropsychologically-impaired subjects, for whom the average length of a neuropsychological assessment can be quite taxing (Walsh, 1994).

One limitation which was considered in the present study was assessor bias. Here, there is the risk that measurement may be biased by an assessor's knowledge of which groups the subjects belong. Three procedural aspects of the present study were intended to reduce this possibility. First, standardised scoring systems were adopted as part of the neuropsychological test and driving measures. Second, was the use of assessors who were impartial to the outcome of the study, and who were acting in their professional capacity. Because of safety concerns, these assessors did have to be briefed on the intention of the present study. However, as a third measure to reduce possible bias, these assessors were blind as to which of the four groups individual subjects belonged during the data collection phase.

Unfortunately, cues given by some subjects did, in some instances, confound this ideal arrangement. Professional drivers were sometimes identifiable by their regulation haircuts, army boots, and a shared civilian vehicle; while a few neuropsychologically-impaired subjects talked about their head injury experiences. Within the assessment procedures, some neuropsychologically-impaired subjects also identified themselves through special needs required. For example, several of these subjects needed help with physically writing questionnaire responses, and some subjects necessitated breaks and/or repetition of test instructions in the neuropsychological testing phase.

Response bias, for subjects participating in the present study, was also taken into account as a potential limitation. Here, extraneous pressures, particularly motivation to perform well, may have differently affected the four subject groups. Unfortunately, this is an artifact of many quasi experimental designs (Lehman, 1991), as already discussed. Every effort was made to counter this effect through assuring confidentiality, and for neuropsychologically-impaired subjects, assuring that any assessment results were innocuous in so far as permission to drive again. Another source of response bias may have been introduced through a subject's inclination toward socially acceptable responses to the questionnaire measures. In particular, data on personal history and driving incidents are prone to socially acceptable responding. In the present study, steps were also taken to counter the likelihood of this form of biased responding by subjects. Confidentiality was assured and subjects were able to see that their names were not recorded on any of the questionnaire forms. The researcher was empathic to individual situations, which facilitated subjects feeling comfortable with the questions asked.

Another possible source of procedural error was a difficulty unavoidable to all single measurement approaches. By definition, these research designs rely on momentary time sampling or the collection of data in one session. Thus, there is no clear way of knowing how recent experiences, or the way a subject is feeling on the day, may have influenced individual subject's performance. Such variability in performance is seen as a particular problem for neuropsychologically-impaired subjects (Stuss et al., 1994). However, single factor approaches are also an unavoidable reality of driving assessments in general. For example, when sitting a driving test, a candidate gets a single measure opportunity to perform to an adequate assessment standard. Nevertheless, despite these inherent uncertainties, single measurement approaches have a distinct advantage when there is need to compare multiple measures across subject groups. This was a fundamental consideration for the present study.

Generalisation from the present findings. Fundamental to the present research design was the generalisation of the results. Hartje et al. (1991) raised this methodological concern for all neuropsychologically-impaired driver research, given the individual nature of different subject groups. Other researchers have questioned the generalisation of research results to the diversity of driving environments, and to the range of situations in which subjects choose to drive (Priddy et al., 1990).

The present study involved a relatively small sample size of 40 subjects, half of whom had sustained neurological damage. Within the recruitment time frame of this study, however, this number was a good representation of neuropsychologically-impaired subjects who were listed with one of two local rehabilitation organisations. An additional consideration was that these subjects had to both meet the research criteria and be willing to participate in the research. Obtaining sufficient clinical samples, such as those employed in the present study, is well established as an ongoing problem for research and often necessitates the use of small-n research designs (Hall & Johnston, 1994).

Apart from the small sample size, a number of other features were peculiar to the four subject groups. For example, subjects were predominantly male and were of a similar age range. All subjects also resided in, or around, the same provincial New Zealand city. Neuropsychologically-impaired subjects met certain selection criteria, including a moderate to severe head injury within the previous seven years, and satisfying visual standards for driving. As already mentioned, these neuropsychologically-impaired subjects were recruited from one of two similar rehabilitation services; this may have categorised subjects and/or imposed additional screening criteria before inclusion into the present study (Rosenthal et al., 1983).

There are limitations when generalising from the present results which stem from the size and specific characteristics of the subject groups. Because of an attempt to optimise internal validity through intensive description within the integrated approach, generality was unavoidably compromised. Consequently, universal statements about the performance of each of the four subject groups should be cautioned. This consideration was emphasised in the exploratory nature of the present study. Nevertheless, the results have external validity due to the rigorous and comprehensive research design. This is a particular strength compared to many other constrained research designs.

Practical implications and future research

Integrated research approach. The present study adopted an integrated approach to describe a range of sociodemographics, driving-related variables, and neuropsychological measures across four distinct subject groups. The relationship of these variables to measures of practical driving was then explored using two current New Zealand driving tests. From this integrated approach and the use of these distinct driving groups, a number of interesting themes emerged for both for the general population and specifically for neuropsychologically-impaired drivers. These findings have practical relevance in terms of variables to be included in neuropsychologically-impaired driver assessment schemes, and what considerations are appropriate to the current New Zealand situation.

The major theme which emerged was the importance of an integrated research design toward understanding the complexity of the driving process. In this regard, the driving performance of all subject groups could be explained through the differential interplay of social and cognitive factors, along with specific aspects of driving experience. Thus, with neuropsychological impairment, there was evidence that social factors such as awareness of deficit and the use of compensatory strategies, contributed to practical driving performance. As already discussed, the role of compensation was supported by several relationships involving changes in driving patterns pre- and post-injury, self-perceptions of driving ability, and reaction time measures. In contrast, in the absence of neuropsychological impairment, test components such as reaction time had a more direct relationship with driving performance.

Another theme was the considerable individual variability in subjects' return to driving. This variability provides a novel insight into the process of driving again following neurological damage. Comparison of subjects at different stages in this process was made possible through the two neuropsychologically-impaired groups. Within group data was also collected through subject's reports of change, and by comparison of retrospective and current driver scale measures. Interestingly, although subjects reflected a wide range of views on return to driving, decisions about when return to driving and modification of existing driving habits were largely personal. A return to driving also tended to correspond with other lifestyle adjustments. A few subjects expressed practical concern over unclear official guidelines regarding an appropriate time to resume driving. Results suggested that factors such as insight into one's neuropsychological impairment may be important variables affecting this decision.

It is recommended that further research is undertaken in this area. Here, a case can be made for longitudinal research to more clearly track the process of return to driving. As a result, it may be possible to make future practical recommendations regarding the most opportune time to evaluate individuals for driving again, thereby aiding standardisation of the assessment process.

At present, many practical assessment schemes quantitatively measure aspects of driving, and are fundamentally similar to standardised learner driving tests. However, as shown by the present study, an integrated research design can reveal qualitative information which is clearly important in the assessment of the neuropsychologically-impaired individual. The combination of data provided by the New Road Test and the Advanced Driver Assessment, for example, highlighted some aspects of qualitative performance not reflected in actual driving scores. Similarly, qualitative measures such as driving patterns, and perceived changes on driver dimensions, gave valuable information on the use of possible compensatory strategies. This type of qualitative information can be as important as the actual quantitative score on a test in an assessment context. Consequently, the present findings emphasise the relevance of other indirect relationships between some tests and the variables they are supposed to measure (Walsh, 1994).

The integration of both qualitative and quantitative data has important practical implications. As already discussed, a major strength of an integrated approach is the ability to identify patterns in the data, such as motivational effects or compensatory strategies, which may enable more accurate inferences about an individual's performance. Unfortunately, many existing assessment schemes which focus largely on quantitative measures do not have this same degree of insight. Therefore, for driver evaluation to meet both clinical and research purposes, the present findings suggest that assessments should make use of qualitative description as well as more popular quantitative measures

Incorporation of specific test measures. Through an integrated approach, it was hoped that social or neuropsychological test factors which correlated with practical driving ability could be identified. Significant relationships could therefore suggest factors for inclusion into larger research designs directed at standardising measurement techniques. This would greatly aid comparisons between studies and assist the development of any assessment procedures for driving again in New Zealand. At present, documented norms are not available for many assessment measures, particularly as they are relevant to the neuropsychologically-impaired driver population.

Driving tests. From a practical viewpoint, it was important that the present study utilised current New Zealand driving tests to measure driving ability. Apart from a value in the assessment of neuropsychologically-impaired drivers, use of these driving tests has some parity with current legal standards for driving in New Zealand. In addition, the present study worked toward establishing some realistic criteria for performance on the practical driving measures. Thus, a professional driving criterion was compared alongside control drivers and the two groups of neuropsychologically-impaired subjects. Subsequently, similarities between control drivers and neuropsychologically-impaired drivers suggest more realistic criteria against which to judge the performance of the neuropsychologically-impaired presenters, who were seeking approval for driving again.

As already discussed, lack of validation studies and normative data is characteristic of the practical driving tests used in the present study, particularly the Advanced Driver Assessment. In conjunction with the present research, some initial normative data was compiled for the Advanced Driver assessment measure (Harwood, 1992). However, further validity and reliability studies for both practical driving tests are warranted. For example, future research would need to continue to work on adequate operational definition of driving behaviours measured by the Advanced Driver Assessment. Standardisation studies are needed to establish norms for both normal and impaired driver population samples. These studies should aim to develop guidelines for interpretation of qualitative observations in addition to actual test scores. Future research could also establish which of the two practical driving measures best suit application to neuropsychologically-impaired driver assessment.

Driver self-rating scales. Some of the specific measures which revealed a relationship with practical driving outcome were driver self-rating scale dimensions. How individuals perceived themselves as drivers appeared to be related to a number of personal and social factors. In particular, the present results suggested the importance of subject's insight into the effects of neurological damage, and the use of compensatory strategies which were perceived as a way overcoming these limitations. Self-rating data has practical application to driver assessment and education programmes, where drivers' perceptions of risk and strategic planning reflect on driver performance.

From the present results, some of the self-rated driver dimensions were shown to be more important in relation to practical driving outcome, particularly for the neuropsychologically-impaired subjects. Although the scales used in the present study have been used in previous New Zealand research (McCormick et al., 1986), their application to a range of driver samples is limited. More extensive standardisation studies are needed, and individual item analysis is warranted.

Questionnaire data The questionnaire data gave some practical insight into the type of adjustments individuals made as a consequence of their neurological damage. Change in job status, for example, was one of the many social, physical and cognitive adjustments characteristic of the neuropsychologically-impaired groups. The symptom checklist demonstrated that subjects were experiencing a number of ongoing effects. Changes identified between retrospective (pre-injury) and current driving frequency and patterns suggested that subjects had attempted to find practical solutions as a way of adjusting to neuropsychological impairment. This latter information, in particular, has practical value as part of an individual's assessment for driving again.

There are problems with measuring sociodemographics and driving-related variables, as already outlined in the present literature review. For example, Evan (1991) points out the wide variation in the kinds of measures used to denote driving experience. The present study's measurement of driving frequency and patterns highlighted that exposure is an important component of driving experience. These measures did not necessarily reflect the quantitative measure of number of years driving. The present results suggested that further research is needed to examine the role of experience in the assessment of neuropsychologically-impaired drivers. Overall, however, there is a need to standardise measurement of a number of subject variables in order for studies to be meaningfully compared.

Neuropsychological tests. Driving requires an adequate level of integrity in a multitude of underlying cognitive functions, many of which can be measured by neuropsychological tests. Of the neuropsychological tests in the present study, the Standardised Road Map Test of Direction Sense, and some of the reaction time measures were related to practical driving performance. Such tests represent a standardised component in assessments which are aimed at identifying aspects of cognitive function important to the driving process. Neuropsychological tests also have the added practical advantage of being safe, accurate and objective within the bounds of the test itself (Jones et al., 1983). Further, the Standardised Road Map Test of Direction Sense and the reaction time measure were both shown to be easily administered, portable, and face valid tests, which are important practical considerations for prospective driver assessment schemes.

The present study identified some of the reaction time trials as significant correlates of driving outcome for all four driver groups. Unfortunately, many previous neuropsychologically-impaired driver studies have lacked neuropsychological test data for control subjects (Korner-Bitensky et al., 1990). Consequently, little is known about ceiling levels on many tests. Across the spectrum, therefore, there is a practical need for information the levels of ability on tests which equate with standards required for driving. Since the present study has identified potential neuropsychological test predictors of driving outcome, the next step is for further research to examine issues, such as cutoff scores on tests and performance factors, in the practical application of neuropsychological tests to driver assessment.

OVERALL CONCLUSION

There is a universal lack of guidelines for the assessment of drivers who have sustained neurological damage. In New Zealand, this situation is complicated by few guidelines or legal mechanisms to ensure driver reassessment following neurological damage. In addition, there is a lack of standardisation and documented norms within existing driving assessment schemes. Consequently, there is a definite need for research which can provide both a valid theoretical base and a practical context for neuropsychologically-impaired driver assessment.

The overall aim of the present research was to provide an integrated approach describing the driving performance and behaviour of neuropsychologically-impaired drivers. At an exploratory level, the present findings justified the importance of this approach toward understanding the complexity of the driving process in general, and specifically for neuropsychologically-impaired driver subjects. In addition, a number of variables were identified which warrant further investigation for their role in neuropsychologically-impaired driver assessment. Apart from a need for validation studies on a larger scale, future studies should also aim to include longitudinal and individual case analyses within an integrated research framework.

In conclusion, the present study provides an entry point for more extensive and intensive research in the neuropsychologically-impaired driver assessment area. In rehabilitation following neurological damage, an individual's well-being, independence and mobility is largely dependent on a return to driving. Coupled with the wider safety issues involved in assessment decisions, the neuropsychologically-impaired driver assessment area is most worthy of future exploration.

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APPENDIX A

DEPARTMENT OF PSYCHOLOGY

MASSEY
UNIVERSITY

DRIVER ASSESSMENT PROJECT

DEMOGRAPHIC DATA

Now we would like to ask you some questions which will help the Researcher understand and interpret the information from this study. Please remember all information is anonymous and confidential. The research team would appreciate if you could try and complete all applicable parts of the questionnaire. Most questions require you to respond only by placing a tick in the appropriate box. It is possible for you to tick more than one response for some questions.

Thank you for your help.

SEX:

- [ ] Male
- [ ] Female

DATE OF BIRTH: ____/____/________

MARITAL STATUS:

- [ ] Single
- [ ] Married/De Facto
- [ ] Separated
- [ ] Divorced
- [ ] Widowed

LIVING ARRANGEMENTS: Do you live (with your) . . .?

- [ ] Spouse
- [ ] Child(ren)
- [ ] Parent(s)
- [ ] Relative(s)
- [ ] Flatmate(s)
- [ ] Friend
- [ ] Caretaker
- [ ] Alone
- [ ] Other

EDUCATION:

What is the highest school qualification you have gained? - tick the nearest equivalent.

- ☐ Left school in standard ☐ /form ☐
- ☐ School Certificate
- ☐ 6th Form Certificate
- ☐ University Entrance
- ☐ Higher School Certificate
- ☐ Bursary
- ☐ Scholarship

Do you have any additional qualifications?

- ☐ None
- ☐ Certificate or Diploma - Please State:______________
- ☐ University (Undergraduate) Degree
- ☐ Postgraduate Degree
- ☐ Other - Please State:______________________________

____

EMPLOYMENT:

What job have you worked in which best represents you?
(eg: the job you have most experience in or are qualified to do)

____

____

Are you working at the moment?

- ☐ No
- ☐ Yes (Please state what you are doing)

____

____

If yes, do you work . . .

- ☐ Full time (more than 30 hours per week)
- ☐ Part Time (less than 30 hours per week)
- ☐ Casual (work as required)
- ☐ Contract (hired for a specific time)
- ☐ On a work scheme/employment programme

If no, are you . . .

- [ ] Still at School
- [ ] Studying at University or Polytechnic or attending a specialist course
- [ ] An unpaid worker (eg parent, caregiver, homemaker, or a volunteer worker)
- [ ] Unable to work
- [ ] Seeking a job
- [ ] Not seeking a job
- [ ] Retired

MEDICAL:

Have you had a significant or major injury/accident/illness?

- [ ] No
- [ ] Yes

If yes -
Can you briefly describe your injury/accident/illness -

____

____

____

____

How long has it been since your major injury/accident/illness?

____________ Weeks
Or ____________ Months
Or ____________ Years

Has anything changed in your ability to do things since your injury/accident/illness?

- [ ] No
- [ ] Yes - What has changed? ____________________

____

____

____

____

Are there any important things you cannot do now?

- [ ] No
- [ ] Yes - What are they? ____________________

____

____

____

____

CHECKLIST:

Do you ever experience any of the following? Please tick.

- [ ] Frequent tiredness
- [ ] Dizziness
- [ ] Near blackout spells
- [ ] Blackout spells
- [ ] Loss of Balance
- [ ] Loss of mobility
- [ ] Seizures
- [ ] Eyesight problems
- [ ] Hearing problems
- [ ] Difficulty communicating
- [ ] Difficulty understanding
- [ ] Difficulty learning/doing new things
- [ ] Easily angered/agitated
- [ ] Easily frustrated
- [ ] Feeling confused
- [ ] Not always alert or watchful of things
- [ ] Difficulty concentrating for more than a short time

- [ ] Disturbed by loud noise, unexpected movements, TV, computer monitors or flashing lights, etc
- [ ] Difficulty working things out
- [ ] Forgetfulness
- [ ] Easily distracted
- [ ] Loss of interest in things
- [ ] Realising there are some things you can no longer deal with
- [ ] Difficulty remembering
- [ ] Often doing things without thinking about them.
- [ ] People telling you that you cannot do things like you used to
- [ ] Easily upset
- [ ] Difficulty correcting mistakes even when you know they are wrong
- [ ] Feeling depressed
- [ ] Unable to carry out plans that you make

MEDICATION:

Do you regularly take medications or drugs for any of the following (listed in alphabetical order):

- [ ] Allergies
- [ ] Brain disorders (eg Alzheimers, Schizophrenia)
- [ ] Chronic pain
- [ ] Depression
- [ ] Diabetes
- [ ] Epilepsy
- [ ] Mental/psychiatric problems
- [ ] Motion(travel) sickness
- [ ] 'Recreational' use
- [ ] Reducing inflammation
- [ ] Sleeping problems
- [ ] Stress/Hypertension
- [ ] Weight reduction

Have you been told about any possible effects of your medication/drugs on driving?

- [ ] No
- [ ] Yes

Do you notice any effects of your medication/drugs on driving?

- [ ] No
- [ ] Yes. What are these effects? ____________________

____

____

ALCOHOL:

Do you drink alcohol?

- [ ] Not at all
- [ ] Occasionally
- [ ] Less than 2 drinks per day
- [ ] More than 2 drinks per day

If you were to drink some alcohol and then drive a car, which of the following would be your main concern?

- [ ] Being caught by the Law
- [ ] Knowing my limit
- [ ] Whether I feel safe to drive
- [ ] Whether others feel I am safe to drive
- [ ] Having to find other transport home
- [ ] None, I do not mix alcohol and driving

THANK YOU VERY MUCH FOR HELPING WITH THIS RESEARCH. WE APPRECIATE YOU GIVING US YOUR TIME, AND HOPE THAT THE INFORMATION WE GATHER WILL BE ABLE TO BENEFIT YOU, AND OTHER PEOPLE WHO WISH TO RETURN TO DRIVING IN THE FUTURE.

IS THERE ANYTHING ELSE YOU WOULD LIKE TO SAY OR WHICH WE SHOULD HAVE ASKED YOU?

APPENDIX B

Table 1. Percentages of drivers rating themselves above, equal to and below average

Bipolar scales used to rate drivers			Percentage rating "me as a driver" below "average"	equal to "average"	above "average"
foolish	-	wise	8.99	35.39	55.62
unpredictable	-	predictable	15.17	32.02	52.81
unreliable	-	reliable	7.30	26.40	66.29
inconsiderate	-	considerate	10.11	27.53	62.36
dangerous	-	safe	11.24	30.34	58.43
tense	-	relaxed	19.66	28.09	52.25
worthless	-	valuable	14.61	48.32	37.08
irresponsible	-	responsible	6.74	35.39	57.86
Total rating			15.73	4.50	79.77

Comparative perceptions of driver ability

Table 2. Differences between driver concepts rated on semantic differential scales

Scales	Differences between ratings of concepts					
	Very Good-Average		Me-Average		Very Good-Me	
	Difference	t value	Difference	t value	Difference	t value
safe	1.45	13.77*	0.82	7.99*	0.63	5.91*
reliable	1.42	13.55*	0.90	8.48*	0.51	4.40*
predictable	1.41	11.73*	0.65	6.54*	0.75	7.61*
considerate	1.40	11.61*	0.90	8.29*	0.48	4.14*
responsible	1.39	13.15*	0.92	9.61*	0.48	4.55*
wise	1.30	14.10*	0.74	8.70*	0.55	5.40*
relaxed	1.26	10.57*	0.30	6.43*	0.46	3.97*
valuable	0.73	8.06*	0.40	4.38*	0.34	2.97

*p<0001

from McCormick et al. (1986)

DEPARTMENT OF PSYCHOLOGY

MASSEY UNIVERSITY

DRIVER ASSESSMENT PROJECT

QUESTIONNAIRE

THIS QUESTIONNAIRE IS ABOUT DRIVING

PLEASE ANSWER ALL SECTIONS OF THE QUESTIONNAIRE

REMEMBER ALL INFORMATION IS CONFIDENTIAL AND ANONYMOUS

Please answer the questionnaire by placing a tick in the boxes which are true of your driving. You may tick more than one response per question if needed for your answer. Thank you for your help.

1 How long have you had your licence -

- [ ] Less than 2 years
- [ ] 2 - 5 years
- [ ] 6 - 10 years
- [ ] 10 - 20 years
- [ ] 20 - 30 years
- [ ] 30 - 40 years
- [ ] More than 40 years

2 Which of these do you drive -

- [ ] Car (Manual)
- [ ] Car (Automatic)
- [ ] Motorbike
- [ ] Commercial Vehicle - What Type: ____________________
- [ ] Other - What Type: ____________________

3 How often do you drive -

- [ ] More than once daily
- [ ] Once daily
- [ ] Several times a week (but not daily)
- [ ] Weekly
- [ ] Several times a month (but not weekly)
- [ ] Less than once a month

4 Your main driving is -

- [ ] Part of my job
- [ ] Travel to and from work/college/daily activities
- [ ] Local routes
- [ ] Short distance journeys (up to 80km/50 miles)
- [ ] Long distance journeys (more than 80km/50 miles)

5 Your usual place of driving is -

- [ ] Inner city
- [ ] Suburbs
- [ ] Out of town/city
- [ ] Main routes/motorways
- [ ] Rural roads

6 You usually drive during -

- [ ] Peak traffic periods
- [ ] Busy traffic periods
- [ ] Moderate traffic periods
- [ ] Minimum traffic periods

7 Have you ever done a Defensive Driving Course?

- [ ] No
- [ ] Yes

8 Have you had any minor incidents which caused damage to your vehicle or to personal property (eg scraped paint, small dents, garage door or fences scratched) -

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

9 As a driver, have you ever caused or been involved in an accident (eg collision with another care, person or thing, damage caused by erroneous driving) which was not reported to your insurance company -

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

Were any of these your fault -

- [ ] Yes
- [ ] No

10 As a driver, have you ever caused or been involved in an accident (eg collision with another car, person or thing, damage caused by erroneous driving) which <u>was</u> reported to your insurance company -

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

Were any of these your fault -

- ☐ Yes
- ☐ No

11 Have you ever been charged with any of the following -

(i) Parking Offences:

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

(ii) Speeding

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

(iii) Instant traffic fines:
(eg driving through red lights, no registration)

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

(iv) Minor traffic offence:
(eg failure to pay fines, accident related, careless driving - settled in Court)

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

(v) Major traffic offences:
(eg drink driving offence, dangerous driving causing injury, failing to stop after an accident - settled in Court)

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

12 Please indicate how you would rate the following driver scales. Place a circle around the number which best describes -

(i) An average driver

(ii) A very good driver

(iii) Me as a driver

Remember that "Me as a driver" refers to your driving as it is now.

1 An Average Driver:

Foolish ______________ Wise
1 2 3 4 5 6 7

A Very Good Driver:

Foolish ______________ Wise
1 2 3 4 5 6 7

Me as a Driver:

Foolish ______________ Wise
1 2 3 4 5 6 7

2 **An Average Driver:**

Unpredictable ____________________ Predictable

1 2 3 4 5 6 7

A Very Good Driver:

Unpredictable ____________________ Predictable

1 2 3 4 5 6 7

Me as a Driver:

Unpredictable ____________________ Predictable

1 2 3 4 5 6 7

3 **An Average Driver:**

Unreliable ____________________ Reliable

1 2 3 4 5 6 7

A very good driver:

Unreliable ____________________ Reliable

1 2 3 4 5 6 7

Me as a Driver:

Unreliable ____________________ Reliable

1 2 3 4 5 6 7

4 **An Average Driver:**

Inconsiderate ____________________ Considerate

1 2 3 4 5 6 7

A Very Good Driver:

Inconsiderate ____________________ Considerate

1 2 3 4 5 6 7

Me as a Driver:

Inconsiderate ____________________ Considerate

1 2 3 4 5 6 7

5 **An Average Driver:**

Dangerous ____________________ Safe

1 2 3 4 5 6 7

A Very Good Driver:

Dangerous ____________________ Safe

1 2 3 4 5 6 7

Me as a Driver:

Dangerous ____________________ Safe

1 2 3 4 5 6 7

6 **An Average Driver:**

Tense ______________ Relaxed

1 2 3 4 5 6 7

A Very Good Driver:

Tense ______________ Relaxed

1 2 3 4 5 6 7

Me as a Driver:

Tense ______________ Relaxed

1 2 3 4 5 6 7

7 **An Average Driver:**

Irresponsible ______________ Responsible

1 2 3 4 5 6 7

A Very Good Driver

Irresponsible ______________ Responsible

1 2 3 4 5 6 7

Me as a Driver:

Irresponsible ______________ Responsible

1 2 3 4 5 6 7

Now we would like you to tell us what you think is -

(a) an average driver

(b) a very good driver

Think about things like what skills/experience they would have, what age they would be, whether there is anything important to driving in their personality or their ability to do things, if they are male or female, and what physical characteristics and abilities they might have.

Description of an Average Driver: ______________

____

____

____

____

Description of a Very Good Driver: ______________

____

____

____

____

THIS QUESTIONNAIRE IS CONTINUED, PLEASE TURN OVER THE PAGE.

PLEASE CHECK (TICK) WHETHER YOU ARE CONCERNED BY ANY OF THE FOLLOWING BEFORE YOU SET OUT DRIVING: -

Checking the vehicle

- ☐ The route you are going to take
- ☐ The choice of driving or not
- ☐ Adjusting seat belts, rear vision mirrors, etc, before setting off.
- ☐ Weather and road conditions (eg.rain and fog, slippery wet roads, poor visibility).
- ☐ Distance to travel (eg long trips)
- ☐ Being familiar with the vehicle that you are driving
- ☐ Time of day (eg night driving, dusk, headlight glare, driving into bright sun, coming home late)
- ☐ Taking unfamiliar routes
- ☐ Feeling drowsy, tired or unwell
- ☐ Peak traffic flows (eg.avoiding rush hours, speed of traffic, motorway)
- ☐ Whether you have taken medication.
- ☐ Driving difficulty (eg.following complicated directions, inner city parking, treacherous road)
- ☐ Consideration for other road users
- ☐ Whether you have consumed alcohol

- ☐ Planning the best route (eg the shortest or least busy route)
- ☐ Driving alone or with passengers (eg feeling comfortable with a small child as passenger, being bothered by someone talking to you while driving)
- ☐ Remembering where you are going
- ☐ Feeling able and confident about driving
- ☐ Your mood (eg feeling angry, agitated, depressed, having your mind on other things)

READ THROUGH THE ABOVE LIST AGAIN
UNDERLINE ANY ITEMS ON THE LIST THAT YOU WOULD
USUALLY ACT ON OR DO SOMETHING ABOUT

WE WOULD LIKE TO THANK YOU VERY MUCH FOR YOUR HELP IN ANSWERING ALL QUESTIONS ON THIS QUESTIONNAIRE. YOUR CONTRIBUTION HAS BEEN A MOST VALUABLE PART OF THE RESEARCH. PLEASE FEEL FREE TO MAKE COMMENT OR TO LET US KNOW OF ANY QUERIES YOU MAY HAVE. THANK YOU AGAIN!

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APPENDIX D

DEPARTMENT OF PSYCHOLOGY

MASSEY UNIVERSITY

DRIVER ASSESSMENT PROJECT

QUESTIONNAIRE

THIS QUESTIONNAIRE IS ABOUT DRIVING

BEFORE YOUR MAIN ACCIDENT / ILLNESS / OR INJURY

PLEASE ANSWER ALL SECTIONS OF THE QUESTIONNAIRE

REMEMBER ALL INFORMATION IS CONFIDENTIAL AND ANONYMOUS

Please answer the questionnaire by placing a tick in the boxes which are true of your driving BEFORE your main accident/illness/ injury. You may tick more than one response per question if needed for your answer. Thank you for your help.

1 How long had you had your licence -

- [ ] Less than 2 years
- [ ] 2 - 5 years
- [ ] 6 - 10 years
- [ ] 10 - 20 years
- [ ] 20 - 30 years
- [ ] 30 - 40 years
- [ ] More than 40 years

2 Which of these did you drive -

- [ ] Car (Manual)
- [ ] Car (Automatic)
- [ ] Motorbike
- [ ] Commercial Vehicle - What Type: ______________________
- [ ] Other - What Type: ______________________

3 How often did you used to drive -

- [ ] More than once daily
- [ ] Once daily
- [ ] Several times a week (but not daily)
- [ ] Weekly
- [ ] Several times a month (but not weekly)
- [ ] Less than once a month

4 Your main driving was -

- [ ] Part of my job
- [ ] Travel to and from work/college/daily activities
- [ ] Local routes
- [ ] Short distance journeys (up to 80km/50 miles)
- [ ] Long distance journeys (more than 80km/50 miles)

5 You usually drove during -

- [ ] Inner city
- [ ] Suburbs
- [ ] Out of town/city
- [ ] Main routes/motorways
- [ ] Rural roads

6 You usually drive during -

- [ ] Peak traffic periods
- [ ] Busy traffic periods
- [ ] Moderate traffic periods
- [ ] Minimum traffic periods

7 Had you ever done a Defensive Driving Course before your main accident/illness/injury?

- [ ] No
- [ ] Yes

8 Had you had any minor incidents which caused damage to your vehicle or to personal property (eg scraped paint, small dents, garage door or fences scratched) -

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

9 As a driver, had you ever caused or been involved in an accident (eg. collision with another care, person or thing, damage caused by erroneous driving) which <u>was not</u> reported to your insurance company -

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

Were any of these your fault -

- [ ] Yes
- [ ] No

10 As a driver, had you ever caused or been involved in an accident (eg collision with another car, person or thing, damage caused by erroneous driving) which was reported to your insurance company -

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

Were any of these your fault -

- [ ] Yes
- [ ] No

11 Had you ever been charged with any of the following -

(i) Parking Offences:

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(ii) Speeding:

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(iii) Instant traffic fines:
(eg driving through red lights, no registration)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(iv) Minor traffic offence:
(eg failure to pay fines, accident related, careless driving - settled in Court)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(v) Major traffic offences:
(eg drink driving offence, dangerous driving causing injury, failing to stop after an accident settled in Court)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

12 Please indicate how you would rate the following driver scales. Place a circle around the number which best describes -

(i) An average driver

(ii) A very good driver

(iii) Me as a driver

Remember that "<u>Me as a driver</u>" refers to your driving <u>BEFORE</u> your main accident/illness/or injury.

1 An Average Driver:

Foolish ______ Wise

1 2 3 4 5 6 7

A Very Good Driver:

Foolish ______ Wise

1 2 3 4 5 6 7

Me as a Driver:

Foolish ______ Wise

1 2 3 4 5 6 7

2 An Average Driver:

Unpredictable ______ Predictable

1 2 3 4 5 6 7

A Very Good Driver:

Unpredictable ______ Predictable

1 2 3 4 5 6 7

Me as a Driver:

Unpredictable ______ Predictable

1 2 3 4 5 6 7

3 An Average Driver:

Unreliable ______ Reliable

1 2 3 4 5 6 7

A very good driver:

Unreliable ______ Reliable

1 2 3 4 5 6 7

Me as a Driver:

Unreliable ______ Reliable

1 2 3 4 5 6 7

4 An Average Driver:

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

A Very Good Driver:

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

Me as a Driver:

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

5 An Average Driver:

Dangerous ______________________ Safe

1 2 3 4 5 6 7

A Very Good Driver:

Dangerous ______________________ Safe

1 2 3 4 5 6 7

Me as a Driver:

Dangerous ______________________ Safe

1 2 3 4 5 6 7

6 An Average Driver:

Tense ______________________ Relaxed

1 2 3 4 5 6 7

A Very Good Driver:

Tense ______________________ Relaxed

1 2 3 4 5 6 7

Me as a Driver:

Tense ______________________ Relaxed

1 2 3 4 5 6 7

7 An Average Driver:

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

A Very Good Driver

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

Me as a Driver:

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

Now we would like you to tell us what you think is -

(a) an average driver

(b) a very good driver

Think about things like what skills/experience they would have, what age they would be, whether there is anything important to driving in their personality or their ability to do things, if they are male or female, and what physical characteristics and abilities they might have.

Description of an Average Driver: ____________________

____

____

____

Description of a Very Good Driver: ____________________

____

____

____

WE WOULD LIKE TO THANK YOU VERY MUCH FOR YOUR HELP IN ANSWERING ALL QUESTIONS ON THIS QUESTIONNAIRE. YOUR CONTRIBUTION HAS BEEN A MOST VALUABLE PART OF THE RESEARCH. PLEASE FEEL FREE TO MAKE COMMENTS OR TO LET US KNOW OF ANY QUERIES YOU MAY HAVE. WE WOULD NOW ASK YOU TO COMPLETE A SECOND QUESTIONNAIRE SO THAT YOUR INFORMATION CAN BE OF MAXIMUM USE TO PEOPLE WHO ARE INVOLVED IN DRIVER ASSESSMENTS.

THANK YOU ONCE MORE!!

APPENDIX E

1(A) How long have you been driving since your main accident/illness/or injury -

- [ ] Less than one month
- [ ] Between one and five months
- [ ] Between six months and one year
- [ ] More than one year
- [ ] More than three years

(B) How soon did you begin driving again -

- [ ] I just did it
- [ ] Friends or family drove with me
- [ ] I bad lessons with a driving instructor
- [ ] I saw other assessment people

(Please specify ______________________)

2 Which of these do you drive now -

- [ ] Car (manual)
- [ ] Car (automatic)
- [ ] Motorbike
- [ ] Commercial Vehicle - What Type: ______________
- [ ] Other - What type: ______________________

3(A) How often are you driving now -

- [ ] More than once daily
- [ ] Once daily
- [ ] Several times a week (but not daily)
- [ ] Weekly
- [ ] Several times a month (but not weekly)
- [ ] Less than once a month

(B) Compared to before your accident/illness/or injury, are you driving more or less?

- [ ] Much more
- [ ] Somewhat more
- [ ] Same
- [ ] Somewhat less
- [ ] Much less

If more or less, please state the main reason

____

____

4 Your main driving is -

- [ ] Part of my job
- [ ] Travel to and from work/college/daily activities
- [ ] Local routes
- [ ] Short distance journeys (up to 80km/50 miles)
- [ ] Long distance journeys (more than 80km/50 miles)

5 Your usual place of driving now is -

- ☐ Inner city
- ☐ Suburbs
- ☐ Out of town/city
- ☐ Main routes/motorways
- ☐ Rural roads

6 You usually drive during -

- ☐ Peak traffic periods
- ☐ Busy traffic periods
- ☐ Moderate traffic periods
- ☐ Minimum traffic periods

7 Have you done a Defensive Driving Course since your main accident/illness/injury?

- ☐ No
- ☐ Yes

8 Since driving again, have you had any minor incidents which caused damage to your vehicle or to personal property (eg scraped paint, small dents, garage door or fences scratched) -

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

9 Since driving again have you, as a driver, ever caused or been involved in an accident (eg collision with another car, person or thing, damage caused by erroneous driving) which <u>was not</u> reported to your insurance company -

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

Were any of these your fault -

- ☐ Yes
- ☐ No

10 Since driving again have you, as a driver, ever caused or been involved in an accident (eg collision with another car, person or thing, damage caused by erroneous driving) which <u>was</u> reported to your insurance company -

- ☐ Never
- ☐ Once
- ☐ A few times
- ☐ Several times
- ☐ Many times

Were any of these your fault -

- ☐ Yes
- ☐ No

11 Since driving again, have you ever been charged with any of the following -

(i) Parking Offences:

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(ii) Speeding

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(iii) Instant traffic fines:
(eg. driving through red lights, no registration)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(iv) Minor traffic offence:
(eg failure to pay fines, accident related, careless driving - settled in Court)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

(v) Major traffic offences:
(eg drink driving offence, dangerous driving causing injury, failing to stop after an accident settled in Court)

- [ ] Never
- [ ] Once
- [ ] A few times
- [ ] Several times
- [ ] Many times

12 Please indicate how you would rate the following driver scales. Place a circle around the number which best describes -

(i) An average driver

(ii) A very good driver

(iii) Me as a driver

Remember that "Me as a driver" refers to your driving SINCE your main accident/illness/or injury.

1 An Average Driver:

Foolish ______________________ Wise

1 2 3 4 5 6 7

A Very Good Driver:

Foolish ______________________ Wise

1 2 3 4 5 6 7

Me as a Driver:

Foolish ______________________ Wise

1 2 3 4 5 6 7

2 An Average Driver:

Unpredictable ______________________ Predictable

1 2 3 4 5 6 7

A Very Good Driver:

Unpredictable ______________________ Predictable

1 2 3 4 5 6 7

Me as a Driver:

Unpredictable ______________________ Predictable

1 2 3 4 5 6 7

3 An Average Driver:

Unreliable ______________________ Reliable

1 2 3 4 5 6 7

A very good driver:

Unreliable ______________________ Reliable

1 2 3 4 5 6 7

Me as a Driver:

Unreliable ______________________ Reliable

1 2 3 4 5 6 7

4 **An Average Driver:**

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

A Very Good Driver:

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

Me as a Driver:

Inconsiderate ______________________ Considerate

1 2 3 4 5 6 7

5 **An Average Driver:**

Dangerous ______________________ Safe

1 2 3 4 5 6 7

A Very Good Driver:

Dangerous ______________________ Safe

1 2 3 4 5 6 7

Me as a Driver:

Dangerous ______________________ Safe

1 2 3 4 5 6 7

6 **An Average Driver:**

Tense ______________________ Relaxed

1 2 3 4 5 6 7

A Very Good Driver:

Tense ______________________ Relaxed

1 2 3 4 5 6 7

Me as a Driver:

Tense ______________________ Relaxed

1 2 3 4 5 6 7

7 **An Average Driver:**

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

A Very Good Driver

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

Me as a Driver:

Irresponsible ______________________ Responsible

1 2 3 4 5 6 7

PLEASE TURN OVER THIS QUESTIONNAIRE

IS CONTINUED ON THE NEXT PAGE

13 Have you made any changes or modifications to your driving since your accident/illness/or injury?

☐ No
☐ Yes

If yes, what are these changes or modifications?

____

____

____

14 Have there been any modifications to your vehicle?

☐ No
☐ Yes

If yes, what are these modifications?

____

____

____

15 Do you notice any differences in your driving now?

☐ No
☐ Yes

If yes, what are these differences?

____

____

____

PLEASE CHECK (TICK) WHETHER YOU ARE CONCERNED BY ANY OF THE FOLLOWING BEFORE YOU SET OUT DRIVING -

☐ Checking the vehicle

☐ The route you are going to take

☐ The choice of driving or not

☐ Adjusting seat belts, rear vision mirrors, etc, before setting off.

☐ Weather and road conditions (eg rain and fog, slippery wet roads, poor visibility)

☐ Distance to travel (eg long trips)

☐ Being familiar with the vehicle that you are driving

☐ Time of day (eg night driving, dusk, headlight glare, driving into bright sun, coming home late)

☐ Taking unfamiliar routes

☐ Feeling drowsy, tired or unwell

☐ Peak traffic flows (eg avoiding rush hours, speed of traffic, motorways)

☐ Whether you have taken medication

☐ Driving difficulty (eg following complicated directions, inner city parking, treacherous roads)

☐ Consideration for other road users

☐ Whether you have consumed alcohol

APPENDIX F

TRANSPORT (DRIVERS LICENSING) REGULATIONS 1985

DRIVERS TEST - SUMMARY SHEET

Name of Applicant: ....
(Surname) (First Names)

....
(Perforate Here)

2. Date of Birth (1-6) | Date | Month | Year | Sex (7) | Male | Female | (Please circle)   .... (Signature of applicant)

Summary of Performance
Mark and Total all U's (unsatisfactories) in Table below:

		Pattern Score	Se.	Sp.	Dir.
8	1.1				
12	1.2				
16	1.3				
20	2.1				
24	2.2				
28	3.1				
32	4.1				
36	4.2				
40	4.3				
44	5.1				
48	5.2				
52	5.3				
56	6.1				
60	6/2				
64	6.3				
68	Total U's				

If test is cancelled or aborted please circle the one main reason:

1. Car not up to WOF standard or no WOF.
2. Applicant shows evidence of drugs/alcohol.
3. Accident wholly or partly caused by applicant.
4. Moving traffic violation.
5. Poor standard of driving.
6. Did not understand directions.
7. Other, please specify ....(72)

| Passed | Failed | Aborted | (73)
(Circle One)

3. Date of Test | | | | (74-79)   .... (Signature of Testing Officer) Print or Name Stamp | | | | | Officer Number (80-83)

Local Body No. | 0 | 1 | 0 | (84-86)   Route No. | 2 | (87)

Licence Type | M/Cycle | M/Car | Taxi | Bus | HGV | M/Trailer |
(Circle)

NEW ROAD TEST
DRIVER PERFORMANCE RATING FORM

1.1 U THE SQUARE / MAIN STREET S U S U S U S

FAILS TO SEARCH ALL DIRECTIONS. SEARCHES WELL.
FAILS TO DECELERATE SMOOTHLY. DECELERATES SMOOTHLY.
FAILS TO SIGNAL TURN. SIGNALS TURN.

1.2 U MAIN STREET / PRINCESS STREET. S U S U S U S

FAILS TO SEARCH LEFT & RIGHT. SEARCHES WELL LEFT & RIGHT.
DOES NOT ADJUST SPEED FOR CONDITIONS. ADJUSTS SPEED FOR CONDITIONS.
FAILS TO STEER AWAY FROM HAZARDS. STEERS AWAY FROM HAZARDS.
FAILS TO SIGNAL TURN. SIGNALS TURN.

1.3 U PRINCESS STREET/BROADWAY AVE. S U S U S U S

FAILS TO SELECT CORRECT LANE. SELECTS CORRECT LANE.
FAILS TO SEARCH ALL DIRECTIONS. SEARCHES ALL DIRECTIONS.
FAILS TO INDICATE TURN. INDICATES TURN.
FAILS TO ACCELERATE/ DECELERATE SMOOTHLY. ACCELERATES/ DECELERATES SMOOTHLY.

NOTE : RELATIVE TIMING OF BEHAVIOUR ELEMENTS IN RELATION TO THE BEHAVIOUR PATTERN IN THE TEST SEGMENT IS ONE OF THE CRITERIA FOR A SATISFACTORY RATING IN EACH OF THE BEHAVIOUR ELEMENTS.

2.1 U WARD STREET / FEATHERSTON STREET. S U S U S U S

FAILS TO REDUCE SPEED SMOOTHLY. REDUCES SPEED SMOOTHLY.
FAILS TO SIGNAL INTENTIONS. SIGNALS INTENTIONS.
FAILS TO SEARCH ALL DIRECTIONS. SEARCHES ALL DIRECTIONS.
FAILS TO GIVE WAY IF REQUIRED. GIVES WAY IF REQUIRED.

2.2 U FEATHERSTON STREET / ROY STREET. S U S U S U S

FAILS TO SEARCH ALL DIRECTIONS. SEARCHES ALL DIRECTIONS.
FAILS TO SIGNAL TURN. SIGNALS TURN.
FAILS TO GIVE WAY IF REQUIRED. GIVES WAY IF REQUIRED.
FAILS TO ACCELERATE SMOOTHLY. ACCELERATES SMOOTHLY.

3.1 U MANOEUVRE / MATAHAU STREET. S U S U S U S

FAILS TO SIGNAL INTENTIONS. SIGNALS INTENTIONS.
FAILS TO SEARCH ALL DIRECTIONS. SEARCHES WELL ALL DIRECTIONS.
FAILS TO ACCELERATE SMOOTHLY IN REVERSE. ACCELERATES SMOOTHLY IN REVERSE.
FAILS TO STEER SMOOTHLY IN REVERSE. STEERS SMOOTHLY IN REVERSE.

4.1 TREMAINE AVENUE / RANGITIKEI STREET. S U S U S U S

FAILS TO SEARCH THOROUGHLY.	SEARCHES THOROUGHLY.
FAILS TO SIGNAL INTENTIONS.	SIGNALS INTENTIONS.
FAILS TO ACCELERATE SMOOTHLY.	ACCELERATES SMOOTHLY.
FAILS TO STEER AWAY FROM HAZARDS.	STEERS AWAY FROM HAZARDS.

4.2 U RANGITIKEI STREET. S U S U S U S

FAILS TO SELECT CORRECT LANE.	SELECTS CORRECT LANE.
FAILS TO ADJUST SPEED FOR CONDITIONS.	ADJUSTS SPEED FOR CONDITIONS.
FAILS TO GIVE WAY TO PEDESTRIANS.	GIVES WAY TO PEDESTRIANS.
FAILS TO SEARCH ALL DIRECTIONS.	SEARCHES ALL DIRECTIONS.

4.3 U RANGITIKEI STREET/FEATHERSTON STREET. S U S U S U S

FAILS TO ACCELERATE SMOOTHLY.	ACCELERATES SMOOTHLY.
FAILS TO STEER SMOOTHLY INTO NEW STREET.	STEERS SMOOTHLY INTO NEW STREET.
FAILS TO SEARCH ALL DIRECTIONS.	SEARCHES WELL ALL DIRECTIONS.
FAILS TO GIVE WAY IF REQUIRED.	GIVES WAY IF REQUIRED.

NOTE : RELATIVE TIMING OF BEHAVIOUR ELEMENTS IN RELATION TO THE BEHAVIOUR PATTERN IN THE TEST SEGMENT IS ONE OF THE CRITERIA FOR A SATISFACTORY RATING IN EACH OF THE BEHAVIOUR ELEMENTS.

5.1 U LOMBARD STREET. S U S U S U S

FAILS TO SEARCH LEFT & RIGHT.	SEARCHES WELL LEFT & RIGHT.
FAILS TO ADJUST SPEED FOR SPEED FOR CONDITIONS.	ADJUSTS SPEED FOR CONDITIONS.
FAILS TO STEER AWAY FROM HAZARDS.	STEERS AWAY FROM HAZARDS.

5.2 U WALDING STREET/TAONUI STREET. S U S U S U S

FAILS TO SIGNAL INTENTIONS.	SIGNALS INTENTIONS.
FAILS TO ADJUST SPEED FOR CONDITIONS.	ADJUSTS SPEED FOR CONDITIONS.
FAILS TO SEARCH ALL DIRECTIONS.	SEARCHES ALL DIRECTIONS.
FAILS TO SELECT CORRECT LANE.	SELECTS CORRECT LANE.

5.3 U TAONUI STREET/CUBA STREET. S U S U S U S

FAILS TO SIGNAL TURN.	SIGNALS TURN.
FAILS TO ACCELERATE SMOOTHLY.	ACCELERATES SMOOTHLY.
FAILS TO SEARCH PARTICULARLY AHEAD.	SEARCHES WELL PARTICULARLY AHEAD.
FAILS TO STEER TO CORRECT POSITION ON NEW ROAD.	STEERS TO CORRECT POSITION ON NEW ROAD.

NOTE : RELATIVE TIMING OF BEHAVIOUR ELEMENTS IN RELATION TO THE BEHAVIOUR PATTERN IN THE TEST SEGMENT IS ONE OF THE CRITERIA FOR A SATISFACTORY RATING IN EACH OF THE BEHAVIOUR ELEMENTS.

6.1 U PITT STREET. S U S U S U S

FAILS TO SEARCH PARTICULARLY BEHIND.	SEARCHES WELL PARTICULARLY BEHIND.
FAILS TO SIGNAL.	SIGNALS INTENTIONS.
FAILS TO STEER SMOOTHLY INTO CORRECT LANE.	STEERS SMOOTHLY INTO CORRECT LANE.
FAILS TO DECELERATE SMOOTHLY.	DECELERATES SMOOTHLY.

6.2 U PITT STREET/CHURCH STREET. S U S U S U S

FAIL TO SEARCH ALL DIRECTIONS.	SEARCHES ALL DIRECTIONS.
FAILS TO STEER INTO CORRECT LANE.	STEERS INTO CORRECT LANE.
FAILS TO SIGNAL INTENTIONS.	SIGNALS INTENTIONS.
FAILS TO ACCELERATE SMOOTHLY.	ACCELERATES SMOOTHLY.
INTERFERS WITH OTHER TRAFFIC.	DOES NOT INTERFERE WITH OTHER TRAFFIC.

6.3 U CHURCH STREET/LINTON STREET. S U S U S U S

FAILS TO SEARCH.	SEARCHES WELL.
FAILS TO SIGNAL INTENTIONS.	SIGNALS INTENTIONS.
FAILS TO DECELERATE SMOOTHLY.	DECELERATES SMOOTHLY.
FAILS TO STEER INTO CORRECT LANE.	STEERS INTO CORRECT LANE.

NOTE : RELATIVE TIMING OF BEHAVIOUR ELEMENTS IN RELATION TO THE BEHAVIOUR PATTERN IN THE TEST SEGMENT IS ONE OF THE CRITERIA FOR A SATISFACTORY RATING IN EACH OF THE BEHAVIOUR ELEMENTS.

GENERAL OBSERVATIONS :

.... NEAR ACCIDENT .... (WHERE,

.... HAZARDOUS MOVING TRAFFIC OFFENCE .... (DESCRIB

....

.... PERFORMANCE NEEDING MUCH IMPROVEMENT .... (DESCRIB

....

TEST SEQUENCE :

TEST SEGMENT PERFORMANCE	SEARCH	PERFORMANCE ON SPEED CONTROL	DIRECTION CONTROL

APPENDIX G

Hazard Identification

Hazard identifications means that drivers will:

(a) employ a scanning technique or search pattern which includes all segments of the scene both front and rear. This scanning will usually be accomplished by moving the eyes at least every two seconds;

(b) predict a plausible path of travel for vehicles and pedestrians in the scene based on environmental, vehicle and driver conditions;

(c) select a reasonable course of action and make the appropriate manoeuvres.

Judgement

(a) A safe following distance by way of the 2 second rule.

(b) A safe stopping distance by way of the 4 second rule.

(c) A safe lead time by way of the 12 second rule.

Manipulating Controls

Manipulating controls means:

(a) Anticipating control for the regulation of power and velocity.

(b) Manipulating steering wheel for guidance of the vehicle.

(c) Manipulating controls for slowing and stopping.

(d) Manipulating controls and other actions for communicating and signalling.

To keep a motor vehicle under control, a driver must have a knowledge of its capabilities and limitations. The motor vehicle is a machine that is capable of a certain range of performance. To make the necessary judgements and decisions in driving requires that the operator knows what the vehicle can or cannot do under various conditions. Such knowledge is also required for predicting the possible actions of other drivers. Consider acceleration, straight ahead directional control and stability, cornering by the vehicle, deceleration and braking.

Observes Traffic Regulations

Observes Traffic Regulations requires a strict adherence to the rules that apply to each of the seven manoeuvres for the entire 40 minute drive.

APPENDIX H

DEFINITION OF TERMS

Moving into the Traffic

Moving into traffic means joining the traffic flow. This may occur when changing from one lane to another. The task also has to be mastered when entering from the edge of a roadway. It may also occur when using a motorway on ramp or entering from a side road.

Moving on the Road

Moving on the road means keeping the vehicle safely on the right road in the proper place. This includes, when cornering, when handling different road surfaces and when handling emergencies.

Moving with the Traffic Flow

Moving with the traffic flow means controlling the vehicle so that it safely and smoothly maintains its correct position with all the other traffic. This includes, when following other vehicles, when travelling in front of others and when travelling abreast of other traffic.

Moving through Traffic

Moving through traffic means moving the vehicle through situations when other traffic may cross your path.
It includes all intersections, controls, signs, pedestrian crossings, railway crossings, officers directing traffic etc.

Moving Past other Traffic

Moving past other traffic means having vehicles travelling in the same direction at different speeds going past each other in safety. It includes passing or being passed.

Moving Back in Traffic

Moving back in traffic means driving the vehicle back along the direction it has just come from and includes reversing into parking spaces and making 'U' turns.

Moving Out of the Traffic

Moving out of the traffic means disengaging from the line of cars and stopping or parking.
It includes getting off motorways, pulling into parking spaces, moving off the road and leaving the road by making left or right turns.

APPENDIX I

Driver Assessment Report

Location..

Name..

Address..

....

Age..

Date................/................/..................

Weather..

Start time..

Finish time..

Referred for training

................/................/..................

Reassessed ..../............/............

Passed..

Signed..

	Hazard Identification				Judgement			Manipulate Controls				Observes Traffic Regs.					
Moving	Identifies Potential Hazards	Predicts Developments	Determines Course of Action	Applies Decision	Applies 2 sec rule – following	Applies 4 sec rule	Applies 12 sec rule	Power & Velocity	Steering & Guiding	Communicating & Signalling	Slowing & Stopping	Uses Correct Lanes	Uses Correct Position	Uses Correct Signals	Observes Signs	Observes Speed Limits	Moving
IN																	IN
Comments																	Comments
ON																	ON
Comments																	Comments
WITH																	WITH
Comments																	Comments
THRU																	THRU
Comments																	Comments
PAST																	PAST
Comments																	Comments
BACK																	BACK
Comments																	Comments
OUT																	OUT
Comments																	Comments

CHOICE REACTION TIME

Make sure the subject is seated a comfortable distance in front of the apparatus, able to rest one hand comfortably on the centre button and reach the remainder of the buttons without stretching.

INSTRUCTION

"In front of you is a panel of 8 lights and a button near each of these light."

"I want to see how quickly you can react to any one of these lights by pressing the button nearest to it, as soon as you see the light come on."

"You may only use one hand at a time, beginning with the hand you write with."

"Which is the hand you write with?" (If subject is ambidextrous, begin with the right hand).

"While you are awaiting for a light to appear, I would like you to press the centre button with the finger tips of the hand you are using."

"Just try each of the buttons so you can see how much weight is required to push them right down."

(Allow time for them to do this)

"Shortly after I say "ready" one of the lights will come on. Reach to it as quickly as you can be raising you ... hand from the centre button and pressing down the button nearest the light. Now press your ... hand on the centre button."

FIRST TRIAL

(Count 1 second for each letter - noted beside the light number for each trial - then press light number). Do that and record the time. Make any further explanations that are necessary to clarify the instructions.

SECOND TRIAL

"Now one more trial before we begin". (Do one more trial and record the result).

"Now we are going to do ten trials with each hand. At the beginning of each trial I will say "ready" which is a signal to you to have your hand on the centre button."

"ready" (proceed with the first ten trials on the preferred hand).

and then say:

"good, and now ten trials in the same way with the other hand"

(proceed with the next ten trials).

then say:

"From now on you will be reacting with one hand and one foot. First you ... (preferred) hand and your ... (preferred) foot which is? I will only be using the centre four lights" (point them out) "when this one, this one and this one (3, 4, and 6) come on, you will turn them off as quickly as you can with your hand, just as you have been doing. When this one comes on (point to light 5) you must turn it off with your foot by moving from the right foot switch to the left foot switch. At the beginning of each trial you must have your hand on the centre button and your foot pressed on the foot switch on your right. Do you understand?"

Clarify any misunderstandings so far and then say: (Plug in foot switch!)

"Now a couple of practice trials ... "ready'.

(A trial first with light number 5 and then light number 4 and another with light number 5. If subjects use both hand and foot ask them to use only one or other).

"Good, now ten trials like that."

Proceed with ten trials, preferred hand and preferred foot and then say:

"Now ten trials with the same foot but with you other hand."

Proceed with the remaining ten trials, then debrief and thank the subject.

APPENDIX K

Extract from: Reaction Time Research Programme (Quentin Fogg, May, 1987)

Table 1

Normative reaction-time data (seconds) for males across age groups.

	MEAN (STANDARD DEVIATION)			
TEST RESULTS	AGE 16-25	AGE 26-35	AGE 36-45	AGE 46-55
Preferred hand	0.562 (0.077)	0.606 (1.104)	0.579 (0.073)	0.606 (0.062)
Non-Preferred hand	0.562 (1.074)	0.579 (0.10)	0.567 (0.072)	0.617 (0.086)
Preferred hand-Preferred foot	0.631 (0.108)	0.677 (0.118)	0.630 (0.079)	0.667 (0.127)
Non-Preferred Hand/Preferred foot	0.638 (0.089)	0.673 (0.137)	0.641 (0.068)	0.672 (0.119)
Preferred foot	0.484 (1.076)	0.510 (0.117)	0.510 (0.082)	0.486 (0.024)

APPENDIX L

MASSEY UNIVERSITY

Private Bag
Palmerston North
New Zealand
Telephone 0-6-356 9099
Facsimile 0-6-350 5611

FACULTY OF SOCIAL SCIENCES

DEPARTMENT OF PSYCHOLOGY

/ /

Dear

My name is Karen Wood and I am doing some Massey University research which concerns driving. With the help of

we are locating people to participate in our research project. Please read through the following page and consider whether you could offer us your time to take part.

I will be contacting you sometime in the next week and any questions or queries you may have can be answered then.

Thank you very much for you cooperation.

Sincerely,

Karen Wood

DEPARTMENT OF PSYCHOLOGY

MASSEY
UNIVERSITY

WOULD YOU LIKE TO BE INVOLVED IN OUR RESEARCH?

We are asking people if they would agree to take part in some university research which looks at driving. As researchers we are interested in what information is needed, and what ways can be used, to assess a person's fitness to drive. Our research concerns all drivers, but is particularly focused on how people deal with driving again following head injury. If you are in this group you may already hold a drivers' licence but can be referred for reassessment because of damage caused by accident or illness. Through comparing head-injured and non head-injured drivers the knowledge we gain will help us to develop a more objective and effective test for assessing fitness to drive.

As a participant, we will ask for about 90 minutes of your time to complete some questionnaires, do a range of small tasks which we think could be related to driving, and undergo a brief practical driving evaluation. All of the information we collect from you will be anonymous (we identify each participant by a code number only) and confidential. Therefore, under no circumstances could any information be used to affect your current driving status. If you agree to participate you will, of course, also have the right to withdraw from the research at any time.

We ask you to consider your participation as a way of helping future victims of head injury in their quest to return to driving. We would welcome any questions or queries you may have regarding the research. Thank you for your consideration.

K Wood.
Karen Wood
Ph.D. Candidate.

George Shouksmith
Professor George Shouksmith
Chief Supervisor.

APPENDIX M

DEPARTMENT OF PSYCHOLOGY

MASSEY
UNIVERSITY

INFORMATION FOR SUBJECTS

You have been asked to take part in a study about driving. The research is concerned with looking at different ways of assessing a person's fitness to drive. This form explains what we, as researchers, would like you to do, and what you as a participant can expect from us.

We will be asking you to do three things. First, we would like you to fill in some questionnaires. One is about driving and requires you to answer questions by ticking a box with your choice from a number of responses. You will be asked also to rate some scales by placing a circle around the appropriate number. There are no right or wrong answers for any of the questions, nor is it a test of you in any way. Another questionnaire asks some general questions about yourself. The only purpose of this is to help us understand and interpret the results of the study.

Second, we will ask you to do some tasks which we think may be related to driving. Again, these are not intended to be threatening and you will probably find them enjoyable and an interesting learning experience.

Finally, we will ask you to take part in a short practical driving evaluation which will be rated only for our research purposes. It is very important to remember that none of the information we get from you (including scores on the practical evaluation) can be used to affect your current driving status. The data we obtain will be collected and identified only by code numbers and will remain confidential to the researcher. We also ensure you that the results of the study are written up and published in such a way that no individuals are able to be identified.

If you agree to participate you will, of course, also have the right to withdraw from the research at any time.

APPENDIX N

INFORMED CONSENT FORM

I have read and understand the attached "Information to Subjects" and agree to take part in this research.

NAME:____

DATE:____________________

SIGNATURE

For taking part in the study, you are entitled to be personally informed of the final results. If you wish this to happen then please write your postal address on the back of this form.

APPENDIX O

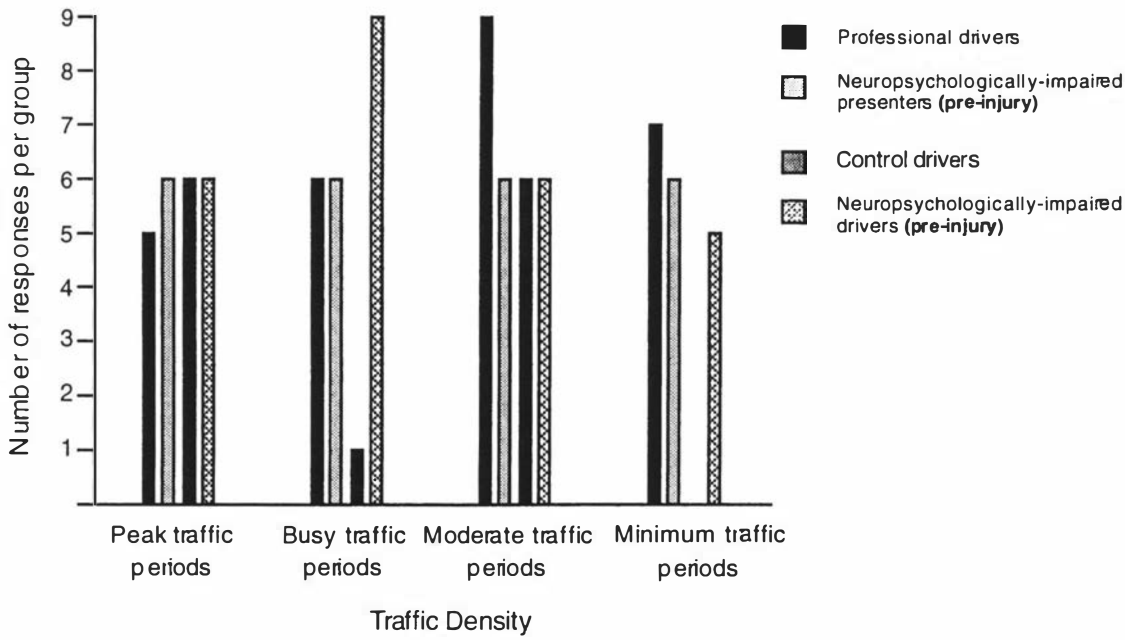

Figure 1. Driving patterns across the four subject groups: Traffic density

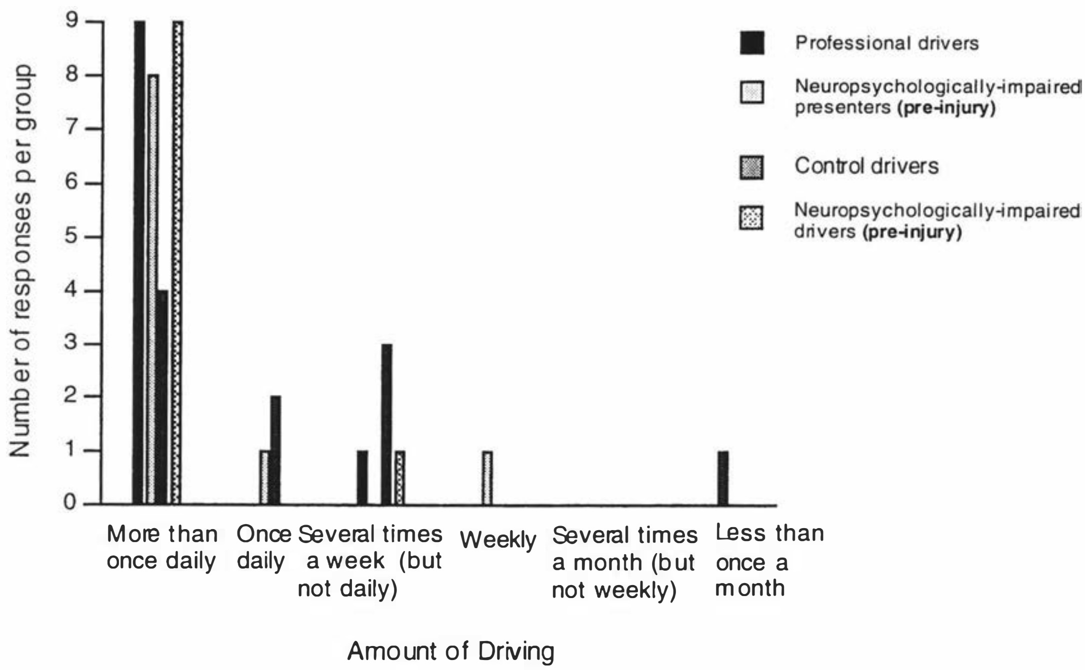

Figure 2. Driving patterns across the four subject groups: Amount of Driving

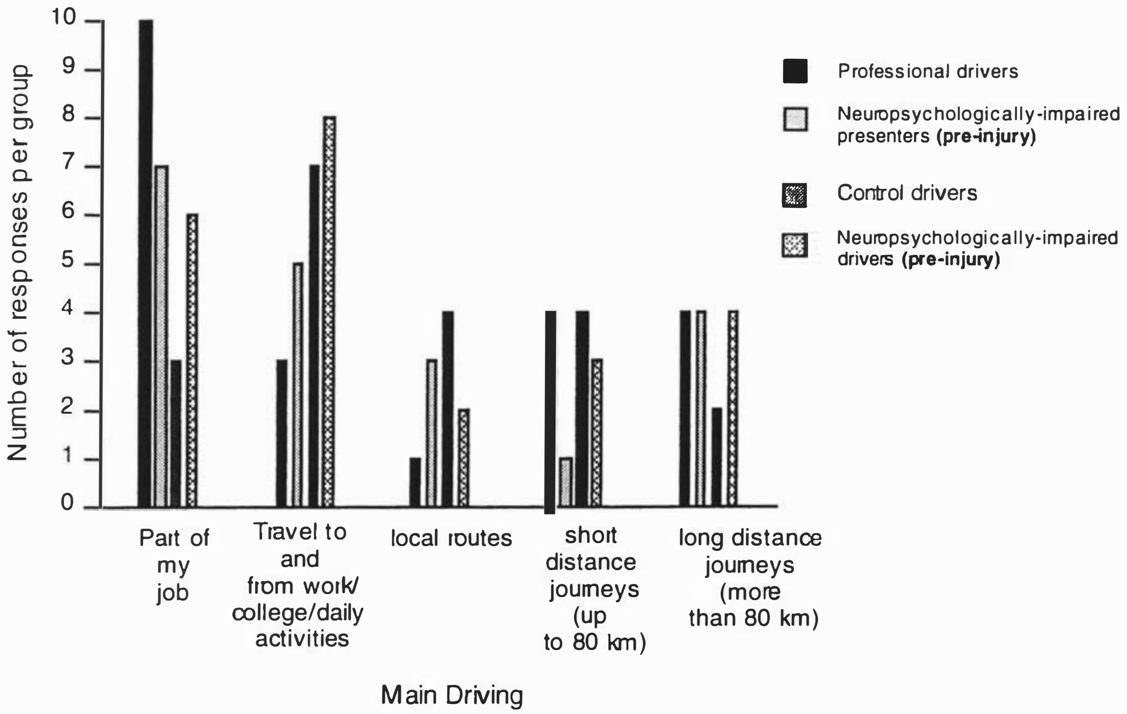

Figure 3. Driving patterns across the four subject groups: Main Driving

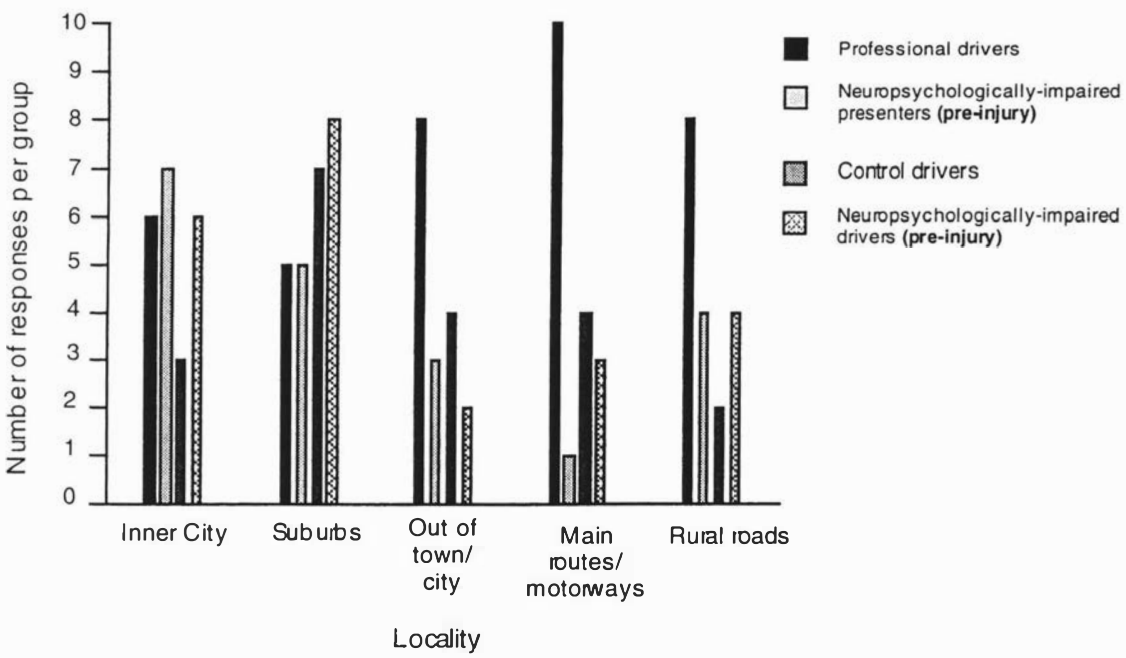

Figure 4. Driving patterns across the four subject groups: Locality

APPENDIX P

Table 1

Mean driver concepts rated on Semantic Differential Scales for Professional drivers

	MEAN (STANDARD DEVIATION)		
SCALES	"Very good driver"	"Average driver"	"Me as a driver"
Foolish-Wise	6.10 (0.74)	3.60 (1.08)	5.60 (0.85)
Unpredictable-Predictable	5.60 (0.97)	3.20 (1.14)	5.20 (0.92)
Unreliable-Reliable	6.00 (0.67)	3.80 (1.03)	5.20 (1.03)
Inconsiderate-Considerate	6.10 (0.88)	3.60 (1.17)	5.20 (1.23)
Dangerous-Safe	6.30 (0.82)	3.80 (3.89)	5.70 (1.34)
Tense-Relaxed	5.30 (1.1)	4.80 (1.03)	5.40 (1.17)
Irresponsible-Responsible	6.30 (0.48)	3.80 (1.40)	5.90 (0.99)

Table 2

Mean driver concepts rated on Semantic Differential Scales for Control drivers

	MEAN (STANDARD DEVIATION)		
SCALES	"Very good driver"	"Average driver"	"Me as a driver"
Foolish-Wise	6.44 (1.01)	4.11 (0.60)	4.90 (0.99)
Unpredictable-Predictable	6.33 (0.87)	4.22 (0.67)	5.20 (1.48)
Unreliable-Reliable	6.22 (1.09)	4.56 (0.53)	5.60 (1.08)
Inconsiderate-Considerate	6.33 (0.87)	3.78 (0.67)	5.30 (0.82)
Dangerous-Safe	6.44 (0.73)	3.89 (1.05)	5.20 (1.03)
Tense-Relaxed	5.56 (1.42)	4.56 (0.88)	5.20 (1.48)
Irresponsible-Responsible	6.78 (0.44)	4.11 (0.60)	5.80 (1.23)

Table 3

Mean driver concepts rated on Semantic Differential Scales for Neuropsychologically-impaired presenters: pre- and post-neurological damage.

SCALES		"Very good driver"	"Average driver"	"Me as a driver"
		MEAN (STANDARD DEVIATION)		
Foolish-Wise	Pre	5.89 (1.45)	4.22 (1.20)	5.33 (1.22)
	Post	5.78 (1.20)	4.00 (0.50)	4.90 (1.29)
Unpredictable-Predictable	Pre	5.67 (1.58)	4.00 (1.32)	5.22 (0.97)
	Post	5.56 (1.24)	3.67 (1.32)	4.50 (0.97)
Unreliable-Reliable	Pre	5.78 (1.48)	4.33 (2.00)	5.22 (1.09)
	Post	5.67 (1.00)	4.11 (1.69)	4.80 (1.23)
Inconsiderate-Considerate	Pre	5.89 (1.27)	3.67 (1.80)	5.44 (0.73)
	Post	5.78 (1.30)	3.90 (1.20)	5.00 (0.67)
Dangerous-Safe	Pre	5.67 (1.32)	4.11 (1.76)	5.56 (0.88)
	Post	5.89 (1.05)	4.11 (1.54)	5.10 (1.00)
Tense-Relaxed	Pre	5.56 (1.24)	3.33 (1.94)	5.22 (0.67)
	Post	6.00 (1.00)	3.89 (1.27)	5.00 (1.05)
Irresponsible-Responsible	Pre	6.33 (0.71)	4.11 (1.90)	5.78 (0.83)
	Post	5.78 (1.20)	4.22 (0.97)	5.40 (0.84)

Table 4

Mean driver concepts rated on Semantic Differential Scales for Neuropsychologically-impaired drivers: pre- and post-neurological damage.

SCALES		MEAN (STANDARD DEVIATION) "Very good driver"	"Average driver"	"Me as a driver"
Foolish-Wise	Pre	6.20 ((0.79)	3.90 (1.45)	5.30 (0.82)
	Post	6.20 (0.79)	3.80 (1.14)	5.40 (0.85)
Unpredictable-Predictable	Pre	6.10 (1.20)	4.00 (1.33)	5.20 (1.55)
	Post	6.40 (0.70)	3.50 (1.65)	5.20 (1.14)
Unreliable-Reliable	Pre	6.40 (0.70)	3.60 (1.51)	5.80 (0.42)
	Post	6.10 (0.88)	3.60 (1.78)	5.60 (1.08)
Inconsiderate-Considerate	Pre	6.30 (0.82)	3.50 (1.43)	5.90 (0.57)
	Post	6.20 (0.92)	3.40 (1.35)	6.00 (0.00)
Dangerous-Safe	Pre	6.30 (0.82)	4.10 (1.73)	5.60 (0.70)
	Post	6.30 (6.75)	3.60 (1.84)	6.10 (0.57)
Tense-Relaxed	Pre	6.20 (0.79)	3.90 (1.29)	5.40 (1.27)
	Post	6.20 (0.79)	3.60 (1.65)	5.00 (1.63)
Irresponsible-Responsible	Pre	6.30 (0.82(	4.00 (1.49)	5.70 (0.82)
	Post	6.10 (0.99)	3.50 (1.65)	6.10 (0.57)

APPENDIX Q

Table 1

Frequency of symptoms checked across the four subject groups

SYMPTOMS CHECKED	NUMBER OF SYMPTOMS Professional drivers	Neuropsychologically impaired presenters	Control drivers	Neuropsychologically impaired drivers
* Frequent tiredness.	0	5	2	7
* Dizziness.	0	2	1	2
* Near blackout spells	0	0	1	1
* Blackout spells.	0	0	0	0
* Loss of balance.	0	2	1	7
* Loss of mobility.	0	4	1	3
* Seizures.	0	0	0	0
* Eyesight problems.	0	6	2	5
* Hearing problems.	1	3	1	2
* Difficulty communicating.	0	1	1	4
* Difficulty understanding.	0	4	0	3
* Difficulty learning/ doing new things.	0	6	1	7
* Easily angered/ agitated.	1	5	0	7
* Easily frustrated.	0	3	1	6
* Feeling confused.	0	2	1	4
* Not always alert or watchful of things.	1	3	1	5
* Difficulty concentrating for more than a short time.	1	6	1	6
* Disturbed by loud noise, unexpected movements, TV, computer monitors or flashing lights, etc.	1	5	0	2
* Difficulty working things out	0	5	0	4
* Forgetfulness.	0	7	1	3
* Easily distracted.	3	5	2	7
* Loss of interest in things.	2	3	2	4
* Realising there are some things you can no longer deal with.	0	3	0	4
* Difficulty remembering.	1	7	1	5
* Often doing things without thinking about them.	1	4	3	3
* People telling you that you cannot do things like you used to.	1	3	1	6
* Easily upset.	0	4	0	6
* Difficulty correcting mistakes even when you know they are wrong.	0	1	0	3
* Feeling depressed.	0	4	1	4
* Unable to carry out plans that you make.	0	2	0	5

APPENDIX R

NOTE FOR ENCLOSED ASCII FILE

This file contains the raw data from which any statistical analyses were performed. Note that not all raw data were included in the final analyses, thus more pertinent variables were drawn from this file to be followed up with the more in-depth statistical procedures. The ordering of raw data in the enclosed ASCII file is as follows:

Data is presented by groups, each comprising ten subjects arranged vertically in the following order

Group 1. "A" = Professional Drivers
Subject 1

10

Group 2. "B" = Neuropsychologically-impaired Presenters
Subject 11

20

Group 3. "C" = Control Drivers
Subject 21

30

Group 4. "D' = Neuropsychologically-impaired Drivers
Subject 31

40

Data for each subject comprises one horizontal line. The order of variables from left to right are as follows:

in file "rawdata.dat"

age = subject age
newroadp = New Road Test total pattern score
search = Search subtest score for the New Road Test
speed = Speed subtest score for the New Road Test
direct = Direction subtest score for the New Road Test
aapat = Advanced Driver Assessment patterns
aaerror = Advanced Driver assessment total errors
driverat = Driving instructor rating (1-7)
r1 = driver self-rating scale foolish-wise dimension
r2 = driver self-rating scale unpredictable-predictable dimension
r3 = driver self-rating scale unreliable-reliable dimension
r4 = driver self-rating scale inconsiderate-considerate dimension
r5 = driver self-rating scale dangerous-safe dimension
r6 = driver self-rating scale tense-relaxed dimension
r7 = driver self-rating scale irresponsible-responsible dimension
symptom = number of reported symptoms
timesinc = time since neurological damage (months)
mmse = Mini Mental State Examination score
bvrtcorr = Benton Visual Retention Test -Revised, number correct score
bvrterr = Benton Visual Retention Test -Revised, error score

money = Standardised Road Map Test of Direction Sense score
moneysec = Standardised Road Map Test of Direction Sense completion time
scfg = Southern California Figure Ground Perception Test score
strword = Stroop Colour-Word Test, Word score (# completed in 45 sec)
strcolor = Stroop Colour-Word Test, Colour score
strcw = Stroop Colour-Word Test, Colour-Word score
traila = Trailmaking Test, Trails A completion time (sec)
trailb = Trailmaking Test, Trails B completion time (sec)
rtph = reaction time, preferred hand (sec)
rtnph = reaction time, non preferred hand
rtphpf = reaction time, preferred hand - preferred foot
rtnphpf = reaction time, non preferred hand - preferred foot
rtpf = reaction time, preferred foot
licence = time licensed, controls, questionnaire response option 1-7
lib4 = time licensed before neurological damage, questionnaire option 1-7
drivsinc = time driving since neurological damage, questionnaire option 1-5
beginhow = how subjects resumed driving, questionnaire response option 1-4
moreless = driving change since neurological damage, questionnaire option 1-5
oftenb4 = driving frequency before neurological damage, questionnaire option 1-6
oftennow = driving frequency since neurological damage, questionnaire option 1-6
defensiv = defensive driving course, 1=yes, 2=no

in file "data2.dat"

morient = Mini Mental State Examination, Orientation subtest score
mrecall = Mini Mental State Examination, Recall subtest score
mattn = Mini Mental State Examination, Attention subtest score
mlang = Mini Mental State Examination, Language subtest score
right = Benton Visual Retention Test -Revised, right-sided errors
omission = Benton Visual Retention Test -Revised, omission errors
burtdir = Benton Visual Retention Test -Revised, distortion errors
persev = Benton Visual Retention Test -Revised, perseveration errors
rotat = Benton Visual Retention Test -Revised, rotation errors
mispl = Benton Visual Retention Test -Revised, misplacement errors
left = Benton Visual Retention Test -Revised, left-sided errors

Note: Any missing values in a data set are indicated by " . " and reasons for any individual cases of missing data have been explained in the preceding text (Chapters 8-11). Clearly, some data was relevant only to subjects who.had sustained neurological damage, hence, the missing values for Professional and Control Driver groups on these variables..

For the multiple linear regression analyses, all groups data were treated together in the first instance, then, as combined neuropsychologically-impaired (brain =1"Damaged") and neuropsychologically-intact (brain =0 "OK").