DRIVING ASSESSMENT FOR INDIVIDUALS WITH BRAIN IMPAIRMENT

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DECLARATION

The research presented in this thesis was undertaken in the Department of Medicine at the University of Sydney, under the supervision of Associate Professor Ian Cameron. Stephen Bowden, PhD, from the Department of Psychology, University of Melbourne, was my co-supervisor. The work presented in this thesis is, to the best of my knowledge and belief, original. This thesis has not been submitted in part or whole for a degree at any other university. Full acknowledgement has been made where the work of others has been cited or used.

ABSTRACT

Many people who have suffered brain impairment - whether acquired or progressive - wish to continue driving as a means of maintaining their mobility and independence. The issue of how to assess competence to drive in traffic among individuals with brain impairment is the focus of the research described in this thesis. A review of the literature indicated that both off-road and on-road approaches have been used to assess driving competence. Off-road approaches include medical examination and neuropsychological testing. Although doctors frequently have a legal responsibility for assessing competence to drive, there was a paucity of data concerning the predictive validity of a medical examination in determining driver skill. Similarly, a clear and consistent relationship between performance on cognitive measures and driving was not evident in the literature. Hence, both of these off-road approaches to determining driving competence required further investigation. On-road approaches to determining driving competence have varied considerably in the nature and complexity of the driving test, driving environment, scoring of driving, and the method in which a final decision regarding driving competence was reached. The reliability and validity of on-road driving assessment also required further research, as did the nature of driving errors committed during the driving test.

A retrospective audit of a driving assessment program, described in Chapter 3, found that a substantial proportion of people (44%) with significant disability were able to complete the program and resume driving. However, the design of the driving assessment program precluded an examination of false negative error rates for the off-road medical and neuropsychological assessments, as not all subjects proceeded to an on-road assessment. Moreover, assessors were not blinded to the results of preceding stages of assessment, and

may therefore have been influenced by the judgements of other assessors. To address these methodological issues a prospective study was conducted in which all subjects proceeded to an on-road driving assessment. In this study, described in Chapter 4, 153 subjects with acquired brain impairment, predominantly traumatic brain injury (TBI) or cerebrovascular accident (CVA), proceeded through each stage of a driving assessment program consisting of medical, neuropsychological and on-road driving assessment. In the on-road driving assessment, one of four driving test routes was used. Assessors were blinded to the results of preceding stages of assessment. Based on their assessments, the doctor and neuropsychologist were each required to predict on-road driving performance, graded as pass, borderline or fail. Results indicated that the Right CVA group and Other CVA group were less likely to pass the driving assessment program than the other diagnostic groups. Furthermore, the Right CVA group was likely to be less successful than the Left CVA group, when these two groups were considered alone. When all demographic, medical and neuropsychological variables were examined in a logistic regression model, the variables diagnosis, duration of diagnosis, finger/nose coordination and three neuropsychological test scores, were found to be significantly associated with the outcome measure, independent of other variables, with a correct classification rate of 78%. The doctor's and neuropsychologist's predictions of on-road performance were not significantly related to the on-road result. Noteworthy also was the failure to find a significant predictive relationship between Mini Mental Status Examination (MMSE) score and the outcome measure. The on-road driving test was found to have high internal reliability.

Interestingly, during the course of data collection for the prospective study described in Chapter 4, no referrals to the driving assessment program were received for individuals with dementia or other forms of progressive brain impairment. A survey of city and rural Aged Care Assessment Teams (ACAT) in New South Wales (NSW) and the Australian Capital Territory (ACT) was undertaken to investigate clinical practice regarding driving by individuals with a diagnosis of dementia, including Alzheimer's Disease (AD). This is described in Chapter 5. Evaluation of fitness to drive was found to be a largely medically based assessment in both city and rural settings, generally consisting of a clinical examination by a geriatrician and administration of the MMSE. Functional evaluations of actual driving competence were conducted by less than half of the assessment teams. Despite the commonly progressive nature of most dementias, fewer than half of the ACAT's surveyed reviewed clients who had been found at first assessment to be safe to continue to drive. These findings raised questions about the on-road driving performance of drivers diagnosed with dementia, and the predictive validity of a medical examination (including administration of the MMSE) and neuropsychological testing for on-road driving performance by drivers with AD and other dementias.

Chapter 6 describes a subsequent prospective study of 19 subjects diagnosed with probable AD, which investigated the relationship between medical variables including MMSE score, neuropsychological variables, and open road driving performance as measured on a standardized road test. The research questions of this study were similar to those of the study described in Chapter 4, investigated in a population with progressive brain impairment. In the AD driver study, a fully standardized driving test and scoring protocol were used. The results indicated few occurrences of abnormal medical variables, and moreover, the doctor's prediction of driving competence was not significantly associated with the outcome measure of final on-road result. MMSE score was, however, a significant predictor of the final on-road result. Although a cut-off score of 22 on the MMSE would have resulted in the fewest false positive and false negative predictions of driving performance, the specificity and sensitivity of the MMSE were inadequate to recommend use of the MMSE for individual determination of driving competence. Neither the neuropsychologist's prediction, nor the neuropsychology test scores were associated with the final on-road result. The high internal reliability of the on-road driving test, and the association between the expert rating of driving performance and the objective score of correct driving actions (shared common variance of 28%), suggest that a standardized road evaluation is a valid means of determining driving competence for people with AD. As there were no accidents or dangerous events, it was concluded that older drivers with a range of cognitive abilities can be safely and reliably evaluated by a road test. The driving test should include recording of hazardous errors.

Recommendations for future research are discussed in Chapter 7. From this series of studies, a standardized on-road driving assessment for ascertaining driving competence is suggested for individuals with acquired or progressive brain impairment. With likely resource constraints however, the development of screening protocols for identification of individuals most at risk of unsafe driving is recommended. The MMSE shows promise for use as a screening protocol within settings such as a dementia clinic. The 'expert model' of prediction of on-road driving performance for drivers with acquired brain impairment, described in Chapter 4, is similarly promising as a means of off-road screening of drivers with non-progressive brain impairment.

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PUBLICATIONS ARISING FROM THIS THESIS

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Fox, G. K., & Bashford, G. M. (1997). Driving and dementia: balancing personal independence and public safety. Medical Journal of Australia, 167, 406-407.

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GLOSSARY

- Doctor: For the purposes of this thesis, the term doctor is used to refer to a qualified medical practitioner.

- Traumatic Brain Injury (TBI): TBI is the most common cause of brain damage (Lezak, 1995). Commonly caused by motor vehicle accidents, falls, assaults and work related accidents.

- Cerebrovascular accident (CVA): Disruption of brain function arising from pathological processes related to blood vessels, primarily due to ischaemia or haemorrhage.

- Alzheimer's Disease (AD): The most common form of dementia, characterised by progressive degenerative neuronal changes within the cerebral hemispheres with concomitant progressive global deterioration of intellect and personality (Lezak, 1995).

- Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975): A formalised mental status examination that briefly tests a restricted set of cognitive functions.

- Trail Making Test: This is a test of complex visual scanning and conceptual tracking. It is given in two parts. Part A requires the drawing of lines to connect consecutively numbered circles on one worksheet, while Part B requires connecting the same number of consecutively numbered and lettered circles on another sheet by alternating between the two sequences (Lezak, 1995).

- Benton Visual Retention Test: A visual recall test, each item of which consists of a three-figure design. Administration A was used for the studies detailed in the following chapters, which requires a ten second exposure to each item with immediate recall by drawing.

- Judgement of Line Orientation: This test examines the ability to estimate angular relationships between line segments by visually matching angled line pairs to 11 numbered radii arranged in a semicircle (Lezak, 1995).

- Visual Form Discrimination Test: A multiple-choice test of visual recognition. Each item consists of a target set of stimuli and four stimuli sets below the target, one of which is a correct match (Lezak, 1995).

- Block Design (BD): A subtest of the Wechsler Adult Intelligence Scale Revised (WAIS-R). A construction test where the subject is required to use the blocks to construct replicas of block constructions, either made by the examiner or pictured in smaller scale (Lezak, 1995).

- Digit Symbol Substitution Test (DSS): A subtest of the WAIS-R. The task is to insert into a blank square underneath a numbered square, the correct symbol for that number, according to a key printed above. The subject is requested to work as quickly as possible, and is allowed 90 seconds.

- Picture Completion (PC): A subtest of the WAIS-R. The subject is shown 20 incomplete pictures of human features, familiar objects, or scenes, arranged in order of difficulty, and asked to say which important part of the picture is missing (Lezak, 1995).

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CHAPTER 1

ASSESSMENT OF DRIVING COMPETENCE AFTER BRAIN IMPAIRMENT: REVIEW OF OFF-ROAD APPROACHES

1.1 Background

Many people who have suffered brain impairment—whether static, progressive or resolving—wish to continue driving to maintain mobility and independence. In highly motorised societies, driving is frequently considered as another activity of daily living. Health care professionals are often called upon to determine whether patients are fit to drive. The issues of who should be permitted to drive following brain impairment and how this should be evaluated are extremely challenging. These issues are the focus of this thesis.

Motor, sensory and cognitive deficits resulting from brain damage may be sufficiently disabling to prevent participation in many activities previously undertaken independently, including driving. Driving a car is a complex task that requires skills and abilities that may be impaired by cerebral lesions and diseases. These skills include visual scanning of traffic and environment, perception and orientation, mental tracking, information processing, judgement and decision making capacity, and executive function (Van Zomeren, Brouwer, & Minderhoud, 1987). The incidence of traumatic brain injury (TBI) has been estimated at 180-200 per 100,000 population per year, with approximately 18% of cases being moderate to severe injuries (Tate, McDonald, & Lulham, 1998). Assuming an Australian population of 18 million, this equates to between 32,400 and 36,000 cases of TBI each year, with 5,800 to 6,500 moderate to severe cases for whom resumption of driving may be a rehabilitation issue. Drawing on the results of a community study in Perth, Western Australia, the annual incidence in Australia of first-ever cerebrovascular accident (CVA) has been estimated as 175 per 100,000 population, with as many as 75% of CVA survivors having persisting significant disability at one to three weeks after CVA (Mykyta, 1992). Although these figures suggest that a significant number of people who suffer brain impairment have a residual disability that might affect driving ability, few studies have examined driver relicensing rates or the resumption of driving among brain impaired patients. In three studies located, relicensing rates of 48% to 62% were reported among patients with brain impairment following rehabilitation (Hopewell & Price, 1985; Quigley & DeLisa, 1983; Shore, Gurgold, & Robbins, 1980). Approximately half the brain impaired patients in rehabilitation settings might therefore be expected to wish to resume driving, and to require assessment of driving competence.

For another group of individuals with brain impairment, the question is not when to resume driving, but rather when to cease. Individuals with progressive cognitive impairment, such as in the case of dementia, may face different issues with regard to driving, but share a common need for a means of determining their competence to drive. The prevalence of dementias such as Alzheimer's Disease increases after the age of 65 and has been estimated to be as high as 47% in those aged 85 years and older (Bylsma, 1997). Thus, a potentially large number of people with cognitive impairment, both static and progressive, may require assessment of their ability to drive. As Brouwer and Van Zomeren (1992) have noted, in most countries the criteria for assessing fitness to drive following brain impairment are quite imprecise, and are often based on a clinician's common-sense reasoning and the face validity of assessment instruments, rather than on empirical evidence. For example, in

1993 the Roads and Traffic Authority in the State of New South Wales in Australia published guidelines for medical practitioners regarding driving following TBI. These guidelines suggested that behavioural and perceptual problems required careful assessment, usually by a neuropsychologist, before a return to driving was considered. Furthermore, driver retraining and on-road assessment may be required before a recommendation can be made about fitness to drive (Roads and Traffic Authority, 1993). In the case of CVA, the guidelines suggest that the overall mental and physical condition be assessed, following an adequate period of recovery and rehabilitation. While visual field defects may be incompatible with driving, hemiparesis would not necessarily preclude a return to driving if appropriate modifications could be made to the vehicle (Roads and Traffic Authority, 1993). Thus while the guidelines suggest further assessment prior to a resumption of driving, little information is given about the nature or type of such assessment.

Brouwer and Withaar (1997) have offered an operational definition of fitness to drive, involving: (i) a low probability of sudden and unpredictable lapses of control of behaviour, (ii) sufficient perceptual, cognitive and motor abilities for the acquisition and application of important driving skills, and (iii) sufficient social judgement and social responsibility. More commonly, however, fitness to drive is defined in relation to licensing standards for driving.

A review of the literature showed that this topic first gained some prominence with the appearance in 1971 of a widely cited article on driving following brain impairment (Bardach, 1971). The studies reviewed were those published from 1971 to the present, identified through citation, Medline and CINAHL search.

Approaches to assessment of driving ability following brain impairment have included off-road and on-road methods. Off-road approaches include medical or clinical examination, psychological and perceptual assessment, administration of a mental status examination, testing in a driving simulator, or driving a vehicle in a closed course such as a parking area. On-road methods vary from relatively brief drives around hospital or university grounds, to standardized routes encompassing a range of traffic densities and driving manoeuvres. Before reviewing assessment approaches aimed at identifying which individuals with brain impairment can drive safely, models of driving behaviour will be considered.

1.2 Models of Driving Behaviour

According to a recent review, no comprehensive model of driving behaviour has been developed (Ranney, 1994). An adequate model of driving behaviour should contribute to the understanding of driving, predict driver behaviour and generate testable hypotheses. Much of the research has focused on accident-causing behaviours, rather than on everyday driving, and this has led to a general lack of success in identifying predictors of safe driving (Ranney, 1994). Ranney (1994) noted that this emphasis on accidents and accident-causing behaviour has led to some confusion about whether driving models should be able to explain everyday driving, or accident-causing behaviours, or both. Early models of driving tended to regard driving as a perceptual motor skill, with accidents being considered as failures of driver skill (Evans, L., 1991). The hypothesised construct of driving skill was thought to be improved by practice and required psychomotor abilities such as visual scanning, attention and reaction time (Hopewell & Van Zomeren, 1990). However, the skill model of driver behaviour is not borne out by empirical evidence. Driver training and education have not been shown to alter accident rates significantly, and young male drivers with optimal perceptual motor skills and interest in driving also have the highest accident rates. Furthermore, high skill drivers also have above average accident rates (Evans, L., 1991). Despite the contrary evidence, the notion of driving as involving a single skill is pervasive. In combination with the concept that knowledge of traffic rules is important, the single skill conceptualisation of driving has been the basis for nearly all state driver licensing examinations (Hopewell & Van Zomeren, 1990). Accident statistics, however, clearly indicate that drivers do not always drive as they did during their licence test, suggesting less than optimal predictive validity for licence tests (Mihal & Barrett, 1976). For example, in the State of North Carolina, 16 year old licensed male drivers have a 20-25% crash rate in their first year of driving (Waller, 1988).

Some models of driving behaviour have attempted to find predictors of accident involvement. Early attempts using visual tests and reaction time as predictors found only weak relationships with accidents, possibly because drivers can compensate for deficiencies in these abilities (Ranney, 1994). Mihal and Barrett (1976) investigated the predictive validity for accident involvement of three categories of information processing measures (perceptual style, selective attention and perceptual motor reaction time). By retrospectively examining the accident records of a group of commercial drivers, they found that the predictors of field dependence, selective attention (based on dichotic listening), and complex reaction time were significantly related to accident involvement. More recently, an aspect of visual attention, termed 'the useful field of view', was found to be a significant predictor of retrospective accidents among older subjects (Ball & Owsley, 1991). While apparently supporting the role of selective attention in the driving task, these two studies evaluated different mechanisms of attention, each dependent on either auditory or visual modalities. This therefore raises questions about the generalizability of the results for selective attention. From these studies it is unclear whether these two modalities of selective attention, auditory and visual, are predictive of driving performance, and if so, whether one modality is a better predictor. Moreover, models such as these, where a specific aspect of perceptual functioning is investigated, are unable to explain the dynamics of control involved in driving (Ranney, 1994).

A problem for studies using accident rates as a criterion measure is that accidents are relatively rare events. This means that many studies may have poor statistical power, with a low probability that they will detect statistically significant differences in rates. Accidents may also have multiple complex causes, some of which may not be related to individual driver factors. Furthermore, errors committed by drivers do not result in accidents on every occasion. The stability and reliability of accident data have been queried, in turn raising the question of the validity of retrospective accident studies (Ranney, 1994). For this reason, prospective data are preferable. The weakness of accident data as a criterion measure has been noted previously, yet alternatives are neither commonly used nor widely available (Ranney, 1994).

Other approaches to modelling driving behaviour, such as the motivational models of driving, have taken a functional rather than a skill based perspective. These models assume that driving is self-paced and that drivers select the amount of risk they are willing to tolerate in any given situation (Ranney, 1994). Risks, together with potential outcomes are seen as the main factors influencing behaviour, together with the goals and expectations of the journey. Motivational models focus on driver behaviour rather than on the level of driver skill in a given traffic situation, consistent with the premise that observed on-road driving may not necessarily reflect the capabilities of the driver (Ranney, 1994). The driver is seen as an active, rather than passive participant in inherently variable driving situations. Several examples of motivational models of driving are discussed by Ranney (1994), who noted that motivational models imply that if driving is largely determined by motives, goals and expectations, the study of driving ability in a laboratory, driving simulator or closed course may be misguided, since in these situations there is no fundamental goal to the driving episode. Much of the criticism of motivational models concerns the lack of detail about relevant goals and motivations, making validation complex because of difficulty in generating testable hypotheses (Ranney, 1994).

Galski and colleagues (1992) proposed what they termed a 'cybernetic' model of driving, with the aim of diagnosing the cause of driving difficulties in subjects with brain damage. The model consists of several interactive components, directed by an information processing mechanism termed the general driving program. The general driving program comprises a dynamic memory containing acquired knowledge and driving experience, into which new driving situations may be added. The general driving program is hypothesised to contain an executive component that directs the general operation of the vehicle. In addition there is a specific driving program that is volitional and implements a particular driving plan, specifying destination, route instructions, travel time, weather and road conditions (Galski, Bruno, & Ehle, 1992). The general driving program requires sensory information, obtained from scanning and attentive processes that are under the general driving program's direction. Integration of this sensory information is conducted by another component, termed the calculation and construction co-processor, which develops a dynamic, three dimensional view using environmental data relevant to driving, such as distance, depth, spatial relationships, velocity and gradients of motion (Galski, Bruno, & Ehle, 1992). This sensory information is passed to the general driving program for action and storage. The general driving program directs another component, the motor output, to physically operate the vehicle. Lastly, a resident diagnostic program assesses the integrity and functioning of the entire system at all times, including cognitive-perceptual-physical skills, executive processes such as planning and goal setting and psychological factors such as personality, emotions, and beliefs (Galski, Bruno, & Ehle, 1992).

The driving model of Galski and colleagues (1992) includes aspects of the skill based and motivational models of driving, and demonstrates some of the difficulties of both types of models. The cybernetic model does not identify a mechanism for switching control of driving and attentional resources between the different components of the model, nor does it indicate what controls the general driving program, a difficulty with specification of control mechanisms common to many information processing models of behaviour (Fodor, 1986). Galski and colleagues (1992) suggested that the utility of their model was demonstrated by the amount of variance (93%) of an on-road driving evaluation that was accounted for by a pre-driver evaluation. The pre-driver evaluation consisted of a battery of psychological tests, a simulator evaluation and a parking lot driving score. An on-road driving performance score, used to determine fitness to drive, was derived from an index of driving skills ranked in order of presumed importance by a driving instructor. Although this research seems promising, the validity of the driving instructor's ratings, and of ranking driving skills in terms of presumed importance, have not been established. Galski and colleagues (1992) selected psychological tests based on postulated measurement of aspects of the cybernetic model of driving. They suggested that the finding that 64% of the variance in the on-road driving test could be accounted for by the psychological tests showed that on-road driving could be understood and predicted in terms of the cognitive processes that these tests were thought to measure. However, as Brouwer and Withaar (1997) point out, with a sample of 35 brain damaged patients, Galski and colleagues selected the 15 variables with the highest correlation with the criterion variable of the on-road driving test, from 46 potential predictors. This statistical analysis is characterised by insufficient numbers of subjects for each predictor in the regression analysis.

Michon (1979, 1989) has proposed a descriptive model with a three level hierarchy to explain the cognitive control of driving. Multitasking is considered a basic feature of the driving task, with driving characterised as involving concurrent activity at the three levels. Control may be switched between levels, according to the experience of the driver and the familiarity of the driving situation. The three levels are the strategic level, the tactical level and the operational level. There are three associated aspects of risk. At the strategic level, time pressure is low, and planning is an important feature. For example, decisions are made about choice of route, or the decision may be made not to drive at all, but to use another form of transport. At this level, dealing with danger predominantly consists of risk acceptance. The driver, while being aware of risk, nevertheless chooses to engage in a hazardous situation or activity (Michon, 1979). Hence, strategic traffic decisions by the driver may allow compensation for lower level perceptuo-motor impairment, for example by avoiding rush hour traffic (Brouwer, Rothengatter, & Van Wolffelaar, 1988). The tactical level concerns behaviour and decisions in traffic, such as adapting speed, or switching on headlights when visibility is reduced by rain. Time pressure for tactical traffic decisions is intermediate, and the associated risk involves the performance of activities that will increase the objective risk of a danger becoming manifest (Michon, 1979). Compensatory behaviours by drivers may also operate at the tactical level, such as adjusting safety margins during merging with traffic in poor visibility. Lastly, the operational level involves the execution of the basic actions of driving, such as steering or braking. Time pressure may be high, and the risk involves coping with threats by performing appropriate manoeuvres aimed at avoiding acute danger (Michon, 1979).

Michon's model (1979) is hierarchical in that decisions made at a higher level determine the cognitive load at a lower level, and driving behaviours may be embedded or nested. For example, a tactical decision to change lanes requires a series of actions at the operational level. The different levels of decision making will require different types of information. While strategic decision making can be largely memory driven, manoeuvring and vehicle control decisions are based on the immediate driving environment and are thus data driven (Ranney, 1994). It is probable that an on-road assessment of driver competence will not elicit much information about strategic decision-making, because such decisions are usually made before actual driving starts (Van Zomeren, Brouwer, & Minderhoud, 1987). Aspects of the driver's motivation may also relate to the different levels of control. For example, in addition to the general purpose of the journey, situations encountered en route may require the formulation of short term goals with necessary adjustments at the tactical level, such as reducing speed or operating windscreen wipers during a rain storm. Uncertainty, arising from an unexpected event or associated with conflict between motives at different levels of control, is proposed as the mechanism for eliciting compensatory behaviour, resulting in a reallocation of cognitive resources (Ranney, 1994). Michon's model thus provides both provision for switching control between the various levels of driving and a mechanism for switching (Michon, 1979). Approaches to the assessment of driver competence in individuals with brain impairment will be discussed with reference to Michon's (1979, 1989) model of driving. Although as a conceptual model of the driving task, Michon's model (1979) has not been rigorously empirically tested, this model is widely cited in the literature concerning driving assessment in subjects with brain impairment, and has made a significant contribution to the conceptualisation of the driving task.

1.3 Approaches to Determining Driver Competence Following Brain Impairment: Off-Road Assessment

1.3.1 Medical Examination

As part of the medical care of their patients, doctors have a responsibility to identify and treat, where possible, conditions that may pose a threat to safe driving (Reuben, 1993). However, a survey of doctors in the United Kingdom regarding laws and recommendations concerning fitness to drive for people with certain medical conditions, showed poor knowledge in several areas (King, Benbow, & Barrett, 1992). An American survey concerning doctors' knowledge of, and attitudes toward, driving by the elderly showed that a majority of doctors felt it was their legal responsibility to assess their patients' capacity to drive. However, the doctors surveyed were generally uncertain as to how to recommend driving restrictions, and were unaware of the American Medical Association's driving guidelines (Miller & Morley, 1993). In Australia, various state authorities have published guidelines to assist medical practitioners in assessing the fitness of their patients to drive safely. These include the Roads and Traffic Authority of NSW (1993), VicRoads in Victoria (1994), and Queensland Transport (1994). However these guidelines do not specify methods for assessing the driving capability of patients with brain impairment, but instead state only that such assessment may be required.

Reuben (1993) has stated that scientific evidence is lacking to support the notion that a doctor's evaluation can correctly identify the safe older driver. Indeed, a review of the literature failed to locate any studies that had examined the efficacy of medical assessment in correctly distinguishing safe from unsafe drivers among subjects with brain impairment, even though in most countries this task legally remains a medical responsibility. While doctors have a legal responsibility to assess safety to drive in patients with brain impairment, there is a lack of information to assist them in this process. The predictive validity of a medical examination in determining driver fitness for patients with brain impairment requires further investigation. This would then allow more specific guidelines to be provided to doctors who are required to undertake this task.

In the medical assessment of driving fitness, it has been recommended that doctors assess aspects of vision, hearing and reaction time; stigmata of severe coronary, pulmonary, renal, hepatic or neurological disease; cognitive function (using global measures such as the Mini Mental Status Examination (MMSE)); motor and joint deficits; and medications (Carr et al., 1991; Odenheimer, 1993; Reuben, 1993; Reuben, Silliman, & Traines, 1988). Co-morbidity is an important issue, particularly in the case of elderly people and people with brain impairment, where, for example, motor or visual dysfunction may be present with cognitive dysfunction, with the potential for additive risk of unsafe driving.

1.3.2 Psychological Assessment and Mini Mental Status Examination

Many of the earlier studies of psychological factors and driving ability tended to describe impairments which were assumed to impact on driving ability. For example, Gurgold and Harden (1978) suggested that deficits in figure ground perception, spatial relationship perception, ocular pursuit, and vertical and horizontal perception might interfere with the ability to drive safely. Cognitive deficits such as deficient judgement, poor reasoning, inability to follow directions and inability to retain directions were also thought to affect safe driving. Gurgold and Harden (1978) recommended the assessment of these deficits through tests such as the Space Visualisation Test (part of the Southern California Sensory Integration Tests) and the Frostig Developmental Test of Visual Perception. The contributions of perceptual or cognitive deficits to driving performance were not formally investigated, however, suggesting an apparent belief in the face validity of the assessment of these perceptual and cognitive abilities in determining driver competence.

A number of studies have examined the relationship between psychological tests and a criterion measure of driving performance. Results of these studies have led to conflicting interpretations. Table 1.1 provides details of the methods and results of the studies reviewed.

TABLE 1.1 Studies of psychological assessment in relation to on-road driving. A summary of the setting, sample, specific psychological measures and results of studies examining the relationship between psychological tests and a criterion measure of driving performance.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Sivak et al., 1981. USA. Health service agencies prospective cohort study	n=41. 23 brain damage subjects, 8 spinal cord injury subjects, 10 normal controls	Ayres Space test, Motor Free Visual Perception Test, WAIS: PC, A, DS, V, PA. Rod-and-Frame, S. California Figure-Ground Visual Perception Test, SDMT, PM, Titmus Vision Tester, Choice RT	Different perceptual/cognitive tests were predictive of driving performance by persons with and without brain damage. PA and PC predictive for subjects with brain damage.
Gouvier et al., 1989. USA. Rehabilitation facility prospective cohort study.	n=25. 10 brain impaired subjects, 7 spinal injury subjects, 8 normal controls.	WAIS: PA, BD, DSS, A and PC. Motor Free Visual Perception Test, Baylor Adult Visual Perceptual Assessment, TMT A & B, SDMT, Visual RT and visual search tasks, DPT	High correlations between all psychometric predictors and driving performance. Concluded that Oral SDMT and DPT could screen for subjects who would be unsafe in on-road evaluation.
Engum et al., 1988. USA. Rehabilitation facility cohort study.	n=94 neurologically impaired individuals with various diagnoses	Cognitive Behavioural Drivers Inventory-battery of computerised tasks adapted from Bracy's Cognitive Rehabilitation Programs, WAIS-R: PC, DSS, TMT A & B	Subjects who passed the road test had better overall CBDI scores than those who failed or who were not allowed to take the road test.
Engum et al., 1989. USA. Prospective cohort, rehabilitation facility.	n=81 subjects with brain impairment	As above	Rank correlation between CBDI result and road test outcome was significant ($p<.002$). PC and TMT B were not good predictors of road test performance.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Rothke, 1989. USA. Retrospective cohort, rehabilitation facility.	n=18 subjects with brain impairment	WAIS-R, WMS, Halstead-Reitan Neuropsychological Battery.	Three significant differences between subjects passing and failing driving evaluation evident on psychological measures: verbal delayed recall of WMS lower for those failing driving test, those passing the driving test were faster on two measures of the TPT time
Kumar et al., 1991. USA. Follow up of subjects following participation in driver training program	n=16 subjects, all male, who completed the driver training program	MMSE, BDI, Barthel Index, Porch Index, WAIS: DS, PC, PA, BD. TMT A&B	Significantly lower performance on DS, PC, PA, BD and TMT A for those restricting their driving and those no longer driving compared to those driving without difficulty.
Brooke et al., 1992. USA. Hospital based cohort with age-matched controls.	n=20 (13 closed head injury subjects, 7 controls)	TMT A&B, TPT, WMS, WAIS-R	Significant correlation between sum of rated scores from TPT and TMT, and driving test outcome ($r = .44$). Difference between VIQ and PIQ, and difference between BD and other performance tests of WAIS-R not related to quantified driving score or driving test outcome.
Galski et al., 1990. USA. Rehabilitation facility retrospective study.	n=37 subjects with cerebral damage	Pre-driver evaluation: BVRT, inattention, cancellation test, left peripheral vision, figure-ground test, impulsivity, inductive reasoning test, depth perception, BD, RT, picture interpretation test, DS, Hooper Visual Organisation Test, distractibility, right peripheral vision, ability to follow directions, anxiety, confusion, slowness, Traffic situations test, hostility	Four items significantly predicted pre-driver evaluation outcome - BVRT, cancellation test, left peripheral vision and behavioural measure of inattention. Neither pre-driver evaluation outcome nor any individual items of pre-driver evaluation were associated with driving test outcome.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Galski et al., 1992. USA. Driver rehabilitation facility prospective cohort.	n=35, traumatic brain injury (TBI) and cerebrovascular accident (CVA)	TMT A&B, Stroop Color and Word Test, Double letter and double symbol cancellation tests, Alternating Attention test, PMT, WAIS-R: DS, DSS, BD, VFDT, RCFT, RPM, Booklet Category Test, Token Test, WMS-R Logical Memory and Verbal Paired Associates.	64% of variance in on-road driving test accounted for by 8 psychological tests: TMT A, RCFT, PMT, VFDT, Double letter cancellation test, WAIS-R BD, RPM (errors).
Galski et al., 1993. USA. Driver rehabilitation facility prospective cohort.	n=106. (TBI=58, CVA=48)	WAIS-R: BD, DSS; Double letter cancellation test, PMT, RPM, RCFT, RT, TMT A and VFDT.	Discriminant analysis of psychological tests for on-road driving test outcome showed sensitivity of 71% and specificity of 87%.
Van Zomeren et al., 1988. The Netherlands. Prospective cohort.	n=9 male TBI	15 word test, BVRT, Tachistoscope, WAIS: PC, PA, DS; TMT A&B, Bourdon dot cancellation task, Stroop Color Word Test, Visual four choice RT, Minnesota rate of manipulation test, finger tapping.	No correlations found between psychological test scores and actual in-traffic driving.
Van Wolffelaar et al., 1990. The Netherlands, prospective cohort.	n=35, 20 TBI subjects, 15 controls	RT, Minnesota rate of manipulation test, TMT A, Tower of London test, and Adaptive Tracking task.	Only two scores (Tracking sidewind and Tracking learning) were significantly associated with the on-road driving test score. Multiple regression analysis showed that driving experience, time since injury and a learning factor together accounted for 67% of variance in on-road driving test.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Hartje et al., 1991. Germany. Rehabilitation facility prospective cohort.	n=65 (35 aphasic, 29 non-aphasic)	Overlapping Lines, Tachistoscopic perception of traffic scenes, complex RT, simple RT, cancellation task and general intelligence testing.	For first four tests (see left), multiple correlation coefficients for on-road driving score was .61 for aphasic and .41 for non-aphasic subjects. For all psychological tests, multiple correlation coefficients for on-road driving were .70 for aphasic and .57 for non-aphasic subjects.
Nouri et al., 1987. UK. Hospital based prospective cohort.	n=40 CVA	Cube copy test, Dot cancellation, RCFT, four choice RT, What's in the square, What else is in the square, Pursuit Rotor, Token Test part V, Titmus Vision tester, Road sign recognition test, Hand sequencing task, RMT Faces, Hazard recognition test.	Scores on 9 tests showed significant differences in on-road driving test outcome. Discriminant analysis for 36 subjects with these 9 tests showed correct classification of 94.9%.
Nouri and Lincoln, 1992. UK. Prospective cohort.	n=40 CVA	Cube copy, dot cancellation, RCFT, What's in the square, What else is in the square, Pursuit rotor, Token Test part V, Titmus vision tester and perimeter, Road sign recognition test, RMT Faces, Hazard recognition task.	13 of 14 cognitive measures showed significant differences between on-road driving test outcome. A random sample of 45 subjects was taken from this study and the above study. Discriminant analysis showed correct classification of the random sample group in 82.2% of cases for outcome of on-road driving test.
Nouri and Lincoln, 1993. UK. Stroke Unit Prospective cohort.	n=52 CVA	27 subjects administered the Stroke Drivers Screening Assessment (SDSA), consisting of dot cancellation task, What's in the square, and Road sign recognition task.	For driving test outcome, sensitivity of 75% and specificity of 89% reported for SDSA. Control group (no cognitive tests) sensitivity of 91% and specificity of 29% reported.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Korteling and Kaptein, 1996. The Netherlands. Prospective cohort.	n=38 TBI subjects, minimally one year post injury.	Perceptual speed, Symbol-Digit Substitution, Time Estimation and Tracking-Reaction.	Performance on both perceptual speed and time estimation tasks was significantly correlated with driving performance. These two tasks, in combination with coma duration and driving experience, accounted for 35.3% of variance in driving test.
Kapust and Weintraub, 1992. USA. Hospital research clinic.	n=2 with diagnosis of probable Alzheimer's Disease	Mattis Dementia Rating Scale, DS, TMT A&B, Target cancellation task, JLOT, Facial Recognition test, Boston Naming test, Oral Word Fluency, 3 Words-3 Shapes test.	Both subjects demonstrated mild to moderate impairment on cognitive tests but one rated safe to drive and the other was not following driving test.
Hunt et al., 1993. USA. University research clinic cross sectional study.	n=38 (12 very mild and 13 mild senile dementia of the Alzheimer type, 13 controls)	WMS -LM, Boston Naming Test, Verbal Fluency, Benton Recall, Benton Copy, TMT A, WAIS -DSS.	All cognitive measures except word fluency were significantly correlated with outcome of on-road test.
Odenheimer et al., 1994. USA. Prospective cohort.	n=30 elderly (6 with diagnosis of dementia)	MMSE, verbal and visual memory components of WMS, TMT A, simple and complex RT.	Significant correlations between road test and MMSE, traffic sign recognition, verbal and visual memory, TMT A and complex RT tasks.
Fitten et al., 1995. USA. Community and hospital clinic prospective cohort	n=83 (15 mild AD, 12 mild vascular dementia, 15 age matched diabetics, 26 elderly controls, 16 young controls)	MMSE, divided attention, sustained attention, Sternberg Memory Test, Visual Tracking.	Road driving test correlated most strongly with Sternberg (.71), visual tracking (-.69), and MMSE (-.63) scores. These three variables together accounted for 68% of variance in drive test score.

STUDY DESCRIPTION	SUBJECT SAMPLE AND n	SPECIFIC PSYCHOLOGICAL MEASURES	RESULTS
Logsdon et al., 1990. USA. Geriatric Clinic.	n=100 consecutive AD patients in 3 groups: no change in driving ability, still driving alone with some difficulty, stopped driving	MMSE, Mattis Dementia Rating Scale, WAIS-R: C, OA, PA, BD; TMT A, Blessed Dementia Rating Scale	No longer driving group was significantly more impaired on MMSE, Mattis construction subtest score and Blessed score compared to the two other groups. Mattis total score was significantly different between non-drivers and no-change group only.
Friedland et al., 1988. USA. Retrospective audit of crashes for participants in longitudinal study of dementia of Alzheimer type (DAT)	n=30 DAT, n=20 healthy age matched controls	WAIS, Mattis Dementia Rating Scale, Stroop, WMS, Verbal Fluency, drawing test, TMT, simple and choice RT (6 DAT subjects received MMSE only)	No significant difference between DAT who crashed and those that did not crash, on any psychological measure, including MMSE.
Lucas-Blaustein et al., 1988. USA. Dementia clinic, retrospective crash rate audit via caregiver questionnaire	n=53 drivers	MMSE, modified Boston Naming Test, Spatial Recognition test and Category Naming task.	Patients still driving had higher MMSE and category naming test scores than those who had discontinued driving. No difference in neuropsychological test scores between those patients who had accidents and those who had not.
Gilley et al., 1991. USA. Retrospective survey of caregivers of consecutive patients in a dementia clinic.	n=487	MMSE	Patients still driving had less overall impairment on MMSE than those who had discontinued driving. MMSE scores were not differentially related to accidents or driving related problems

Note the following abbreviations:

WAIS	Wechsler Adult Intelligence Scale Subtests: Picture Completion (PC), Arithmetic (A), Digit Span (DS), Vocabulary (V), Picture Arrangement (PA), Digit Symbol Substitution (DSS), Block Design (BD), Comprehension (C), Object Assembly (OA)
WAIS-R	Wechsler Adult Intelligence Scale – Revised; Subtests as for WAIS
SDMT	Symbol Digit Modalities Test
PMT	Porteus Maze Test
RT	Reaction time
TMT	Trail Making Test
DPT	Driver Performance Test
WMS	Wechsler Memory Test; Subtest: Logical Memory (LM)
TPT	Tactual Performance Test
JLOT	Judgement of Line Orientation Test
BDI	Beck Depression Index
BVRT	Benton Visual Retention Test
VFDT	Visual Form Discrimination Test
RPM	Raven's Progressive Matrices Test
RCFT	Rey Complex Figure Test
RMT	Recognition Memory Test
MMSE	Mini Mental Status Examination

Sivak and colleagues investigated the effects of brain damage on perceptual /cognitive skills and driving, on both a closed course and the open road (1981). Subjects included 23 people with brain impairment arising from CVA, TBI and cerebral palsy, eight people with spinal cord damage, and ten normal controls. Sivak and colleagues reported that different perceptual /cognitive tests were predictive of open road driving performance by subjects with and without brain impairment. Specifically, performance on Picture Arrangement (PA) and Picture Completion (PC) (two subtests from the Wechsler Adult Intelligence Scale or WAIS (Wechsler, 1955)), were significantly correlated with open road driving performance only among subjects with brain impairment (Sivak et al., 1981). Sivak and colleagues (1981) interpreted this result as indicating that the nature of the driving task might be different for the brain impaired versus the non brain impaired groups. Gouvier and colleagues (1989) examined the predictive ability of a variety of psychometric measures, a knowledge test and driving a small scale vehicle, for their criterion measure of driving a full size vehicle on a closed course. There were 25 subjects in three groups: brain injury (ten subjects), spinal cord injury (seven subjects) and able-bodied (eight subjects). Their results indicated that the best predictors of the criterion measure were the Oral Symbol Digit Modalities test (Smith, 1968), the tracking simulator, the knowledge test, and driving the small size vehicle (Gouvier et al., 1989). It is noteworthy that the criterion measure of driving performance on a closed course, while reliable, had not been validated against an objective measure of on-road driving.

The Cognitive Behavioural Driver's Inventory (CBDI) is a battery consisting of 27 tests relating to information processing. Pass or fail status on the CBDI was based on standard scores on the 27 tests and was found to be significantly related to open road driving test outcome (Engum et al., 1988b, 1989). However, subjects classified as borderline on the CBDI were equally likely to pass or fail the on-road test. The borderline zone consisted of standard scores of between 47 and 52, which corresponds with Trail Making Test A (TMT A) (Reitan, 1958) scores of between 49 and 63 seconds. This is a large range and hence the driving performance of many brain impaired subjects could not be reliably predicted on the basis of the CBDI (Brouwer & Van Zomeren, 1992). In another study that examined performance on psychological tests and open road driving, results indicated that only a test of delayed verbal recall (Wechsler Memory Scale) and the two measures from the Tactual Performance Test were significantly associated with results of the driving test (Rothke, 1989).

One study examined the relationship between performance on psychological tests and the type of driving undertaken by subjects following participation in a driving training program (Brouwer & Van Zomeren, 1992). Six months after participation in the driving training program, subjects were divided into three groups. The first group drove without difficulty. The second group did not drive on freeways, or during busy traffic hours or hazardous weather conditions, and tended to restrict their driving to familiar routes. The third group did not succeed in obtaining a driver's licence. Performance was significantly lower for Groups 2 and 3 compared to Group 1 on four subtests of the WAIS (Digit Symbol, Picture Completion, Picture Arrangement and Block Design), and on TMT A. No significant differences in performance on the neuropsychological tests were detected between Group 2 and Group 3. The authors concluded that on the basis of neuropsychological tests alone, it would be difficult to predict safe resumption of driving (Kumar et al., 1991). Brooke and colleagues (1992) combined data from neuropsychological tests into indexes on the basis of presumed sensitivity to deficits in cognitive skills necessary for driving. They found a significant relationship between one index, the sum of rated scores from the Trail Making Test and the Tactual Performance Test, and a global rating of on-road driving performance (Spearman's $r = .44$). This correlation, however, was not sufficient to predict driving performance precisely, as it accounted for only 19.4% of common variance. Post hoc tests showed no other correlations between cognitive test results and the quantified driving score or the global assessment of driving performance. The number of correlational analyses examined was not specified. Interestingly, in this study driving performance was examined only three to six months after closed head injury, earlier than in many other studies (Brooke et al., 1992).

Galski and colleagues (1990) initially found that none of the battery of 21 perceptual and neuropsychological tests they employed in a pre-driving evaluation correlated with the outcome of the driving test. In a subsequent study, the psychological test battery was changed, so that seven psychological tests considered as sensitive for measuring perceptual and cognitive abilities required for driving were administered, prior to an on-road assessment (Galski, Bruno, & Ehle, 1992). The results showed that 64% of the variance of the driving test performance was accounted for by the psychological tests. The differences in the psychological tests administered between this and the earlier study reflect a shift from assessing largely visual perceptual abilities, to evaluating more complex visuospatial planning and organisational abilities and mental tracking skills. In a third study, the psychological tests administered were further modified with the addition of two tests, a reaction time task and a timed visuomotor test. The sensitivity and specificity of these psychological tests in predicting performance on the driving evaluation were reported as 71% and 87% respectively (Galski, Bruno, & Ehle, 1993). The authors indicated that remediation training would be recommended for subjects scoring below cut-off scores on the psychological tests. These cut-off scores appear to have been set at approximately the mean score for subjects passing the on-road driving test. As discussed previously, however, the regression and discriminant analyses by Galski and colleagues have been questioned because of the relatively small number of subjects for the number of predictor variables examined (Brouwer & Withaar, 1997).

In contrast to the above studies, some investigators have failed to find correlations between performance on a range of neuropsychological tests and on-road driving tests. Van Zomeren and colleagues (1988), who examined a group of severely head injured subjects who had resumed driving, suggested that other factors might influence driving competence, such as level of driving experience and ability to compensate for driving difficulties. In an another study, Van Wolffelaar and colleagues (1990) examined subjects with severe head trauma, who were five to ten years post injury and had already resumed active driving. No relationship was found between either ratings of 'lower' or 'higher' cognitive function and a practical driving test. In this study, 'lower' cognitive functions were defined to include reaction time, eye-hand coordination, and mental tracking. 'Higher' functions were defined to include mental supervisory and executive functions. The authors concluded that neuropsychological assessments may not be sufficiently accurate to predict driving performance in normal traffic in brain injured subjects five to ten years post injury. However, as the subjects in this study were already relicensed, they may not be representative of the typical patients encountered by health professionals, who are generally seeking to resume driving for the first time since brain impairment. Furthermore, if driving experience is an important factor in determining driving performance after brain impairment, as Van Zomeren and colleagues have proposed, then comparing drivers with driving experience after brain impairment to drivers without experience may be potentially confounding (Van Wolffelaar, Brouwer, & Van Zomeren, 1990; Van Zomeren et al., 1988).

Driving ability in subjects with brain damage, who were categorised as aphasic or non-aphasic, was examined by Hartje and colleagues in Germany (1991). While a significant association was found between the overall driving result and the cognitive tasks used by the German authorities for the assessment of driving ability (involving visual orientation, visual perception and reaction time), it was not sufficient to allow valid individual predictions. Similarly, no clear association between performance on an aphasia test and overall rating of driving performance was found.

Nouri and colleagues have examined driving performance after CVA in a series of studies. Nouri, Tinson and Lincoln (1987) investigated the relationship between cognitive ability and driving after CVA in a group of 40 subjects, using a battery of 13 cognitive tests. Subjects were graded as pass, borderline or fail based on a road test over a set route. Cognitive test results were compared across grades of driving performance and significant differences were found on nine of the 23 measures. Nouri and colleagues used discriminant function analysis to select ten tests as best predictors of performance on the road test. The results provided correct classification of 94% of subjects. While these results appear promising, the validity of the discriminant function has been questioned because of the disproportion between the high number of variables used and the relatively small sample size (Hartje et al., 1991).

In a second study from Nouri's group, another 40 subjects completed a cognitive test battery which was the same as that used in the previous study, with the exception of three tests excluded from the series (Nouri & Lincoln, 1992). Subjects also completed a driving test. Fourteen scores were derived from the cognitive test scores, and 13 of the 14 scores showed significant differences between road test grading categories. The authors also noted that the road test results differed substantially between the first and second studies, as the majority of subjects passed the road test in the first study while the majority failed the road test in the second. The results of these two studies were pooled and a random sample of 45 subjects was selected. Discriminant equations were then derived from these results and applied to the remaining 34 subjects, with correct classification of 79% of subjects achieved. Nouri and Lincoln (1992) noted that the predictive equations were more effective at identifying those who would fail a road test than those who would pass. For screening purposes, this was considered desirable. In a third study, Nouri and colleagues prospectively compared their Stroke Drivers Screening Assessment (which consisted of three cognitive tests: Dot Cancellation, What's in the Square, and Road Sign Recognition) with standard assessment by a doctor (Nouri & Lincoln, 1993). Fifty-two subjects who had experienced a CVA underwent a road test and were graded as either pass or fail. Subjects were then randomly allocated into two groups. One group was tested on the Stroke Drivers Screening Assessment and the score obtained was used to predict the likelihood of passing a road test. The controls were requested to seek the advice of their doctor regarding their fitness to drive. Nouri and Lincoln (1993) reported a sensitivity of 75% and a specificity of 89% for the Stroke Drivers Screening Assessment, and a sensitivity of 91% and a specificity of 29% for the controls who had requested their doctor's advice regarding driving. They concluded that use of the Stroke Drivers Screening inventory could reduce the proportion of unsafe drivers resuming driving, and might have advantages over assessment by a doctor alone.

In a related study, the test-retest reliability of the Stroke Drivers Screening Assessment was examined in 36 subjects who had suffered a CVA, who were assessed on two occasions six weeks apart (Lincoln & Fanthome, 1994). While significant practice effects were observed on three of six individual subtest scores, overall results showed that subjects did not change categories between assessments, indicating that repeated assessment was unlikely to change the prediction of driving ability.

A recent study examined 33 subjects with TBI, at least one year post injury (Korteling & Kaptein, 1996). Four neuropsychological tasks were administered, selected to assess attentional/temporal, perceptual and perceptual/motor abilities. The tests were a perceptual speed test, Symbol-Digit Substitution test, a time estimation task and a tracking-reaction task. An open-road driving test administered by the Dutch Licensing Authority preceded the neuropsychological tasks. The perceptual speed and time estimation tasks were found to have the strongest correlation with the criterion measure of the driving test, and when combined with the variables of coma duration and previous driving experience, accounted for 35% of the variance of the driving test. Nevertheless, regression analysis showed that 46% of the unfit drivers would be predicted to pass the driving test based on the neuropsychological tests, whereas 20% of the fit drivers would be predicted to fail. The authors concluded that the predictive value of these neuropsychological tests was not sufficient to permit replacement of the open road driving test.

A small number of studies have examined driving ability and performance on cognitive tests in persons with dementia. In one study, two subjects with a diagnosis of probable Alzheimer's Disease (AD) underwent assessment of neuropsychological and driving abilities (Kapust & Weintraub, 1992). In both cases, neuropsychological assessment indicated a mild to moderate level of dementia severity, with moderate to severe impairment of memory functions. Based on the driving test, however, one subject was judged safe to drive, while the other was advised to cease driving. These pilot results indicate that driving ability may not be predictable solely on the basis of neuropsychological assessment. Another study examined 25 subjects diagnosed with very mild to mild AD, and 13 elderly controls, who completed neuropsychological assessment followed by an on road driving test (Hunt et al., 1993). Five of the subjects with mild AD were judged to be unsafe drivers. All but one of the cognitive measures were significantly correlated with the outcome of the road test in the expected direction. The authors suggested that attention, language and visuoperceptual abilities may be particularly correlated with driving performance in AD. In another study, 30 elderly drivers, of whom six had a diagnosis of dementia, underwent cognitive testing and a standardized driving test (Odenheimer et al., 1994). Statistically significant correlations were observed between road test score and MMSE, traffic sign recognition, visual and verbal memory, TMT A and complex reaction time tasks. However, because of a large overlap in MMSE scores between those subjects who passed the road test and those who failed, Odenheimer and colleagues (1994) suggested that MMSE alone was inadequate for predicting driving performance.

A recent study examined road driving ability and performance on attention, perception and memory tasks (Fitten et al., 1995). There were two mild dementia groups (one AD group and one vascular dementia group) and three control groups (a clinical group of age matched subjects with diabetes, and two community groups of age matched healthy subjects and younger subjects). In the four elderly groups, the driving test score correlated most strongly with a memory test, a visual tracking task and MMSE score, and correlated moderately with a sustained attention task. Stepwise multiple regression analysis indicated that the best predictors of the drive score were the memory test, MMSE and visual tracking, with a total R^2 of .68. However, limitations of the MMSE's discriminating power were evident when higher MMSE scores were examined. At the upper end of the MMSE range, MMSE score did not correlate well with the driving test score, suggesting limited usefulness of this test as a driver screening device (Fitten et al., 1995). The authors concluded that type and degree of cognitive impairment were better predictors of driving skills than age or medical diagnosis.

The relationship between driving status and performance on cognitive tasks was investigated in a group of 100 subjects with a diagnosis of AD (Logsdon, Teri, & Larson, 1992). Subjects were categorised into three groups: (i) no change in driving ability, (ii) still driving but with some difficulty, and (iii) no longer driving due to cognitive problems. Mean MMSE scores and Mattis Dementia Rating Scale Construction subtest scores were significantly different between the groups, in the expected direction. None of the other cognitive measures, such as four subtests of the WAIS-R and TMT A, differentiated between the groups. In another study, a mental status score, together with a visual attention measure termed the Useful Field of View, were found to be significant predictors of vehicle accident frequency in older drivers (Owsley et al., 1991).

Three studies have examined crash rates retrospectively in subjects with dementia. One study found that there were no significant differences on any neuropsychological measure or MMSE score between the dementia group that had experienced crashes and the group that had not (Friedland et al., 1988). Another study surveyed subjects with dementia and found that the MMSE scores of subjects still driving were significantly higher than the scores of subjects who had discontinued driving (Lucas-Blaustein et al., 1988). However, there was no significant difference in mean mental status scores between drivers for whom crashes had been reported and those without crash reports. A third study found significantly lower MMSE scores for subjects with dementia who had ceased driving (Gilley et al., 1991). However, MMSE scores were not related to the occurrence of accidents or any driving related problems.

To summarise, there appears to be no clear and consistent relationship between performance on cognitive measures and a driving criterion measure, such as a road test. A number of neuropsychological tests have been reported as good sources for prediction of on-road driving performance, including the Picture Arrangement, Picture Completion and Block Design subtests of the WAIS and WAIS-R; Symbol Digit Modalities Test oral version; Tactual Performance Test; cancellation tasks; Trail Making Test A; Rey Complex Figure Test; Raven's Progressive Matrices; Visual Form Discrimination Test; simple and complex reaction time tasks; MMSE; visual tracking tasks; and the Mattis Dementia Rating Scale. However, Picture Completion, TMT B, Word Fluency and MMSE have also been reported as poor sources of prediction of on-road driving performance. Some studies found that none of the neuropsychological tests employed were related to the on-road outcome (Galski, Ehle, & Bruno, 1990; Van Zomeren et al., 1988). The absence of a consistent relationship may be due in part to the heterogeneous samples of subjects, their prior driving experience, the different cognitive measures used, and the heterogeneity of the criterion measures, some of which may be more sensitive tests of driving ability. In elderly subjects, including those with a diagnosis of dementia, a relationship between MMSE score and driving performance has been noted, although the low specificity of the MMSE precludes individual predictions about driving ability. In the few studies that have addressed the question, a consistent relationship has not been found between MMSE score and the incidence of accidents in drivers with a diagnosis of dementia.

1.4 Driving Simulator Assessment

The use of simulators to assess driving ability has generally involved either a commercial driving simulator, or an experimental simulator designed for research purposes, which may measure only some aspects of the driving task. A commercial driving simulator usually consists of a driver's seat, steering wheel, indicators, and brake and accelerator pedals. In front of the subject a film is projected, depicting driving scenes to which the subject is required to react as if they were driving. Commercial driving simulators have been reported as useful for highlighting likely driving problems, and for demonstrating these problems in a functional way to individuals with brain damage and their families (Cimolino & Balkovec, 1988; Quigley & DeLisa, 1983). Driving simulators have also been found useful as training tools for younger subjects, but not for older people (Cimolino & Balkovec, 1988).

With regard to the predictive validity of commercial simulator tests, one study found that overall simulator driving score, post traumatic amnesia duration and full scale IQ (test was not specified) significantly differentiated between patient groups judged able to drive and those judged unable to do so (Hopewell & Price, 1985). However, the simulator driving score alone correlated poorly with the expert judgement of driving skill. Galski, Bruno and Ehle (1992) found that only two simulator measures were significant predictors of outcome of an on-road driving test. These simulator measures were: (i) the appropriate use of indicator signals on an introductory driving film, and (ii) the percentage of valid attempts to steer out of potentially hazardous situations. In a subsequent study using the same driving simulator, with a similar, albeit larger, patient group, a sensitivity of 65% and specificity of 80% for predicting performance on the on-road component of the assessment were observed for the driving simulator measures (Galski, Bruno, & Ehle, 1993). Differences in sample size and power between these two studies by Galski and colleagues (1992 n=35, 1993 n=106) are noteworthy and may account for some of the reported variation in predictive ability of the driving simulator for on-road driving.

With regard to experimental simulators, Lings and Dupont (1992) described a 'mock car', or part-task driving simulator, which measured grip strength, maximum force applied when operating pedals and handbrake, maximum isometric force applied when turning the steering wheel when locked, direction and speed of steering wheel turn, and various reaction times. Lings and Dupont (1992) suggested that their simulator measured some of the basic motor and psychomotor functions required for manoeuvring the vehicle. However, the simulator was not validated against other measures of driving ability. Brouwer and colleagues described an experimental simulator which measured operational driving skills such as lateral position control, braking speed and gap judgement (Brouwer & Van Zomeren, 1992; Van Zomeren et al., 1988). The results indicated that subjects with brain impairment were significantly impaired with regard to the speed or precision of operational traffic tasks. The quality of operational level driving skills was strongly correlated with scores on corresponding neuropsychological tests of information processing and visual motor coordination. However, for the subjects with brain impairment, the correlations between scores on the neuropsychological tests and an expert judgement of driving quality were low. Lateral position control scores were not associated with an overall judgement of driving competence (Van Zomeren et al., 1988).

Brouwer and Van Zomeren (1992) have also described an interactive 'virtual environment' driving simulator developed at the Traffic Research Centre, Haren, The Netherlands. This simulator involves 'driving' a real car that is stationary, in a realistic virtual environment, in which other artificially intelligent traffic participants interact with the human driver. The gear and pedal controls of the test car are part of the virtual environment, so that their characteristics change in accordance with the simulated speed of the test car. No experimental data from this interactive simulator was identified in a review of the literature.

A fully interactive driving simulator such as that at the Traffic Research Centre requires expensive technology, thus raising the question of cost effectiveness of simulator assessment. It is clearly more cost effective to examine driving behaviour on the road, rather than attempt to simulate driving. However, interactive driving simulators may allow examination of the tactical aspects of driving, without endangering the subject or other road users.

Some deficiencies have been noted with simulator use. A significant difficulty with commercial driving simulators is the lack of interaction between the driver's actions and the actions being depicted in the stimulus driving film. That is, failure to brake, or steering in an incorrect direction, is not reflected in the film. Subjects have reported that this lack of interaction results in an absence of a feeling of driving (Galski, Bruno, & Ehle, 1992), with the consequence of poor face validity of driving simulator assessments. A driver on the road does not operate in isolation and hence there is a need for driving assessment to focus on the interaction between the driver and the driving environment. Additionally, a further limitation is the lack of visual peripheral field stimulation from the simulator. Use of a simulator to determine the need for driving aids might also be questionable, given, for example, the rigid steering mechanism of commercial simulators compared to power steering, with almost zero resistance, available in real vehicles (Cimolino & Balkovec, 1988).

To summarise, driving simulators have at best only moderate predictive ability for motor vehicle operation and on-road driving performance, and hence their worth for assessment purposes is not convincing. Driving simulators may be useful for helping people with brain impairment and their families to gain insight into deficits that preclude driving. Major improvements to driving simulators to enhance realism and interactivity will make high demands on technology with consequent cost implications, thereby raising questions about the cost effectiveness of a simulated assessment of driving ability.

1.5 Closed Course and Car Park Tests

Examination of studies of driving ability following brain impairment published since 1975 show that some investigators have evaluated driving skill through assessment of closed course or car park driving often as an adjunct to on-road testing. Alternatively, adequate performance on a closed course may be a prerequisite for progression to an on-road test.

Sivak and colleagues (1981) used a closed course evaluation in addition to open road driving in subjects with acquired brain damage. Five tasks were scored on the closed course. These were straight tracking, driving in a figure eight, S-curve tracking, blind stop, and S-curve tracking with a secondary task. In the secondary task the subject listened to a sequence of words interspersed with numbers, and was required to make a sound upon hearing a number. In terms of Michon's (1979) model of driving, these tasks involve the operational level of driving performance, with multitasking required when the secondary task is administered. Sivak and colleagues (1981) found that in the case of subjects with brain impairment, none of the closed-course measures correlated significantly with a composite index from the open road evaluation. Interestingly, for subjects without brain impairment, some closed course measures did correlate significantly with the open road composite index. The authors suggested that the nature of the driving task might be different for brain impaired and non brain impaired groups, and that traditional closed course driving manoeuvres might not tap driving related skills of persons with brain impairment. No further explanation of this view or rationale was given. In fact, Sivak and colleagues may have been suggesting that the task demands of their closed course driving test presented a different cognitive load for brain impaired drivers compared with drivers without brain impairment.

Stokx and Gaillard (1986), examining subjects with traumatic brain injury (coma duration of one to eight weeks) and matched normal controls, used what they termed an 'instrumented' car to examine driving ability on a closed section of highway. Four elementary driving tasks were used: shifting gears, braking from a speed of 80 kilometres per hour, slalom driving through cones and slalom driving with a secondary task. For the secondary task four lights were mounted on the side of the car. The lights flashed in random order and subjects responded to the flashing of each light by pushing the horn. The time taken and the number of errors were recorded for each driving task. Results suggested that although the brain impaired group tended to commit more errors on the driving tasks than the control group, the difference was not significant on any measure. Brain impaired subjects were slower than controls on all tests, however, consistent with the observation of the authors that the brain impaired subjects took great care not to make errors, whereas they were less concerned about their response speed. Again, this type of driving assessment is restricted to the examination of only certain aspects of vehicle operation, thus providing limited information regarding overall driving skill. While time to make a response was measured, there was no traffic present to influence vehicle speed; possibly allowing more time to compensate for slowed reaction time.

Schweitzer and colleagues (1988) used 'expert' ratings of driving in a full sized vehicle manoeuvred about a closed course, as their criterion measure of driving competence. The background of the expert rater was not specified. There were 25 subjects in three groups, ten with traumatic brain injury, seven with spinal cord injury and eight normal controls. Eight specific manoeuvres were evaluated: starting and stopping, left turn from stop, right turn from stop, left turn while slowing, right turn while slowing, slalom navigation at ten mph, slalom navigation at 15 mph and an evasive manoeuvre. Performances on following instructions, tracking, braking, accelerating and appropriate speed control were also rated. Again, these tasks are largely operational in nature, and are limited in their generalizability to driving performance in traffic. Significant differences in driving performance between the groups were observed, with the control group being rated highest for driving performance, and the traumatic brain injury group receiving the lowest rating.

In other examples of closed course driving assessments, readiness to sit a Department of Motor Vehicles driving test for relicensing in the State of Washington, USA, was determined by a parking lot assessment (Quigley & DeLisa, 1983). Prior to on-road assessment subjects were assessed in their ability to perform a range of tasks including transferring into the vehicle, using the car controls and performing simple manoeuvres. In another study Engum and colleagues (1989) used a closed course test as a precursor to open road driving. Conducted in a car park, the closed course component focused on operation of miscellaneous controls, use of adaptive equipment and execution of basic tasks. The basic tasks included starting the vehicle; turning; using the accelerator, brake, seatbelts, handbrake and gear selector; and adjusting mirrors (Engum et al., 1989). Galski and colleagues similarly used both parking lot and on-road evaluation, and noted that the parking lot section of their evaluation yielded little useful information about actual driving behaviour (Galski, Bruno, & Ehle, 1992, 1993; Galski, Ehle, & Bruno, 1990).

In an interesting study that included pre-planned interactions with a collaborator's vehicle, assessment of performance in traffic was combined with assessment on a closed course (Wilson & Smith, 1983). In the closed course, the subject was required to negotiate a roundabout that the collaborator's vehicle had already entered. Subsequently the collaborator's vehicle overtook the subject's vehicle. Later, at the end of the closed course, an emergency stop manoeuvre was tested when at a certain location a dummy was thrown into the path of the test car. This more comprehensive, closed course assessment encompassed complex operational aspects of driving, particularly a non-routine (emergency) driving event. Unlike other closed course driving assessments, subjects in this study were not driving in total isolation and therefore this study more closely approximated a real driving situation. However, the closed course component of this test did not examine the tactical level of driving.

In a study of 30 elderly drivers aged over 60 years, six of whom were diagnosed with dementia, the driving test included closed course and in-traffic components (Odenheimer et al., 1994). The closed course component served as a screening measure prior to in-traffic driving, and allowed observation of vehicle manoeuvres. Each subject was required to demonstrate familiarity with car controls, and then execute seven basic tasks that were scored on a two point scale. These were: to drive in a straight line, back up, turn left, turn right, angle park, parallel park, and drive between five cones in one direction and then in the other. No statistical relationship was found between age and the closed course score. The correlation between the closed course and in-traffic segment driving scores was moderate ($r = .60$, $p < .01$), suggesting that a closed course does not adequately satisfy the requirements for assessing driving performance. The authors reported that the closed course was particularly inadequate for providing data about a driver's ability to interact with complex traffic patterns, although they suggested that expansion and diversification of the closed course test might improve its validity.

Scoring of off-road assessments has usually involved judging the adequacy and accuracy of basic manoeuvres, and recording the time taken for the execution of various tasks, such as the number of cones displaced in slalom manoeuvres (Sivak et al., 1981; Stokx & Gaillard, 1986). It is noteworthy that while the time to make a response was measured in some of these studies as a dependent variable, there was no traffic present in the closed course to influence vehicle speed, potentially allowing the subject more time to compensate for increased reaction times. Schweitzer and colleagues (1988) employed two expert ratings of eight specific manoeuvres completed while driving an appropriately modified vehicle about the closed course. They reported inter-rater agreement on 86 percent of observations. Use of two point scales to rate performance on basic driving tasks has been also reported (Engum et al., 1989; Galski, Ehle, & Bruno, 1990; Odenheimer et al., 1994). Wilson and Smith (1983) scored the closed course manoeuvres on a five-point scale, with additional qualitative judgements regarding some items, such as parking the car safely or being aware of the driving environment. Two raters were present in the car and out of 3300 ratings the two raters disagreed on two occasions only (Wilson & Smith, 1983).

To summarise, closed course driving assessments allow evaluation of competence of some aspects of motor vehicle control, such as steering, tracking and braking. However, the tactical or interactional aspects of driving cannot generally be observed. No information may be derived from such an assessment as to the driver's ability to participate in traffic, as there is no opportunity to observe interactions between the driver and other traffic participants. Closed course driver assessments may therefore lack validity as a predictor of open road driving in typical traffic conditions. In a study in which another vehicle was introduced into the closed course, the driving behaviour observed was still insufficient to reflect driving in traffic (Wilson & Smith, 1983). Nonetheless, while a closed course assessment is not complex enough to test the integration of skills required for safe driving in traffic, it may be useful in determining whether a subject meets minimum standards of competence for an open road assessment.

1.6 Conclusion

A review of the literature indicates that a comprehensive model of driving is lacking, which may in part explain the general lack of success in identifying predictors of safe driving. Moreover, the use of accident data as a criterion measure for models of driving is problematic, because of the relative infrequency of accidents and their multiple causes. It is clear from accident statistics, however, that drivers do not always drive as they did during their licensing examination, suggesting inadequate predictive validity from licence tests. Similar issues are present when attempting to determine competence to drive following brain impairment. Generally the criteria for assessing fitness to drive following brain impairment, like those for ordinary licence testing, are quite vague, and based on common sense reasoning and face validity of assessments, rather than on empirical evidence (Brouwer & Van Zomeren, 1992). Such assessments have included medical examinations, psychological assessment, driver simulators, and off-road and on-road driving tests. While in many jurisdictions doctors have a legal responsibility to assess competence to drive for their patients with brain impairment, there is a lack of data about the predictive validity of medical examination for assessing driver skill, and this area requires further investigation. Similarly, a clear and consistent relationship between performance on cognitive measures and driving is not evident in the literature. Studies examining cognitive performance and driving ability are noteworthy for the heterogeneity of the subjects, the variety of cognitive measures used and the heterogeneous criterion measures, many lacking standardization and replicability. Driving simulators have been found to have only moderate predictive ability for driving, and suffer the major shortcoming of a lack of face validity.

Closed course or off-road driving assessments may be an inadequate test of the criterion behaviour, as no information may be drawn from these assessments concerning the ability to participate in traffic. Closed course tests, however, may provide valuable information regarding car handling skills and readiness for an in-traffic evaluation. It is recommended that a brief off-road examination of vehicle handling skill precede any on-road driving assessment. This ensures that drivers whose vehicle handling skills are so inadequate as to preclude safe open-road driving can be identified without endangering themselves and others. Also, if vehicle modifications are required, such as a spinner knob for steering, these can be appropriately fitted and their use practised, before encountering other traffic.

CHAPTER 2

ON-ROAD ASSESSMENT OF DRIVING COMPETENCE AFTER BRAIN IMPAIRMENT: REVIEW OF CURRENT PRACTICE*

A review of studies employing open road assessment reveals a variety of approaches, ranging from short, informal tests in varying conditions, to the use of a standardized course with predetermined manoeuvres rated according to explicit criteria. In general, little attention has been devoted to issues such as reliability and standardization of on-road assessments. One example of an on-road test in which reliability and standardization were examined with normal subjects is the Driver Performance Test (Jones, M. H., 1978). This on-road driving evaluation was developed for the assessment of high school learner drivers, and was also tested for reliability in groups of older experienced drivers. The test consisted of a set route designed to fulfil requirements for traffic density and specified driving manoeuvres, and which could be reproduced in other locations. Jones' (1978) test was conducted by a trained driving instructor, whose responsibilities included the safety of the car, route directions, scoring of occasions when the instructor was required to take control of the vehicle, and the occurrence of any hazards. The majority of scoring was performed by an independent coder seated in the rear of the vehicle, who attended only to the driver's behaviour. The scoring sheet was a route map with symbols indicating the driver's behaviour to be observed at each location, with the observed behaviour to be compared to

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a previously determined criterion of performance. Any deviation from the precisely defined correct response was recorded as incorrect (Jones, M. H., 1978).

Over the course of Jones' (1978) standardized route, several critical aspects of a manoeuvre, for example a left turn, were observed and rated several times, with the ratings made separately rather than simultaneously. That is, driving manoeuvres were broken into components, each of which were rated for correctness, with the aim of enhancing scorer reliability. The test required many observations of simple behaviours, with 110 discrete items scored. Jones (1978) administered the Driver Performance Test to 194 high school driving students, 67 of whom were retested within two weeks. The test-retest total score correlation coefficient was reported as .40 ($p < .001$). A further reliability study was conducted with 42 novice drivers and 48 experienced drivers, all of whom completed the Driver Performance Test twice on a single day. The correlation coefficients between the two tests were .84 and .82 for the novice and experienced drivers, respectively. The author concluded that the Driver Performance Test was a reliable instrument to measure driving performance in novice and experienced drivers.

2.1 Methods of On-Road Assessment of Brain Impaired Subjects

2.1.1 Use of On-Road Driving Assessments as an Outcome Measure to Validate Off-Road Assessment

Some studies have attempted to validate off-road methods of assessment of driving competence, such as psychological tests or closed course driving tests, against the criterion measure of on-road driving performance. That is, the predictive validity of the off-road assessment has been examined in relation to on-road driving performance. Some of these studies, such as that by Sivak and colleagues (1981), have based their on-road test procedure on the work of Jones (1978). Sivak and colleagues (1981) investigated the effects of brain damage (arising from CVA, TBI and cerebral palsy) on cognitive skills and driving ability, and used an on-road driving assessment with a route standardized for difficulty, traffic density and required manoeuvres. They employed a 17 kilometre course of light to moderate traffic density, and evaluated driving on the basis of 144 predetermined actions along the route, which were rated as either well executed or not. The results indicated that subjects with brain impairment, as a group, achieved significantly lower mean percent correct driving scores than normal control subjects (Sivak et al., 1981). Engum and colleagues (1989) investigated the validity of an off-road driving assessment battery for subjects with brain impairment, predominantly CVA and TBI. They also based their on-road driving test procedure on that of Jones, utilising a procedure in which six criteria were assessed as subjects drove through 144 predetermined manoeuvres. The six criteria were gap acceptance (merging into traffic stream with a safe gap between vehicles), limit line (vehicle halted at correct position at intersection or traffic signals), observation (directly or through use of a mirror), path (maintenance of correct path of vehicle), speed (correct speed of vehicle) and communication (use of proper turn signals to indicate intention). Engum and colleagues (1989) suggested that their on-road test measured tactical and strategic aspects of driving, and reported a significant relationship between the off-road battery and the open road driving test outcome. It is unlikely, however, that any of the strategic aspects of driving could have been observed in a test in which the route and the time of day of testing were predetermined, and instructions regarding driving actions were given by the driving instructor.

On-road driving assessment has also been employed as a criterion measure of the training effects of driving simulation exercises (Kewman et al., 1985). Before and after driving simulation training in a small electric powered vehicle, driving performance was evaluated on a standard course on city streets using a normal vehicle. During the on-road test, lane position was rated every 30 seconds, and each of the 17 turns in the fixed course was rated in terms of correctness of vehicle position and vehicle tracking. Predefined safety errors were also recorded. The subject was also required to monitor yellow caution signs along the route, as an attentional and visual monitoring task. These ratings were combined to form a composite driving score. Correlations between the composite score and the driver educator's independent rating of driving performance were reported as high (Rho=.60, $p<.01$ 1 week pretraining, Rho=.65, $p<.01$ post training), and were interpreted by the authors as supporting the validity of the driving composite score as a predictor of driving ability (Kewman et al., 1985).

Hartje and colleagues (1991) compared performances on psychological tests and a practical driving examination in a group of brain damaged patients with and without aphasia. The authors selected two highly comparable standardized routes in two cities, each of which comprised nine miles on motorways, twelve miles on secondary roads, and nine miles in heavy city traffic. Using a protocol with approximately 280 observable actions of driving performance for the route, a driving instructor rated the adequacy of each action. These were grouped into 13 categories of driving behaviours, and included aspects of signalling, keeping in lane, changing lanes, stopping at traffic lights, observing speed limits and giving right of way. In addition to the detailed recording of driving actions, the instructor globally rated driving performance, and this rating was considered the criterion measure.

Significantly fewer aphasic patients (42%) than non-aphasic patients (72%) passed the driving examination. Multiple regression analysis showed that the amount of variance explained by the nine most frequently observed driving actions (64% for aphasic and 57% for non-aphasic patients) was not sufficient to preclude other factors influencing the overall judgement by the driving instructor (Hartje et al., 1991). In other words, other aspects of the driving performance, such as the necessity for intervention by the instructor, may have influenced the overall judgement of the driving instructor, such as the necessity for intervention by the driving instructor. Given the uncertainty surrounding the predictive validity of the driver licensing test discussed earlier, the use of the driver educator's rating of driving performance as a criterion measure by both Kewman et al. (1985) and Hartje et al. (1991) might be questioned. Similar concerns about ratings made by 'expert judges' are raised by studies in which the result of a motoring school test given by a driving instructor, or of a test by an Automobile Association, has been employed as the criterion measure of driving competence (Nouri, Tinson, & Lincoln, 1987; Van Zomeren et al., 1988).

Fox, Bashford and Caust (1992) examined the predictive validity of psychological and medical examinations for on-road driving, and rated five areas of driving performance during on-road assessment of brain impaired subjects. These were planning and judgement, vehicle positioning, reaction time, speed control and observation. Three standard open road driving routes of increasing complexity were used, with the most complex incorporating freeway driving, road map navigation and multistorey car park manoeuvres. Route selection was determined by the examiners, based on the subject's driving experience. The more complex routes in this study may have examined aspects of the tactical level of cognitive control of driving. The results indicated that in 36% of cases the doctor was unable to predict driver competence on the basis of a medical examination, and the authors concluded that medical assessment alone may not be a reliable means of determining driver competence. While only a small number of false positive errors were attributed to neuropsychological assessment, in 25% of cases the neuropsychologist was unable to predict on-road driving performance on the basis of neuropsychological assessment. Unfortunately the design of this study precluded evaluation of false negative error rates for predictions of driver competence.

Whilst not utilising a standardized route, Galski, Bruno and Ehle (1993) described an open road evaluation where performance on specific manoeuvres was rated, and behaviours such as impulsivity, distractibility, confusion and inattention were noted. Inclusion of these behavioural observations suggests that the authors were attempting to move beyond simply evaluating the operation of the vehicle, toward examining some aspects of the tactical level of driving. The sensitivity of the predriver evaluation including neuropsychological evaluation, a driving simulator and an on-road driving score for predicting on-road test failures ranged from 49% for a parking area evaluation to 80% for the on-road driving score. Specificities for the car park drive score and for the on-road driving score ranged from 80% (simulator evaluation) to 88% (combined predriver evaluation and simulator score).

2.1.2 Examination of Driving Abilities in Various Patient Groups by On-Road Assessment

Other investigators have examined driving ability following brain impairment in different diagnostic groups, with the aim of characterising deficient driving skills. An on-road assessment has served as the criterion standard of driving ability in these studies. Wilson and Smith (1983) asked subjects with a stroke diagnosis to drive through traffic of various densities to a predetermined destination, where a closed course assessment was conducted. Subjects were requested to follow road signs to the destination, although they could ask examiners for directions. During the journey, two examiners rated performance at various predefined points, such as T-junctions, roundabouts, entering or exiting motorways, and on turning right, according to prespecified criteria. Many of the criteria were not explicitly defined however, for example, the requirement to "signal in plenty of time". Nevertheless, the approach of Wilson and Smith (1983) shows some aspects of the tactical components of the driving task being evaluated. For example, subjects had to plan their route and take the correct exit for their destination from the motorway, requiring them to monitor the exits, and position themselves in the appropriate lane to exit.

Using a standardized open road course, Brooke et al. (1992) monitored the performance of critical driving behaviours in subjects with traumatic brain injury. The critical behaviours largely concerned operational aspects of driving such as basic control, turning, parking, and pathfinding. One of the authors' measures that reflected a tactical component was the judgement of gaps in traffic flow, where impulsivity or slowness could be noted.

Some studies have examined on-road driving performance in subjects with dementia. Hunt and colleagues (1993) developed a 'partially standardized' on-road test, where subjects drove along a predetermined route in low volume traffic, following one step commands from the examiner. Driving behaviours concerned operational aspects of driving. Also recorded in this study were instances of other drivers being demonstrably irritated by the subject's driving. In a study with elderly subjects, some of whom were diagnosed with dementia, Odenheimer and colleagues (1994) developed a road test featuring a fixed route and use of the same vehicle, conducted at a prescribed time of day in clear weather. There were 68 scored tasks in the in-traffic section, including turns, merges, responses to traffic signs and signals, driving straight, and performing more complex manoeuvres such as a three-point turn. To pass a task, all components of that task had to be correctly completed. The components included scanning the environment, positioning the vehicle, travelling at an appropriate speed, and using turning signals. Driving instructions were presented to subjects as single step commands, and subjects were not asked to find their way. This test also appears to rely on operational aspects of driving in determining competence. Reliability and validity of this test were discussed in terms of relationships between the in-traffic scores and a driving instructor's global evaluation of performance ($r = .74$, $p<.01$), and between averaged road test scores and cognitive measures. The authors noted that while widely accepted by licensing agencies, their criterion standard of a global evaluation by a driving instructor lacks specific information about driving performance. This information is important for the assessment of driving competence in the brain impaired population, in order to determine the necessary vehicle modifications, training requirements and compensatory potential.

In another example of a standardized test, a road assessment was conducted over a Veterans Affairs Medical Center road network on Saturday mornings only, to ensure consistent low level traffic conditions (Fitten et al., 1995). Subjects in this study included two mild dementia groups and three control groups. The road test consisted of a six stage driving course, 2.7 miles long, with each stage presenting a different degree of driving complexity. Each test drive was recorded by a wide-angle camera mounted on the roof of the vehicle above the driver's head. A driving instructor scored driving performance, with a maximum number of points possible for an error free drive. Approximately 80% of the points related to specific performances at each of the six stages, while 20% involved more general aspects of the drive, such as adequate judgement on the road, and absence of direct instructor intervention. Interestingly, as part of their examination of the validity of their on-road test, Fitten and colleagues obtained collision and moving violation records for all older participants, for the two year period preceding their involvement in the study. A negative non significant correlation was observed between the drive score and number of collisions/moving violations per thousand miles driven.

To summarise, open road driving examinations can be categorised into those examining the predictive validity of other assessment methods, and those examining the driving performance of brain impaired subjects with various diagnoses. In both categories, there appears to be a gradual progression towards the use of standardized route driving tests in which certain driving manoeuvres are rated. For the best opportunity to observe potential errors and compensatory potential in driving by brain impaired subjects, it is necessary to devise an on-road test of sufficient complexity and duration so that judgement and decision making by the subject can be observed. In order to ensure that all candidates are tested fairly and the decision regarding driving fitness is based on the same quantity and quality of information, each candidate should, as far as possible, receive the same test, at least in terms of duration, difficulty and traffic density. Although no studies directly comparing the validity of standardized and nonstandardized driving routes were located, the available evidence supports a test standardized in terms of route, driving manoeuvres and duration as the soundest approach to on-road testing.

2.2 Use of a Dedicated Test Vehicle Versus the Client's Own Vehicle in On-Road Assessment of Driving

The majority of studies that have investigated on-road driving testing of subjects with brain impairment reported using dedicated test vehicles with dual control brakes (Fitten et al., 1995; Hunt et al., 1993; Kapust & Weintraub, 1992; Odenheimer et al., 1994), sometimes with other safety and control adaptations, such as engine cut out switches (Fox, Bashford, & Caust, 1992). An example of a highly specialised test vehicle, developed in an effort to obtain objective driving measures, is provided by Fitten and colleagues (1995). The test vehicle was fitted with an on-board computer to register input from video and audio equipment, and from sensors installed to monitor braking, steering, speed, distance, elapsed time and crossing of the road centre line. Additionally, the drivers' lateral eye movements were monitored by computer, using mini electrodes placed at the external canthus of each eye (Fitten et al., 1995). The authors reported that an Alzheimer's Disease group drove more slowly than a vascular dementia group and three control groups, whereas the mean lateral eye movement score for the Alzheimer group was similar to that of an older control group and significantly lower than the means for the vascular dementia group and younger control groups (Fitten et al., 1995).

In contrast, other studies have reported using the subject's own vehicle during the on-road test (Jones, R., Giddens, & Croft, 1983; Wilson & Smith, 1983). The choice of whether to use the subject's own car may be influenced by the subject's concern that a test in an unfamiliar car will be unfair, as their driving experience is usually confined to their own vehicle. Nevertheless, use of the same vehicle for each test contributes to the standardization of the evaluation process, by ensuring that the technical specifications of the vehicle are the same for each subject. More importantly, dual control of the vehicle enhances the safety of those in the test vehicle, and of other road users. Use of a dual control vehicle for driving assessment is therefore strongly recommended. As many subjects require vehicle modifications in order to drive, a modifiable vehicle may be required to test which adaptations are most suitable, prior to potentially costly changes to the subject's own vehicle. As the safety of the brain impaired driver and the instructor or examiner is of primary concern during the driving assessment, it might be considered unethical to place them in the potentially dangerous environment of a vehicle that is not suitably modified, without safety features enabling the instructor or rater to control the vehicle if necessary.

2.3 Scoring of In-Traffic Evaluations

Approaches to scoring the on-road test have primarily involved a calculation of the number of errors, or alternatively, of the number of correct manoeuvres. Jones (1978) has defined the minimal requirements for an effective on-road driving test as: (i) a large number of independently scored items, to enhance reliability and provide independence of one score from the next; (ii) a simple scoring procedure, in particular simplicity of the rater's response and unmistakable cues to proper location on the scoring sheet; (iii) low complexity of the driving behaviours to be scored, since the scoring of driving behaviours will be more reliable if the behavioural elements observed at any one time are of the lowest possible complexity; (iv) clear specification of the correct responses, which may be then learned by raters, enabling use of identical standards of performance; and (v) a sufficient sample of driving behaviours, to reflect the spectrum of situations which drivers normally encounter as they interact with traffic.

However, approaches such as Jones' (1978) have not been utilised by many centres providing driving assessment for individuals with brain impairment. Consequently, there are various on-road test scoring procedures, such as rating driving actions on a five-point scale (Wilson & Smith, 1983), or measuring the time taken for various driving actions and the number of errors incurred in performing the driving actions (Brooke et al., 1992). Others have rated observed actions on two point scales, such as correct or incorrect, and safe or unsafe (Galski, Bruno, & Ehle, 1993; Hartje et al., 1991; Hunt et al., 1993; Nouri, Tinson, & Lincoln, 1987; Odenheimer et al., 1994). Some investigators have subjectively rated driving skill with qualitative descriptions, or rating scales (Kapust & Weintraub, 1992; Schweitzer et al., 1988).

Scoring driving behaviours over non-standardized routes is of doubtful validity, since it cannot be assumed that each subject experienced the same opportunities for making errors. In some studies the criteria for 'correct' responses were not clearly defined, so that the same driving action may have been scored differently by different examiners or on different testing occasions. Thus, the testing and scoring process needs to be standardized if on-road assessment is to have high validity. In two studies where interrater reliability was specifically examined, agreement between the raters was high. Odenheimer and colleagues reported an interrater reliability of .74, while Fitten and colleagues reported reliabilities of between .64 and .91 depending on the raters (Fitten et al., 1995; Odenheimer et al., 1994). Both of these studies used highly standardized on-road driving tests, including the driving route and the scoring procedures. These findings indicate that high reliability in rating driving performance can be achieved, although substantial standardization of the driving test may be a necessary pre requisite.

Studies have varied in the number of raters of driving performance. Many investigators have used only one rater in the vehicle during the on-road test, either an occupational therapist or a driving instructor (Galski, Bruno, & Ehle, 1993; Hartje et al., 1991; Jones, R., Giddens, & Croft, 1983; Kapust & Weintraub, 1992). Others have used two raters (Fox, Bashford, & Caust, 1992; Hunt et al., 1993; Wilson & Smith, 1983). Two research raters and a driving instructor were employed in the Odenheimer study (Odenheimer et al., 1994). The subject may also be required to give a global self-rating of driving performance (Hartje et al., 1991). Complex audio, video and computer recording of the driving test to enable objective measurement of certain aspects of car control and driver behaviour have been reported (Fitten et al., 1995).

Jones (1978) suggested that both a driving instructor and an independent rater are required for safety reasons. This enables the instructor, seated beside the driver, to concentrate on the maintenance of vehicle safety and provide guidance to the subject, while the other rater is free to observe all manoeuvres without distraction. In addition, some critical aspects of driving performance, such as the driver's visual scanning behaviour, cannot be properly viewed from the front seat. A standardized test, where the same observations must be made of each subject, is most easily achieved when the rating task is separated from the maintenance of vehicle passage and safety.

2.4 Determination of Final Result of On-Road Evaluation

In addition to characterising the driving performance of brain impaired subjects, many of the studies reviewed made a judgement regarding the subject's competence to resume driving. This judgement was often the final result of the in-traffic assessment, and represented a subjective overall rating, rather than a driving score derived from correct or incorrect responses made during the driving test (Brooke et al., 1992; Galski, Bruno, & Ehle, 1993; Nouri & Lincoln, 1992). In many studies the basis of the final judgement of driver fitness is unclear. The development of guidelines for the interpretation of on-road errors in the derivation of the final judgement regarding driver competence is an important area of research and requires further investigation.

One study found that the overall rating of driving performance by the examiner did not relate very well to the objective error scores, as the overall number of errors did not explain the final rating, nor did it differentiate between the head injury and control groups (Van Zomeren et al., 1988). The examiner considered the errors made by the head injured subjects as more serious than those made by subjects in the control group, suggesting that explicit scoring of driving performance may not enhance the validity of assessment unless more complex aspects of traffic behaviour are incorporated into the driving test. In contrast, Brooke and colleagues (1992) found that the global rating of driving was significantly related to the quantified driving score ($r = .58$). Correlations between the rater's global evaluation of driving and driving scores derived from the number of correct driving manoeuvres have been reported, with correlation coefficients of between .74 and .83 reported by Sivak and colleagues, and a correlation of .74 reported by Odenheimer and colleagues (Odenheimer et al., 1994; Sivak et al., 1981). Where a fully standardized test is used, it is more likely that an overall rating will be based on the same information for each subject, thereby enhancing reliability. A potential consequence of the lack of standardization of the on-road test is illustrated by inconsistencies in road test results seen in studies by Nouri's group (Nouri & Lincoln, 1992; Nouri, Tinson, & Lincoln, 1987). In the 1987 study the majority of subjects passed the road test, while in the later (1992) study, following a change in driving instructor and assessment route, the majority failed. In the absence of obvious differences in samples of drivers, these results raise the interesting question of why the pass rate changed so dramatically with alterations in instructor and route. Perhaps the criteria for adequate performance used by the two driving instructors were different, or the two routes differed markedly in complexity.

Hartje and colleagues (1991) argued that a comprehensive driving test is not sufficient for a perfect prediction of final global proficiency rating. They found that a significantly higher number of subjects who required intervention by the instructor during the on-road test, failed the final global evaluation, as judged by the instructor. This could not be explained on the basis of number of on-road errors alone, and thus it appeared that the need for direct intervention by the instructor had an additional influence on the final global rating (Hartje et al., 1991).

An alternative approach to the assessment of driving has been proposed by Brouwer and Van Zomeren (1992), whereby all brain impaired drivers receive training in strategic and tactical level compensatory behaviours, until training goals are attained or a preset maximum number of lessons is exceeded. Brouwer and Van Zomeren (1992) suggest that the validity of driver assessment procedures could then be evaluated based on the ability to predict the number and nature of lessons required. Driving incompetence would therefore be defined as an inability to reach the criterion of a safe driver within the limits of available training and technical adaptations. This proposed driver assessment format more readily satisfies the rigorous research requirements for evaluation of predictive validity. However, the cost of providing all brain impaired drivers with lessons raises serious funding issues.

One criticism of on-road tests of driving ability concerns the issue of rater bias when assessing brain impaired subjects (Carr et al., 1991). Most studies that have used an on-road assessment have included raters who were not blinded to the diagnosis of the subjects. This occurs as a function of the clinical, rather than experimental nature of many studies. Additionally, there may be ethical concerns related to exposing raters to the potentially dangerous driving of brain impaired subjects, and the consequent need for raters to be particularly vigilant. Van Zomeren and colleagues (1988) approached this problem by using a partially blinded rater. In their study, the rater (a non-clinician) was told that all the participants had suffered concussion, whereas half had incurred severe cerebral concussion and the remaining half were normal controls. A possible additional benefit of specifying objective criteria for adequate driving performance may be a reduction in the effects of rater bias.

Some investigators have made qualitative recommendations regarding the driving status of their subjects, which might be interpreted as qualifying their judgement of 'safe'. These include recommendations of restricted licences, such as driving during daylight hours only, or not driving on freeways (Hopewell & Price, 1985; Jones, R., Giddens, & Croft, 1983). The empirical basis for such recommendations is not clear, as accidents often occur within a short distance from home.

To summarise, a review of studies incorporating practical driving tests showed that where tests were standardized and objective criteria for adequate performance specified, expert ratings of driving competence were strongly associated with objective performance scores, with large effect sizes reported (Cohen, 1988). Other factors may influence the expert ratings, such as the examiner being required to intervene when driving. The use of nonstandardized driving tests may produce results of uncertain validity.

2.5 Conclusion

Jones' (1978) work on the construction of a standardized test for learner drivers has direct implications for improving the validity of driving tests for people who have incurred brain impairment. Although Jones developed this exemplary protocol two decades ago, few driving examination centres have adopted this type of procedure. According to Jones' (1978) recommendations, the behaviour sampled by the test must be of sufficient duration and complexity to allow observation of several driving situations and manoeuvres. For reliability and replicability, each candidate should undergo the same test, insofar as this is possible given the constraints imposed by disability. The route and the manoeuvres required should be standardized, and conducted in as consistent an environment as possible, including traffic density. To avoid discriminating against the disabled driver, the test should not substantially more difficult than ordinary licence testing. However, the test should remain sufficiently challenging to allow the manifestation of any cognitive and perceptual sequelae of brain impairment incompatible with safe traffic participation, and the elimination of unacceptable levels of risk. Given that there is wide variation in the quality of driving performance among the normal driving population, similar variations should realistically be anticipated among those driving following brain impairment (Wilson & Smith, 1983).

An important innovation in the task of rating driving performance is to separate the responsibility for maintaining the safety of the vehicle from the task of assessing driving skill. This strategy will enhance the safety of all concerned and improve the quality of data obtained. An additional requirement, essential for safety, is a fully modifiable, dual control vehicle. If an adequate sample of driving behaviour is obtained, on-road evaluation allows recommendations to be made regarding driving competence. An adequate sample of driving behaviour is one where the common driving manoeuvres required in a normal driving environment are observed several times. A synthesis of the driving literature suggests that it is necessary to assess speed maintenance, vehicle tracking, visual scanning, vehicle position relative to other vehicles, mirror use and braking (for example, Evans (1991), Jones (1978)). These behaviours should be observed in a variety of manoeuvres, such as left or right turn at controlled and uncontrolled intersections, roundabouts, T-junctions, during lane changes and merging. On-road testing does not allow any guarantees to be made regarding the brain impaired person's future driving record, however, and clinicians should not be asked to make such a judgement. The criterion validity of standardized on-road assessment of brain impaired subjects, including the specificity and sensitivity of judgements of safe driving, requires further development. Similar investigation of the criterion validity of licence testing of normal drivers is also required. Also requiring further research is the relationship between the necessity for intervention by the driving instructor during the driving test and the final judgement regarding competence.

The studies detailed in the following chapters address some of these issues. Following a retrospective audit of a driver assessment program, further studies were undertaken to explore the predictive validity of medical and neuropsychological assessment for driving, and the reliability and validity of a standardized on-road driving test in drivers with acquired brain impairment, as well as in those with the progressive brain impairment associated with Alzheimer's Disease. Driving simulators were not examined, as a driving simulator was not readily available for experimental study, and furthermore, because driving simulator performance has not been found to relate closely with on-road driving performance. Closed course driving assessments were similarly not investigated.

CHAPTER 3

RETROSPECTIVE AUDIT OF THE FIRST 129 CLIENTS OF THE COORABEL DRIVER ASSESSMENT PROGRAM*

3.1 Introduction

The Coorabel Driver Assessment Program commenced in January 1988 at the Royal Rehabilitation Centre Sydney, with the objective of providing reliable and thorough assessment of driver competence in people with physical or cognitive disability resulting from brain impairment, spinal injury or orthopaedic injury. To examine the Program's success in achieving this objective, a retrospective audit of the first 129 consecutive referrals to the Coorabel Program was conducted in 1991.

Similar retrospective studies have been previously reported, for example Quigley and DeLisa (1983), Jones and colleagues (1983, 1987), and Simms (1985). Findings from these studies varied. One study suggested that among post-CVA subjects, differential success in pre-driving testing and driver training might be anticipated between left-CVA and right-CVA subjects (Quigley & DeLisa, 1983). However, no significant differences in driving assessment failure rates between left and right CVA subjects were reported in another study (Jones, R., Giddens, & Croft, 1983). An on-road test was employed in some studies as the criterion measure, although poor performance on off-road tests by subjects could preclude

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administration of the on-road driving test (Croft & Jones, 1987; Jones, R., Giddens, & Croft, 1983; Quigley & DeLisa, 1983). Other studies used driver relicensing by statutory authorities as the criterion measure of driving competence (Shore, Gurgold, & Robbins, 1980; Simms, 1985). The predictive validity of the diagnosis for driving outcome, and the value of off-road tests for the determination of driving ability were examined in some studies (Croft & Jones, 1987; Jones, R., Giddens, & Croft, 1983; Quigley & DeLisa, 1983). However, as subjects could fail sections of the assessment and be precluded from continuing further in the assessment process, information about outcome measures was not available for all subjects, and specificity and sensitivity could not be determined.

As in the study by Jones and colleagues (Jones, R., Giddens, & Croft, 1983), this present audit of the Coorabel Program was intended to review the assessment process and methodology, and examine the success rates for various subject groups. The study also sought to examine the variables age and chronicity (time since diagnosis) in addition to sex and diagnosis, with respect to both the final outcome and the result of each stage of assessment. It was hypothesised that diagnosis, age, and chronicity would be associated with outcome of the driving assessment, while sex would not. As a retrospective audit of clinical data, this study failed to satisfy most of the criteria for a standardized, controlled test of driving assessment outcome, as discussed in Chapter 1. However, it was viewed as a valuable pilot study to gauge the nature of the subject group and respective population, and to examine aspects of the assessment procedure and the performance of subjects at each stage of the assessment process.

3.2 Method

The Coorabel Driver Assessment Program consisted of three stages of assessment: medical, neuropsychological, and on-road. Prior to the on-road driving assessment, an off-road screen was conducted to determine the necessity for vehicle modifications. Data were not collected from this pre-driving screen.

3.2.1 Medical Assessment

A doctor undertaking specialist training in Rehabilitation Medicine conducted the medical examination. This included a general neurological examination, with visual fields tested by confrontation and borderline cases subsequently referred to an ophthalmologist. Static visual acuity was tested, although dynamic visual acuity was not. Memory was briefly assessed by immediate and five minute delay recall of three objects. To examine visuospatial skills, subjects were required to draw a clock face and a cube. Subjects were judged to have passed the medical assessment if no medical contraindications for driving were detected, as specified by the NSW Roads and Traffic Authority Medical Guidelines (1993). These guidelines list few absolute medical contraindications for driving following brain damage. They include recurrent seizures, impairment of consciousness or awareness, recurrent attacks of transient ischaemia, and visual field defects such as homonymous hemianopia (Roads and Traffic Authority, 1993). Subjects with a clear contraindication for driving were judged to have failed the medical assessment and were not permitted to continue with the program. Subjects were considered as borderline if a deficit was detected which required neuropsychological and/or on-road assessment to clarify its significance.

3.2.2 Neuropsychological Assessment

Neuropsychological assessment involved the administration of tasks which examined a variety of cognitive functions, including visuoperceptual abilities, speed of information processing, visual scanning, mental tracking, flexibility, planning and organisation. Both quantitative and qualitative aspects of performance were noted. The tests administered were: the Visual Form Discrimination Test (VFDT) (Benton et al., 1983), a multiple choice test of visual recognition; the Judgement of Line Orientation Test (JLOT) (Benton et al., 1983), which examines the perception of angular relationships; Trail Making Tests A and B (TMT A and TMT B) (Reitan, 1958), which are tests of visual conceptual and visuomotor tracking; the Benton Visual Retention Test (BVRT) (Benton, 1974), a visual recall test; and the Wechsler Adult Intelligence Scale Revised subtests Picture Completion (PC), Block Design (BD) and Digit Symbol Substitution (DSS) (Wechsler, 1981), which are tests of perceptual organisation and attention. Subjects demonstrating significant visuoperceptual impairments (for example, scoring at a level indicative of severe defect on the Benton tests as specified in the test manuals) or excessive slowing of visual scanning or information processing (that is, attaining scores on Trail Making Test A or B lower than the tenth percentile according to Lezak's (1983) norms), were judged to have failed the neuropsychological assessment and were not permitted to continue with the Program. Those subjects who presented with evidence of mild visuoperceptual deficit, slowing, or behavioural deficits such as rigidity, impersistence, distractibility, or impulsiveness, were judged to be borderline, and were permitted to proceed to off-road and on-road assessment with caution.

3.2.3 On-Road Assessment

All subjects who passed the medical and neuropsychological assessments then proceeded to an on-road assessment of driving. The test was conducted in a vehicle with automatic transmission, power steering, dual brakes and an engine cut-out switch. Additional vehicle modifications were available if necessary. The on-road driving test was conducted by a professional driving instructor and an occupational therapist. The driving instructor, seated in the front passenger seat, provided instructions to the subject and maintained safe passage of the vehicle. The occupational therapist, seated behind the driving instructor, observed the subject and recorded performance on a checklist. A copy of the checklist appears in Appendix 1. Five areas of driving performance were observed: planning and judgement, vehicle positioning, reaction time, speed control and observation. Both the nature and frequency of errors were recorded and information from the checklist was integrated into a written report.

One of four standard driving routes was used, each of which required about 50 minutes to complete. The least complex drive was conducted within the Centre grounds and the most complex in heavy density traffic and incorporated freeway driving, road map navigation and multistorey car park manoeuvres. Selection of the route was determined by the subject's licence status and driving experience. Feedback regarding adequacy of performance was provided to the subject at the conclusion of the assessment. Usually two on-road assessments were completed prior to a judgement about a subject's driving performance. Performance was rated as pass, borderline or fail. A fail was recorded when significant and frequent problems were scored in all five observed areas of driving performance, in addition to intervention being required by the driving instructor to ensure safe passage of the vehicle, or where significant and frequent problems occurred in three or four of the observed areas of driving performance in addition to substantial intervention being required by the driving instructor. In the case of a borderline result, remedial training was offered by the driving instructor to improve the skill level and the subject was subsequently re-assessed. The maximum number of assessments provided was four, with up to 20 remedial lessons.

As the data collected were frequency data, chi-square analysis was used for statistical analysis. All statistical analyses were performed using SPSS/PC+ 4.0.

3.3 Results

Subject details and assessment outcomes are shown in Table 3.1. Of 129 subjects, seven failed the medical assessment and a further 25 failed the neuropsychological assessment, and were therefore precluded from progressing to on-road driving assessment. Of the remaining subjects (n=97), 57 passed the on-road assessment, 24 failed the on-road assessment, and 16 failed to complete or withdrew. In summary, 57 subjects (44%) passed through all phases of the assessment process, while 56 subjects (43%) failed a stage of the assessment process, and 16 subjects (12%) withdrew from the assessment.

With regard to sex, 98 (76%) were male and 31 (24%) were female. In terms of age, 73 (57%) were aged 60 years or more, with 35 of these aged at least 70 years. Within the 70+ age group a higher rate of withdrawals during the testing period was noted, probably because of concomitant medical problems. Subjects within the 70+ age group were less likely to pass the assessment program (χ^2=15.41, df=6, p<.01).

No referrals were received within four weeks of diagnosis, and most subjects (79%) were more than six months post diagnosis when referred. A trend was noted for subjects with a chronicity of 12 months or greater to be more likely to fail the on-road assessment (χ^2=8.51, df=4, p<.10).

TABLE 3.1 Assessment outcome by age, sex, diagnosis and chronicity for all subjects (n=129).

	TOTAL	PASS TOTAL	FAIL TOTAL	MED. FAIL	NEURO. FAIL	ON-ROAD FAIL	WITH-DREW
Total	129	57	56	7	25	24	16
SEX							
Male	98	44	41	4	20	17	13
Female	31	13	15	3	5	7	3
AGE (years)							
<=19	2	0	1	0	0	1	1
20-39	21	10	9	2	5	2	2
40-49	33	16	16	2	7	7	1
60-69	38	22	14	1	7	6	2
70+	35	9	16	2	6	8	10
DIAGNOSIS							
Left CVA	39	16	15	2	6	7	8
Right CVA	33	14	17	4	7	6	2
Other CVA	10	6	4	0	4	0	0
Head Injury	12	4	7	0	4	3	1
Cerebral Tumour	4	3	1	0	0	1	0
Para/Quadriplegia	3	3	0	0	0	0	0
Cerebral Palsy	5	1	4	0	1	3	0
Multiple Sclerosis	5	2	1	0	0	1	2
Musculoskeletal	8	6	1	0	0	1	1
Other	10	2	6	1	3	2	2
CHRONICITY							
<=4 weeks	0	0	0	0	0	0	0
4 weeks-6 months	27	14	9	1	4	4	4
6-12 months	37	19	11	2	6	3	7
>12 months	65	24	36	4	15	17	5

With regard to diagnosis, it was noted that the non-brain impaired subjects (musculoskeletal, paraplegia or quadriplegia) failed assessment less frequently (10%) than subjects with brain impairment (53%; χ^2=6.87, df=1, p<.01). For subjects with brain impairment, diagnosis was not found to be associated with pass or fail outcome (χ^2=1.45, df=4, p<.90)). No statistically significant difference was found in failure rates between left and right hemisphere cerebrovascular accident (CVA) groups (χ^2=.86, df=1, p<.90).

While only seven subjects failed the medical assessment, in 47 cases (36%) the physician was unable to reach a final decision regarding driver competence. Of these 47, 17 failed the neuropsychological assessment, and a further 12 failed the on-road assessment. A further eight subjects withdrew from the Program and only ten of the 47 subjects were successful. Of the 75 subjects who passed the medical assessment, eight failed the neuropsychological assessment and a further 12 failed the on-road assessment. Thus, medical assessment failed to identify 20 potentially incompetent or unsafe drivers.

Thirty-one subjects were classified as borderline by the neuropsychologist and of these, 13 failed and 12 passed the on-road assessment, and six withdrew. Three of the 51 subjects who passed the neuropsychological assessment subsequently failed the on-road assessment.

3.4 Discussion

Examination of the outcomes of the 129 cases indicates that the Driving Assessment Program assisted many people to resume driving. People referred to the Program generally had significant disabilities, and their ability to drive was considered by the referring agency to be questionable. Despite this, 57 of the 129 subjects succeeded in all stages of assessment, and were able to resume driving.

The marked numerical dominance of males in this group can in part be attributed to a greater representation of males in traumatic brain injury and cerebrovascular disease (Jones, R., Giddens, & Croft, 1983). With regard to chronicity, the relatively small number of referrals within six months and the absence of referrals within four weeks of diagnosis, were consistent with the common clinical practice of recommending an adequate period of recovery and rehabilitation prior to consideration of resumption of driving. The finding of a trend for subjects with a chronicity of 12 months or longer to be more likely to fail the assessment, may reflect a higher level of initial disability in these subjects, and they may require longer periods of rehabilitation before the resumption of driving becomes a realistic goal.

In terms of the performance of different diagnostic groups, the finding of a differential success rate between brain impaired subjects and non-brain impaired subjects was consistent with previous reports (Jones, R., Giddens, & Croft, 1983; Shore, Gurgold, & Robbins, 1980). The absence of a significant difference in success rates between right and left hemisphere CVA groups is consistent with the findings of Jones and colleagues (1983) but not with those of Quigley and DeLisa (1983).

A significant methodological weakness of this exploratory study was that false negative error rates could not be examined, because subjects judged to have failed the medical or neuropsychological stage of assessment were not permitted to continue to the next stage. Nevertheless the results suggest that medical assessment alone may not be a reliable means of judging driver competence, because in 36% of cases the doctor was unable to make a judgement regarding driving ability. Furthermore, of 75 subjects judged by the doctor to have passed the medical assessment, 12 (16%) failed the on-road assessment. While the testing of motor deficits and visual acuity are relatively easily completed in a medical assessment, the much broader area of cognitive ability is frequently overlooked. Hence comprehensive testing of all abilities relevant to driving is rarely conducted, and a medical assessment may be an inadequate basis for a judgement concerning fitness to drive in those subjects with disability.

An important contribution of neuropsychological testing to the assessment process might be suggested by the small number of false positive errors (that is, passing subjects who are later found to be unsafe) arising from the neuropsychological assessment. However, without knowledge of false negative error rates, the relationship between the neuropsychological assessment and the outcome is unclear. This limitation is present in all similar uncontrolled clinical studies where not all subjects have had the opportunity to proceed to on-road driving assessment (for example, Jones and colleagues (1983), and Simms (1985)). Moreover, the validity of individual perceptual and neuropsychological tests to assess the skills and abilities required for safe driving was not examined in this study. Another methodological weakness of this pilot study was that the neuropsychologist and occupational therapist were not blinded to the results of prior stages of assessment, and therefore may have been influenced by a prior judgement of 'borderline' driving ability.

As most of the people referred to the Driver Assessment Program were thought by the referring agency to be at risk of unsafe driving, the results of this study might be generalised to individuals with brain impairment with a similar level of disability, such as those individuals requiring a period of inpatient rehabilitation. To address the methodological issues described above a prospective controlled study was proposed in which all subjects would proceed to an on-road assessment, to allow the evaluation of the predictive validity of medical and neuropsychological assessments for on-road driving. In this and other research, an on-road driving assessment has been employed as the 'gold standard' or final arbiter of driving ability. However, as discussed in Chapter 2, a review of the literature failed to locate studies in which the on-road assessment itself had been examined as a measurement technique. The proposed study was therefore designed to examine both the predictive validity of medical and neuropsychological examinations for driving competence, and to study the on-road assessment itself in terms of validity and reliability.

CHAPTER 4

PREDICTING DRIVING PERFORMANCE AFTER BRAIN IMPAIRMENT

4.1 Introduction

The impetus for this study came from questions prompted by a retrospective audit of the first 129 clients of the Coorabel Driving Assessment Program, described in the previous chapter. These questions concern the validity of two different off-road assessment methods for predicting on-road driving performance, namely medical and neuropsychological assessments, and also the validity of the on-road assessment itself.

Two surveys have shown poor knowledge among physicians of methods for assessing their patients' capacity to drive (King, Benbow, & Barrett, 1992; Miller & Morley, 1993). While guidelines similar to those by the NSW Roads and Traffic Authority (Roads and Traffic Authority, 1993) have been published to assist medical practitioners in assessing the fitness of their patients to drive safely, they tend to lack specific information about methods of assessment. As described in Chapter 1, a literature review revealed a lack of studies examining the efficacy of medical assessment in reliably distinguishing safe from unsafe drivers with brain impairment. It has been suggested that in the case of older drivers, the concept of medical clearance for driving is less valuable than an approach which identifies risk factors for unsafe driving (Reuben, 1993). Such an approach could feasibly be applied to drivers of all ages with brain impairment. However, the identification of specific risk factors requires further research. This study aimed to examine the predictive validity of medical examination for determination of fitness to drive for individuals with brain impairment, and to identify any medical variables associated with driving performance.

Age has previously been reported as being associated with crash rate for drivers. Elderly drivers have an higher crash rate per miles driven compared to middle-aged drivers, and furthermore the crash experience of those aged over 60 years approximates that of drivers under 25 (Carr et al., 1992; Reuben, Silliman, & Traines, 1988). However, in a study examining the effects of age on a standardized open-road driving test, no statistical difference between three groups of normal drivers (18-19 years, 25-35 years and 65+ years of age) for average total driving score was found (Carr et al., 1992). In the present study, the variable age was examined in relation to driving performance in a group of drivers with brain impairment. Diagnosis is another variable that has previously been examined in relation to driving performance, particularly with regard to the laterality of lesions. In one study equivalent driving assessment failure rates were reported for right and left hemisphere CVA subjects (Jones, R., Giddens, & Croft, 1983). Subsequently, in a study where the driving ability of aphasic and non-aphasic subjects with brain damage was examined, no clear association was found between performance on subtests of an aphasia test and the overall rating of driving performance, although significantly fewer aphasic than non-aphasic subjects passed the driving examination (Hartje et al., 1991). The present study aimed to examine the association between diagnosis and driving performance in a group of drivers with brain impairment.

Frequent use of the Mini Mental Status Examination (MMSE) as part of the assessment of driving competence is evident in the literature, as discussed in Chapter 1. For elderly subjects a relationship between MMSE score and driving performance has been reported.

However, the low specificity of the MMSE for road test performance precluded individual predictions about driving ability (Fitten et al., 1995; Odenheimer et al., 1994). Studies examining the relationship between MMSE score and driving performance in younger subjects were not located in a literature search. Hence, this present study aimed to investigate the predictive validity of the MMSE for driving performance in drivers of varying ages, who have sustained brain impairment.

As detailed in Chapter 1, no consistent and clear relationship between performance on neuropsychological tests and a driving criterion measure, such as an on-road driving test, is evident in the literature. Some neuropsychological tests (for example, some subtests of the WAIS/WAIS-R and Trail Making Test B) have been reported as both good and poor sources for prediction of on-road driving performance (Van Zomeren et al., 1988). This study sought to investigate the validity of neuropsychological tests for predicting on-road driving capability in individuals with brain impairment. A further area of investigation in this study was the nature of driving errors committed by drivers with brain impairment during the on-road driving evaluation, and the reliability of the on-road assessment itself.

In order to examine these questions, several changes to the driving assessment procedure were made, and these will be described in detail in the methods section. The specific research questions investigated in this study were:

1. Are physicians able to make an accurate prediction of driving performance on the basis of a medical assessment?

2. How do variables such as MMSE score, medical diagnosis, age, and medical variables relate to on-road driving performance?

3. Does neuropsychological assessment allow an accurate prediction of on-road driving performance?

4. Is the on-road assessment consistent and reliable?

How do the occupational therapist and driving instructor's rating of driving performance relate to the objective scoring of the standardized on-road driving test?

4.2 Method

This study was a prospective investigation, approved by the Medical Ethics Committee of the Royal North Shore Hospital, Sydney. It was conducted at the Coorabel Driver Assessment Program within the Royal Rehabilitation Centre Sydney. All subjects with brain impairment referred to the Coorabel Driver Assessment Program during the study period were included. Subjects were referred from hospital, rehabilitation and community settings. All subjects proceeded through every stage of assessment, except those whose medical assessment required them to be legally prohibited from driving, and who were then unable to complete on-road assessment. For example, those subjects with a history of recent epileptic seizure activity were not able to proceed to an on-road driving test. The number of subjects excluded as a result of being legally prohibited from driving is not known, as records for these individuals were not retained. Staff involved with each stage of assessment were blinded to the results of other stages of assessment.

The sample comprised 153 consecutively referred subjects, who were assessed by a doctor and a clinical neuropsychologist, and then underwent an on-road driving assessment conducted by an occupational therapist and a driving instructor. Subject characteristics are detailed in Table 4.1.

TABLE 4.1 Subject characteristics.

TOTAL NUMBER OF SUBJECTS	153
SEX	
Male	118 (77.12%)
Female	35 (22.86%)
DIAGNOSIS	
Brain Injury	29 (18.95%)
Left CVA	45 (29.41%)
Right CVA	40 (26.14%)
Other CVA	19 (12.42%)
Other neurological illness	20 (13.07%)
AGE	
Mean	57.4 years (SD=17.05 years)
Range	17- 84
CHRONICITY	
Mean time since diagnosis	2.9 years (SD=2.3 years)
Range	1- 17

Seven subjects had not held a driving licence prior to the diagnosis, while for three subjects driving histories were not available. The remaining 143 subjects were all driving prior to the onset of the neurological event. Forty-seven subjects had resumed driving prior to assessment in this program, while 102 subjects had not resumed driving prior to our assessment. Data regarding resumption of driving were not available for four subjects. Of the 47 subjects who had resumed driving, four reported having had one accident since the diagnosis, and one subject reported two accidents. None of these subjects had discontinued driving. The remaining subjects did not report any accidents.

Procedure

Several changes were made to the driving assessment procedure utilised in the study described in Chapter 3. These changes will be described in detail, and included:

1. The doctor, clinical neuropsychologist, occupational therapist and driving instructor were blinded to other ratings and judgements of subject performance during the assessment process.

2. The doctor and the neuropsychologist were required to predict on-road driving performance as one of pass, borderline or fail, on the basis of their respective clinical assessments.

3. The medical assessment was standardized in an attempt to ensure that the doctor's prediction of driving performance was based on the same clinical information for each subject. It was also expanded to include administration of the MMSE.

4. All subjects proceeded to on-road assessment regardless of their performance on medical or neuropsychological assessment. The only exceptions were subjects legally prohibited from driving who were excluded from the program. Requiring all subjects to proceed to on-road driving testing allowed the investigation of false negative error rates in prediction of driving performance.

5. The on-road assessment was further standardized. While four routes continued to be used, each of these was standardized. Freeway driving, navigation and

multistorey car park manoeuvres were no longer employed, because of a lack of relevance to some drivers.

4.2.1 Medical Assessment

The medical assessment, conducted by a doctor completing specialist training in Rehabilitation Medicine, was standardized and involved assessment of medical and driving history, administration of the MMSE according to standard instructions (Folstein, Folstein, & McHugh, 1975), and a physical examination. A copy of the MMSE appears at Appendix 5. During the course of data collection, eight doctors were sequentially involved with the Driver Assessment Program and performed the medical examinations. In the medical examination a range of sensory and motor abilities were rated as normal or abnormal. The sensory and motor abilities assessed included visual attention, sensory attention, tone and reflexes, clonus, power, sensation, coordination, diplopia and nystagmus. Visual acuity and visual fields were also assessed. Visual attention was assessed by presentation of visual stimuli to the left field, the right field and then simultaneously to both fields, with inattention being recorded when failure to respond to simultaneous stimulation was evident. Sensory inattention was assessed by sensory stimulation of the left hand, the right hand and then both hands, with inattention being recorded upon failure to respond to both. Visual acuity was assessed with normal correction by Snellen's chart. Visual fields were assessed by confrontation. The doctor recorded whether there were possible contraindications to driving in accordance with the RTA Medical Guidelines (Roads and Traffic Authority, 1993). Finally, for the purposes of the study, the doctor was required to make a prediction regarding driving performance based on the medical assessment. The rating scale was pass, borderline or fail. Pass was defined as a prediction of safe, competent driving performance. Fail was defined as a prediction of clearly unsafe, incompetent on-road performance. Borderline was defined as a prediction of errors being made on-road with the potential to compromise safety.

A standardized medical assessment form was used to record all the information required for the study, thus minimising the amount of writing required of the doctor. This form is reproduced in Appendix 2. The doctor also completed a Roads and Traffic Authority (RTA) Medical Report Form, shown in Appendix 3 which was forwarded to the RTA upon the completion of all stages of assessment, accompanied by a letter detailing the final results of assessment. All subjects were informed about the assessment process, including the requirement for notification of the RTA of assessment results, and all subjects signed consent forms prior to commencement of assessment. In general the RTA adopted the recommendations of the Coorabel Driver Assessment Program cancelling the driving licences of those individuals found not to be competent to drive. The RTA could alternatively request that the individual undertake a Roads and Traffic Authority (RTA) Disability Driving Test, and base its subsequent decision on the result of this test. However the RTA Disability Driving Test is designed primarily for those drivers with physical handicap rather than cognitive impairment. Any driver successfully completing the Coorabel Driver Assessment Program who was found to require physical modifications to their vehicle was also required by the RTA to complete the Disability Driving Test. In addition, any subject who wished to appeal the result of their driving assessment with the Coorabel Program, could also take the RTA Disability Driving Test.

4.2.2 Neuropsychological Assessment

A clinical neuropsychologist administered a standardized battery. The tests were selected on the basis of previous reports of the predictive ability of psychological tests for driving (Schweitzer et al., 1988; Sivak et al., 1981). Additionally, the test battery was intentionally kept brief to enhance subject cooperation. The tests are shown in Table 4.2.

TABLE 4.2 Neuropsychological tests administered.

Visual Form Discrimination Test (VFDT)
Judgement of Line Orientation Test (JLOT)
Trail Making Tests A and B (TMT A and TMT B)
Benton Visual Retention Test (BVRT)
Wechsler Adult Intelligence Scale - Revised (WAIS-R) subtests: Picture Completion (PC) Block Design (BD) Digit Symbol Substitution (DSS)

The Visual Form Discrimination Test (Benton et al., 1983) is a multiple choice test of visual recognition. The Judgement of Line Orientation Test (Benton et al., 1983) examines perception of angular relationships. Trail Making Tests A and B (Reitan, 1958) assess visuoconceptual and visuomotor tracking abilities. The Benton Visual Retention Test (Benton, 1974) is a visual recall test. The Wechsler Adult Intelligence Scale - Revised subtests Picture Completion, Block Design and Digit Symbol Substitution (Wechsler, 1981) are tests of perceptual organisation and attention. This neuropsychological test battery was shorter than that used in some previous studies (Engum et al., 1988a; Galski, Bruno, & Ehle, 1992), and did not include assessment of aspects of verbal memory, since, as discussed in Chapter 1, verbal memory has not previously been found to be reliably related to driving performance. In the pilot study described in Chapter 2, it was found that subjects referred for a driving assessment often indicated that they did not see the relevance of the neuropsychological tasks for driving. Consequently, the neuropsychological tests had poor face validity with regard to driving for many subjects and hence in the current study the test battery was intentionally designed to be concise to maximise subject cooperation. Some subjects were unable to complete the pencil-and-paper tasks such as the Benton Visual Retention Test or the Digit Symbol Substitution test, because of motor impairments such as weakness and incoordination. For these subjects data are listed as missing for the tests concerned.

The neuropsychologist was also required to predict the outcome of on-road driving evaluation using the same ratings of pass, borderline or fail, as in the medical assessment.

4.2.3 Driving Assessment

The driving assessment was conducted by an occupational therapist and a driving instructor. Prior to the driving assessment a brief off-road screen was conducted in the occupational therapy department in which information was obtained on driving history, physical capabilities and knowledge of road law and road craft. Strength, mobility and vision were assessed to determine the need for vehicle modifications such as a spinner knob for steering, or hand controls. Data from the off-road screen were not retained and hence were not included in the data analysis.

The on-road assessment was conducted in a vehicle with dual brakes, engine cut-off switch, automatic transmission and power steering. A spinner knob or hand controls were installed if required. During the road test the driving instructor, seated in the front passenger seat, provided directions to the subject and maintained safe passage of the vehicle, and the occupational therapist, seated behind the driving instructor, recorded driving performance according to a standardized protocol. One of four standardized driving routes in suburban Sydney, with light to moderate traffic density, was used in each assessment. The routes were of increasing complexity, each requiring about 50 minutes to complete. Route selection was determined by the subject's licence status and driving experience. Data are not available concerning the route used for each subject. All driving was done during daylight. The occupational therapist recorded the frequency of errors in five areas of driving performance as well as the frequency of instructor interventions. The driving score sheet is presented in Appendix 1.

The areas of driving performance rated were: planning and judgement, vehicle positioning, reaction time, speed control and driver observations. Planning and judgement refers to the driver's judgement of the traffic flow and safety to enter traffic (for example planning passage through an intersection). Vehicle positioning refers to the placement of the vehicle on the road and within the traffic lane. Reaction time is the time required for decision making and action, such as reactions to the actions of others, and responses to traffic signals. Speed control is the monitoring and maintenance of appropriate and safe speed. Driver observations refers to the monitoring of other traffic and the driving environment.

After a discussion between the driving instructor and the occupational therapist (the 'expert raters'), a consensus overall rating of either pass or fail was made. This rating was termed the 'final on-road result'. The expert raters did not use the 'borderline' rating, so that unequivocal feedback about driver safety and competence could be provided to the referring agencies. The result of the assessment was then forwarded to the referring agency and the RTA. In addition, where subjects required vehicle modifications, a disability driving test was also required and conducted by the RTA.

For some subjects, particularly those for whom vehicle modification had been required, more than one on-road assessment was necessary to determine driving ability. In these cases, remedial driving training was offered to subjects by the driving instructor to improve skill level and increase experience prior to the subsequent re-assessment. In this study data analysis was based on the first driving assessment for all subjects, prior to any remedial instruction. However, data from driving assessments made after remedial instruction are also available for CVA subjects.

The statistical analyses included correlational analyses (Pearson's (r_p), Spearman's (r_s) and Point Biserial (r_{pb})), reliability analysis, analysis of variance and logistic regression. Pearson's r was used for examining the linear relationship between two variables. Where variables were ranked, such as in a prediction of on-road driving performance, Spearman's rank-order correlation coefficient was used. In analyses where one variable was dichotomous, such as the final on-road result, the Point Biserial correlation coefficient was used. Reliability analysis of the on-road driving test was conducted using coefficient alpha, which requires finding the variance of the individuals' scores for each item, and then summing these variances across all items. Analysis of variance was used for testing differences between the mean number of driving errors for each diagnostic group. With regard to the prediction of on-road driving performance, the dependent variable had only two values, pass or fail. Because the dependent variable is dichotomous, the necessary assumptions for hypothesis testing in regression analysis are violated, and therefore logistic regression was used. All statistical analyses were performed using SPSS/PC+ 4.0.

4.3 Results

The four routes used for the on-road driving assessment were not equivalent. However, since data regarding which route a subject took were not available the scores obtained from the on-road data were analysed together. Seventy-five (49%) subjects passed the on-road assessment, while 78 (51%) failed. A detailed analysis of the data is provided below. Results for the medical variables and the examination of the relationship between the doctor's prediction of on-road performance and final on-road result will be presented, followed by results for the neuropsychological variables and the relationship between the neuropsychologist's prediction of driving performance and the final on-road result. In the third section, the on-road assessment variables and reliability analysis will be presented.

4.3.1 Medical Assessment and Relationship to On-Road Result

The variables examined in the medical assessment were scored as normal or abnormal. Occurrences of abnormal motor abilities were found, with more than 40% of subjects demonstrating abnormalities in tone/reflexes, power and heel/toe walk coordination. The results for the medical variables are shown in Table 4.3. Background rates of these abnormalities in the general population were not available. Fourteen (9%) subjects were judged in the medical assessment to have possible contraindications for driving according to RTA criteria, and of these, three passed the on-road assessment and 11 failed. Correlation analysis found no association between age and any of the medical variables, suggesting that the occurrence of abnormal medical variables was not simply a function of increasing age.

TABLE 4.3 Frequency of normal and abnormal results for medical variables for all subjects (n=153), and number of missing cases for each variable. Subjects were rated as normal or abnormal for each medical variable.

VARIABLE	NORMAL	%	ABNORMAL	%	MISSING
Visual Attention	147	96.1	3	2.0	3
Sensory Attention	142	92.8	8	5.2	3
Visual Field	143	93.5	7	4.6	3
Tone / Reflexes	77	50.3	73	47.7	3
Clonus	135	88.2	14	9.2	4
Power	87	56.9	63	41.2	3
Sensation	128	83.7	22	14.4	3
Finger-nose coordination	110	71.9	39	25.5	4
Supination / pronation	104	68.0	45	29.4	4
Toe Tap	103	67.3	45	29.4	5
Heel / Toe walk	82	53.6	67	43.8	4
Diplopia	147	96.1	2	1.3	4
Nystagmus	144	94.1	5	3.3	4

Correlation analysis was used to examine the relationship between the medical variables and the physician's prediction of driving performance, and revealed significant correlations in the expected direction. That is, abnormal medical variables were associated with the doctor's prediction of failure in the on-road test, for the variables visual attention (r_s = -.21, p=.01), sensory attention (r_s = -.21, p=.009), visual fields (r_s = -.25, p=.002), abnormal tone/reflexes (r_s = -.20, p=.01), clonus (r_s = -.18, p=.03), power (r_s = -.23, p=.005), sensation (r_s =- .28, p=.0005), finger-nose coordination (r_s = -.21, p=.009), supination/pronation (r_s = -.19, p=.02) and heel/toewalk coordination (r_s = -.30, p=.0002). However no significant associations were found between the doctor's prediction of driving performance and the presence of diplopia (r_s = .09, p=.29), nystagmus (r_s = -.004, p=.97), or toe/tap coordination (r_s = -.12, p=.16). Results of the correlation analysis are shown in Table 4.4.

TABLE 4.4 Results of correlation analysis examining the relationship between medical variables, scored abnormal or normal, and doctor's prediction of driving performance, for all subjects (n=153).

MEDICAL VARIABLE	SPEARMAN'S r	p VALUE
Visual Attention	-.21	.01
Sensory Attention	-.21	.01
Visual Field	-.25	.002
Tone / Reflexes	-.20	.01
Clonus	-.18	.03
Power	-.23	.005
Sensation	-.28	.0005
Finger / nose coordination	-.21	.009
Supination / Pronation	-.19	.02
Toe Tap	-.12	.16
Heel / Toe Walk	-.30	.0002
Diplopia	.09	.29
Nystagmus	-.004	.97

The mean number of medications prescribed per subject was 1.7 (SD=1.6), with a range of 0-8. Mean MMSE score was 27.0 (SD=3.4), with a range of 7-30. The range of MMSE scores for those subjects who passed the on-road test was 7-30, while for the subjects who failed, the range was 16-30. The score of 7 appears to be an outlier, with 95% of MMSE scores 20 or greater. Excluding the outlier, the range of MMSE scores for the subjects who passed the on-road test was 19-30. Table 4.5 illustrates the frequency data for MMSE scores for all subjects.

TABLE 4.5 Frequency data for MMSE scores for all subjects (n=153).

SCORE	FREQUENCY	PERCENTAGE
7	1	0.7
16	1	0.7
17	1	0.7
18	1	0.7
19	1	0.7
20	2	1.4
21	3	2.0
22	4	2.7
23	6	4.1
24	4	2.7
25	12	8.1
26	13	8.8
27	11	7.4
28	22	14.9
29	31	20.9
30	35	23.6
Missing	5	3.3

A significant association between the doctor's prediction of driving competence and the MMSE score was observed (r_s = -.40, p<.001). Subject age was not significantly associated with the doctor's prediction of driving competence (r_s = .12, ns). The doctor's prediction and the neuropsychologist's prediction for final on-road result were significantly associated (r_s = .26, p<.005). Table 4.6 illustrates frequency information for the predictions of pass, borderline and fail, for driving competence by the neuropsychologist and doctor, for all subjects.

TABLE 4.6 Frequencies of pass, borderline and fail predictions for driving competence by neuropsychologist and doctor for all subjects (n=153).

PREDICTION OF DRIVING COMPETENCE	NEUROPSYCHOLOGIST	DOCTOR
(Missing)	(1)	(3)
Pass	73	95
Borderline	66	47
Fail	13	8
TOTAL	153	153

None of the medical variables was significantly correlated with the final on-road result. The Spearman's correlation analysis for the medical variables (scored as normal or abnormal) and the final on-road result (scored as pass or fail), is shown in Table 4.7.

TABLE 4.7 Results of Spearman's correlation analysis for medical variables, scored normal or abnormal, by final on-road result, scored pass or fail, for all subjects (n=153).

MEDICAL VARIABLE	SPEARMAN'S r	P VALUE
Visual Attention	-.14	.09
Sensory Attention	-.11	.17
Visual Field	-.03	.75
Tone / Reflexes	-.01	.86
Clonus	-.09	.30
Power	-.07	.38
Sensation	.01	.89
Finger / nose coordination	.04	.67
Supination/ Pronation	-.08	.33
Toe Tap	-.14	.08
Heel / Toe Walk	-.09	.27
Diplopia	.12	.15
Nystagmus	.04	.62

The number of medications (r_{pb} = .076, ns), age (r_{pb} = .163, ns), and MMSE score (r_{pb} = .190, ns) were not significantly associated with the final on-road result. However, if the MMSE outlier score of 7 is excluded from the analysis, MMSE score was significantly associated with final on-road result (r_{pb} = -.27, $p<.001$). Diagnosis was also significantly correlated with the final on-road result (r_{pb} = -.28, $p<.001$). As indicated in Table 4.8, the majority of subjects in the diagnostic groups Brain Injury, Left CVA and Other CVA passed the on-road evaluation. However, subjects in the diagnostic groups Right CVA and Other Neurological, were significantly less likely to pass the driving assessment (χ^2=13.51, df=4, p<.01). Moreover, an examination of the final on-road results for Right and Left CVA subjects alone showed that Right CVA subjects were significantly less likely to pass the driving assessment than Left CVA subjects (χ^2=6.83, df=1, p<.01), a medium effect size (Cohen, 1988).

TABLE 4.8 Final on-road result by diagnostic group for all subjects (n=153).

DIAGNOSIS	n	PASS	PERCENT	FAIL	PERCENT
Brain Injury	29	19	65.5	10	34.4
Left CVA	45	25	55.6	20	44.4
Right CVA	40	11	27.5	29	72.5
Other CVA	19	12	63.2	7	36.8
Other Neurological	20	8	40.0	12	60.0

The duration of diagnosis was significantly associated with the final on-road result (r_{pb} = -.19, p<.01), with a longer time since diagnosis being associated with an increased likelihood of a result of failure in the final on-road result. The physician's prediction of driving competence was also significantly associated with the outcome measure of the expert rating of driving competence, termed the final on-road result (r_{pb} = .29, p<.001).

4.3.2 Neuropsychological Assessment and Relationship to On-Road Result

The performance on cognitive tasks is illustrated by the mean, standard deviation and range of the neuropsychology test scores, as shown in Table 4.9. Performance was poor relative to norms on Trail Making Tests A and B, Benton Visual Retention Test errors and Digit Symbol Substitution (Lezak, 1995). The oldest group of subjects was used as the reference group for the norms, so that the performance of all subjects could be assessed without disadvantaging older subjects.

TABLE 4.9 Mean, standard deviation and range of neuropsychological test scores for all subjects (n=153).

TEST	MEAN	SD	RANGE	MISSING
Visual Form Discrimination Test	26.57	4.51	10-34	(1)
Judgement of Line Orientation Test	22.76	5.53	2-32	(1)
Trail Making Test A (seconds)	71.57	47.76	20-433	(0)
Trail Making Test B (seconds)	176.71	115.58	40-900	(6)
Benton Visual Retention Test correct	5.53	1.89	1-10	(3)
Benton Visual Retention Test errors	7.39	3.84	1-19	(3)
Picture Completion (raw score)	13.31	4.43	1-20	(2)
Block Design (raw score)	20.91	10.38	1-46	(2)
Digit Symbol Substitution (raw score)	28.75	12.43	3-68	(9)

The neuropsychology test scores were all significantly associated with the neuropsychologist's prediction of on-road performance, with poor performance on the neuropsychological tests associated with a prediction of incompetent driving performance (see Table 4.10). All of the neuropsychology test scores were significantly associated with the MMSE score in the expected direction (see Table 4.10). The neuropsychologist's prediction of driving test performance was associated with MMSE score ($r_s = -.41$, $p<.001$).

TABLE 4.10 Association between neuropsychological test scores and neuropsychologist's prediction of driving competence, and between neuropsychological test scores and MMSE score, for all subjects (n=153).

NEUROPSYCHOLOGICAL TEST	ASSOCIATION WITH NEUROPSYCHOLOGIST PREDICTION r_s	ASSOCIATION WITH MMSE SCORE r_p
Visual Form Discrimination	-.48 $p<.0001$	.22 $p<.01$
Judgement of Line Orientation	-.39 $p<.0001$	.22 $p<.01$
Trail Making Test A	.49 $p<.0001$	-.44 $p<.001$
Trail Making Test B	.35 $p<.0001$	-.25 $p<.01$
Benton Visual Retention correct	-.49 $p<.0001$	.46 $p<.001$
Benton Visual Retention errors	.46 $p<.0001$	-.51 $p<.001$
Picture Completion	-.55 $p<.0001$	.48 $p<.001$
Block Design	-.47 $p<.0001$	.31 $p<.001$
Digit Symbol Substitution	-.48 $p<.0001$	.36 $p<.001$

As detailed in Table 4.11, all of the neuropsychology test scores, with the exception of the Visual Form Discrimination Test, were associated with the final on-road result. The neuropsychologist's prediction of driving test outcome was significantly associated with the final on-road result ($r_{pb} = .36$, $p<.001$).

TABLE 4.11 Association between neuropsychological test scores and neuropsychologist's prediction of driving competence with final on-road result for all subjects (n=153).

NEUROPSYCHOLOGICAL TEST	POINT BI-SERIAL r	SIGNIFICANCE
Visual Form Discrimination	-.18	ns
Judgement of Line Orientation	-.37	<.001
Trail Making Test A	.26	<.01
Trail Making Test B	.34	<.001
Benton Visual Retention correct	-.26	<.01
Benton Visual Retention errors	.27	<.001
Picture Completion	-.23	<.01
Block Design	-.22	<.01
Digit Symbol Substitution	-.25	<.01
Neuropsychologist's Prediction	.36	<.001

4.3.3 On-Road Evaluation

Driving error data and the number of instructor interventions were recorded for all subjects for the first on-road evaluation. The mean total number of errors in the driving assessment was 29.71 (SD=18.46), with a range of 0-101. The mean, standard deviation and range for number of errors in each driving category on the driving assessment are shown in Table 4.12. The driving categories were observation, speed, planning and judgement, vehicle positioning, and reaction time. The total driving error score was calculated by summing the errors in each of the driving categories observation, speed, planning and judgement, vehicle positioning and reaction time. The total driving error scores are also shown in Table 4.12.

TABLE 4.12 Mean number, standard deviation, and range for driving errors in the driving categories observation, speed, planning and judgement, vehicle positioning, reaction time and instructor interventions, plus total driving errors excluding instructor interventions, in driving assessment for (1) all subjects (n=153), (2) subjects who passed final on-road result (n=75), and (3) subjects who failed final on-road result (n=78).

ERROR CATEGORY	MEAN ERRORS	SD	RANGE
(1) ALL SUBJECTS			
Observation	9.15	8.18	0 - 42
Speed	2.72	3.40	0 - 14
Planning and Judgement	8.57	8.36	0 - 54
Vehicle Positioning	8.17	7.29	0 - 38
Reaction Time	1.11	3.11	0 - 23
Instructor Interventions	2.63	4.92	0 - 34
Total Errors	27.71	18.46	2 - 101
(2) SUBJECTS WHO PASS ON-ROAD			
Observation	8.36	7.02	0 - 30
Speed	2.29	3.19	0 - 14
Planning and Judgement	5.59	5.15	0 - 25
Vehicle Positioning	5.43	5.63	0 - 29
Reaction Time	0.73	2.06	0 - 12
Instructor Interventions	0.96	2.06	0 - 12
Total Errors	22.40	13.50	2 - 69
(3) SUBJECTS WHO FAIL ON-ROAD			
Observation	9.91	9.15	0 - 42
Speed	3.13	3.57	0 - 14
Planning and Judgement	11.47	9.78	0 - 54
Vehicle Positioning	10.84	7.74	0 - 38
Reaction Time	1.48	3.85	0 - 23
Instructor Interventions	4.25	6.21	0 - 34
Total Errors	36.83	19.88	0 - 101

The number of errors in the categories planning and judgement (r_{pb} = .37, p<.001), vehicle positioning (r_{pb} = .42, p<.001) and number of instructor interventions (r_{pb} = .33, p<.001) were significantly associated with the final on-road result in the expected direction, with an increase in errors or interventions correlated with an increased likelihood of failure. The number of errors in observation (r_{pb} = .10, ns), speed (r_{pb} = .16, ns) and reaction time (r_{pb} = .12, ns) were not related to the final on-road result.

The relationship between the total number of errors incurred in the driving assessment and background, medical, neuropsychological and outcome variables was examined via correlational analyses, as shown in Table 4.13. The total number of errors incurred in the driving assessment was significantly associated with age of the subject (r_p = .41, p<.01), with a higher age being associated with a higher number of errors on the driving test. The total number of driving errors was not significantly associated with number of medications (r_p = .13, ns), nor with MMSE score (r_p = -.10, ns). Total number of driving errors was significantly associated with both the doctor's prediction (r_s = .29, p<.003) and the neuropsychologist's prediction (r_s = .17, p<.05) of driving test outcome. The total number of driving errors was significantly associated with all the neuropsychology test scores (see Table 4.13). The driving test outcome, a consensus rating by the expert judges referred to as the final on-road result, was highly associated with the objective score of total number of errors from the driving assessment (r_{pb} = .39, p<.0001). That is, the expert rating of driving competence shared 15% common variance with the total error score derived from the objective evaluation of driving performance.

TABLE 4.13 Associations between total number of driving errors incurred on driving test and background, medical, neuropsychological and outcome variables for all subjects (n=153).

VARIABLES	TOTAL ERRORS r	p VALUE
Age	r_p = .41	p<.001
Number of Medications	r_p = .13	ns
MMSE Score	r_p =-.10	ns
Doctor's Prediction	r_s = .29	p<.0003
Visual Form Discrimination Test	r_p =-.20	p<.01
Judgement of Line Orientation Test	r_p =-.20	p<.01
Trail Making Test A	r_p = .34	p<.001
Trail Making Test B	r_p = .36	p<.001
Benton Visual Retention Test correct	r_p =-.30	p<.001
Benton Visual Retention Test errors	r_p = .36	p<.001
Picture Completion	r_p =-.27	p<.001
Block Design	r_p =-.42	p<.001
Digit Symbol Substitution	r_p =-.24	p<.01
Neuropsychologist's Prediction	r_s = .17	p<.05
Final On-Road Result	r_{pb} = .39	p<.0001

The relationship between diagnosis and number of driving errors was examined using analysis of variance (ANOVA). For the error category planning and judgement, the number of errors incurred by subjects in the Left CVA diagnostic group was significantly greater than those in the Brain Injury diagnostic group (f=3.24, df= 4, p=.014). In the other error categories, no significant differences between diagnostic groups were found. The total number of driving errors for subjects who achieved a pass in the final on-road result (mean errors = 22.40, SD=13.50) was significantly lower than that of subjects who failed (mean errors = 36.83, SD=19.88, f=2.17, 2 tail probability = .001).

As illustrated in Table 4.14, an analysis of the internal reliability of the error scores from the driving assessment showed a Cronbach's alpha of .92, indicating a highly reliable test

(Anastasi, 1982). Item-Total correlations for the six categories of driving error scores are also shown in Table 4.14, and ranged from .67 to .88, all within acceptable limits (Cohen, 1988).

TABLE 4.14 Reliability analysis for driving test error categories for all subjects (n=153).

ERROR CATEGORY	ITEM - TOTAL CORRELATION
Observations	.67
Speed	.88
Planning and judgement	.73
Vehicle positioning	.76
Reaction time	.83
Instructor interventions	.81
Reliability coefficient	alpha = .92

To examine the relationship between the driving error scores, and the outcome measure of final on-road result, a forward stepwise entry logistic regression was conducted with the final on-road result as the dependent variable, and the following predictor variables: total error score, number of instructor interventions, and driving error scores for observation, speed, planning and judgement, vehicle positioning, and reaction time. The total error score and the number of instructor interventions were found to be significantly associated with the final on-road result, with 80.0% of subjects correctly classified as passing the on-road assessment, and 66.2% of subjects correctly classified as failing, with an overall correct classification rate of 73.0% (-2 log likelihood χ^2=169.42, df=149, significance = .12).

To construct an expert model for the prediction of the outcome measure of final on-road result, all demographic, medical and neuropsychological variables were examined as predictor variables in a logistic regression model using a forward stepwise method. The variables diagnosis, doctor prediction and neuropsychologist prediction were treated as categorical variables for the analysis. The variables duration of diagnosis, diagnosis, Judgement of Line Orientation Test, Trailmaking Test B, Block Design and finger/nose coordination were found to be significantly associated with the outcome variable of final on-road result, independent of the other variables. The model resulted in 80.6% of subjects correctly classified as 'pass', 75.4% correctly classified as 'fail', with an overall correct classification rate of 78.0% (-2 log likelihood χ^2=118.71, df=122, significance = .57).

Forward stepwise logistic regression was used to examine a possible interaction effect between the total number of errors and the number of instructor interventions. No interaction effect was found (-2 log likelihood χ^2=212.04, df=152, significance = .0009).

4.3.4 Post-Training Driving Assessment

With regard to performance on the post training driving assessment, data are available for 60 subjects only, all of whom had a diagnosis of cerebrovascular accident (right, left or other). Mean number of driving errors, standard deviation and range for each driving category are shown in Table 4.15.

TABLE 4.15 Mean, standard deviation and range of errors for each driving error category, sustained on driving assessment and post-training assessment (n=60 CVA subjects).

ERROR CATEGORY	MEAN	SD	RANGE
Observation	10.03	9.51	0 - 42
Observation 2	7.28	6.76	0 - 24
Speed	3.38	3.82	0 - 14
Speed 2	3.43	4.12	0 - 16
Planning, judgement	10.42	8.90	0 - 47
Planning, judgement 2	8.60	9.71	0 - 50
Vehicle positioning	9.57	7.31	0 - 38
Vehicle positioning 2	7.43	6.96	0 - 25
Reaction time	1.13	3.11	0 - 18
Reaction time 2	0.85	2.10	0 - 10
Instructor interventions	2.68	3.86	0 - 18
Instructor interventions 2	1.82	4.07	0 - 26
Total errors 1	34.53	17.91	4 - 101
Total errors 2	27.60	19.56	4 - 87

Of these 60 subjects, 33 (55%) passed the post-training driving assessment, and 27 (45%) failed. A comparison of performances on the pre- and post-training driving assessments (excluding instructor interventions) for these 60 subjects showed a significant reduction in mean total number of driving errors (t=3.11, df=59, 2 tail probability = .003), a small effect size (Cohen, 1988). Examination of the categories of driving error showed a significant reduction in number of driving errors for two categories of error only. These were errors in observation (t=2.07, df=59, 2 tail probability = .042) and errors in vehicle positioning (t=2.24, df=59, 2 tail probability = .029). There were no significant differences in the mean number of errors between pre- and post-training test for these 60 subjects in the categories of speed, planning and judgement, and reaction time, or number of instructor interventions.

4.4 Discussion

In this study 75 (49%) subjects were judged to be competent to drive on the basis of our outcome measure, a standardized on-road driving assessment, and 78 (51%) were judged not competent to drive. This success rate in driving assessment following brain impairment is similar to that reported in previous studies (Hopewell & Price, 1985; Shore, Gurgold, & Robbins, 1980). However, only 14 subjects (9.2%) were judged by the doctor to have possible contraindications for driving according to RTA criteria (Roads and Traffic Authority, 1993), suggesting that RTA criteria are not sufficiently stringent to exclude those people with brain impairment who are not competent to drive.

4.4.1 Medical and Demographic Variables and Driving Performance

Age was significantly associated with the total number of driving errors, with increased age being associated with a larger number of driving errors. However, age was not associated with the final on-road result. Elderly drivers have been reported to have an increased crash rate per miles driven compared to middle-aged drivers, and furthermore the crash experience of those aged over 60 years has been reported as approximating that of those aged under 25 years (Carr et al., 1992; Reuben, Silliman, & Traines, 1988). However, in a study by Carr and colleagues examining the effects of age on a standardized open-road driving test, no statistical difference between three groups of normal drivers (18-19 years, 25-35 years and 65+ years of age) for average total driving score was found (Carr et al., 1992). In addition, when the mean error score was examined Carr and colleagues found the elderly driver group to have a significantly lower error score than either of the younger groups. Carr and colleagues (1992) suggested that their elderly drivers' superior performance can be explained in part by fewer speeding errors. Interestingly, the number of errors in speed control was not a significant predictor of outcome in the present study. The finding of a significant effect of age for total number of driving errors in this study suggests the possibility of an interaction between ageing and the effects of brain impairment on driving ability. It is possible that our expert raters did not consider the increased number of errors by some of the older drivers as involving 'serious' driving errors, and may therefore have rated the errors to be less important for driving safety. That is, while the expert raters noted the occurrence of errors, the nature of the errors may have led the raters to consider their potential impact on driving competence as lower.

The duration of the diagnosis was significantly associated with the final on-road result, with a longer duration of diagnosis being associated with a decreased likelihood of passing the on-road evaluation. Subjects with a longer duration of diagnosis may have had a more severe level of disability initially, therefore requiring a longer period of recovery before driving became a realistic rehabilitation goal. The diagnosis was also a significant predictor of the final on-road result. Subjects in the Right CVA and Other Neurological groups were less likely to pass the on-road evaluation than subjects in other diagnostic groups. Moreover, when only the Right CVA and Left CVA groups were compared, the Right CVA group was significantly less likely to be successful in the on-road assessment than the Left CVA group. This difference in pass rates contrasts with two earlier studies in which no clear relationship between laterality of lesion in CVA subjects and driving performance was detected (Hartje et al., 1991; Jones, R., Giddens, & Croft, 1983), but is consistent with other studies in which right CVA subjects were found to be less likely to successfully complete a driver assessment program (Bardach, 1971; Quigley & DeLisa, 1983). Although Hartje and colleagues (Hartje et al., 1991) noted that significantly fewer aphasic than non-aphasic subjects passed their driving examination, this result may reflect language impairment compromising performance on the driving test through inability to comprehend instructions, rather than a direct effect of left hemisphere dysfunction on driving ability.

The doctor's prediction of driving performance was significantly associated with most of the medical variables and with the MMSE score, but not with age (see Table 4.4). Interestingly, while more than 40% of subjects demonstrated abnormality on the medical variable of tone/reflexes, this variable was not found to be significantly associated with the doctor's prediction. This may reflect a view that an abnormality in tone or reflexes can be compensated for while driving, or alternatively it may be an unreliable measure. It seems reasonable to assume that the doctor's prediction of on-road driving performance would be based largely on the medical variables and MMSE score. However, the medical variables and MMSE score were not significantly associated with the final on-road result, while the doctor's prediction of on-road performance was significantly correlated with the outcome measure. This raises the question of whether other factors were involved in the doctor's prediction. These results fail to illuminate the criteria by which the doctor's prediction of on-road driving performance was made. If the outlier MMSE score is disregarded, the MMSE scores were correlated with the final on-road result. Therefore it might be presumed that the doctor's prediction was based, at least in part, on MMSE score. However, on the basis of these results it is difficult to suggest guidelines for the contents of a medical examination for the driving assessment of subjects with brain impairment. Reuben (1993) has suggested that for older drivers a more valuable approach to medical examination may be to identify risk factors for unsafe driving. This suggestion is pragmatic and could be applied to drivers of all ages with brain impairment. However, the results of this study do not enable the identification of specific medical risk factors, and Reuben's suggested approach requires further research.

The range of MMSE scores, including the outlier score, for those subjects who passed the on-road evaluation was greater (7-30) than the range for those failed (16-30). If the outlier score of 7 is again excluded, the range of MMSE scores for those subjects who passed the on-road evaluation (19-30) was not substantially different to the range for those who failed (16-30), suggesting that the MMSE has insufficient sensitivity and specificity for individual prediction of driving competence. Odenheimer and colleagues (1994) examined a group of 30 elderly drivers, of whom six had a diagnosis of dementia, and reported a large overlap in MMSE scores between subjects passing and failing the road test, from which they concluded that MMSE alone was inadequate for predicting driving performance. In one study where a significant relationship between mean MMSE score and the driving related outcome measure was found, the mean MMSE score achieved by the subjects was lower than in the present study (Logsdon, Teri, & Larson, 1992). As 59.5% of subjects in this present study achieved scores of 28 or above on the MMSE, there may be a ceiling effect for MMSE score in relation to on-road driving performance, as suggested by Marottoli and colleagues (Marottoli et al., 1994). Subject age may also be a factor relating to the predictive validity of the MMSE for on-road driving performance. Studies that have found a positive result for the predictive ability of the MMSE have typically involved elderly subjects, rather than the wider age range of subjects included in this study.

When all demographic, medical and neuropsychological variables were examined as predictors of final on-road result using forward stepwise logistic regression, six variables together demonstrated an overall correct classification rate of 78%. These were diagnosis, duration of diagnosis, Judgement of Line Orientation Test, Trail Making Test B, Block Design test, and finger/nose coordination. This model of on-road driving performance might be considered as an 'expert model' derived from off-road variables. These results suggest that together with information about diagnosis and duration, the administration of three psychological tests and a coordination task, 78% of subjects could be correctly classified as either safe or unsafe to drive. However the remaining 22% of subjects would be misclassified, so that the replacement of an on-road driving test by this expert model cannot be recommended for the individual assessment of driving competence.

In relation to the first research question of this study, the results suggest that although the doctor's prediction of driving competence was correlated with the outcome measure of the expert rating of driving competence, it was not a significant predictor of outcome when considered with other variables. Moreover, it was not clear which components of the medical assessment were most useful to the doctor in determining driver competence, and hence it is difficult to make recommendations regarding the nature and content of a medical assessment for the purpose of determining fitness to drive. With regard to the second research question, concerning the relationship between background and demographic variables and on-road driving performance, the 'expert model' of driving performance suggested that diagnosis and duration of diagnosis were significant predictors of on-road driving performance, and were making separate contributions to the variance of the final on-road result. As discussed above, comparisons of the diagnostic groups indicated that fewer subjects in the Right CVA and Other Neurological groups passed the on-road driving assessment, and moreover when considered separately, results for Right CVA and Left

CVA subjects showed that Right CVA subjects were less likely to pass the driving assessment than Left CVA subjects. In terms of duration of diagnosis, a longer duration was likely to be associated with a more severe initial disability. Interestingly, one medical variable, finger-nose coordination, which involves aspects of fine muscular coordination principally related to cerebellar functioning, was also included in the 'expert model' as a significant predictor of outcome, with a separate contribution to the variance of the outcome measure. It is not immediately clear why this variable, for which 72% of subjects were rated as 'normal', was a significant predictor of outcome. In general, however, it can be concluded that medical variables alone cannot be recommended as appropriate criteria for the determination of driving competence.

4.4.2 Neuropsychological Variables and Driving Performance

All neuropsychology test scores were correlated with the neuropsychologist's prediction of outcome, and with the total number of driving errors made during the driving assessment. In addition, all neuropsychology test scores, with the exception of the Visual Form Discrimination Test scores, were correlated with the final on-road result. With regard to the third research question defined in this study, three neuropsychological test scores were found to be significant predictors of outcome: Judgement of Line Orientation test, Trailmaking Test B and Block Design. These tests measure aspects of visuomotor tracking, visual attention, perceptual organisation and perception of angular relationships. The other tests administered did not contribute to the predictive ability of the neuropsychological assessment. The neuropsychologist's prediction of driving performance was not included in the 'expert model' however, despite being significantly correlated with the final on-road result. This is because the neuropsychologist's prediction was not found to have made a contribution to the variance of the final on-road result independent to that of the Judgement of Line Orientation Test, Block Design subtest and Trail Making Test B.

The Judgement of Line Orientation Test was included in the test battery for this study because it requires subjects to make judgements about the degree of angle of lines (Benton et al., 1983), which may be a component factor for the ability to judge velocity. In driving the ability to judge velocity relates to the judgement of the speed of oncoming traffic, and the consequent gap required to enter traffic flow. A possible relationship between the Trail Making Test B and Judgement of Line Orientation Test is illustrated by the situation where slowing in mental tracking and visual scanning, and inaccurate judgement of traffic velocity leads to the slow evaluation of traffic gaps at intersections, so that in the time taken by the subject to evaluate and accept or reject the traffic gap, the traffic situation has changed and another judgement is required. Deficits reflected in poor performance on Trail Making Test B and Judgement of Line Orientation Test may separately undermine driving safety, or they may interact to impair driving fitness. The finding of an association between one of the Wechsler subtests, Block Design, and driving performance is consistent with some earlier reports (Galski, Bruno, & Ehle, 1992; Kumar et al., 1991).

Van Zomeren and colleagues (1988) found a poor relationship between neuropsychological tests of information processing and on-road driving performance as rated by an expert judge, and offered two explanations. The first explanation was the possibility of a confounding effect of driving experience with on-road test performance. The second was that the neuropsychological tests administered in many studies were mainly relevant to operational aspects of driving and did not measure higher order or executive cognitive functions relevant to driving. Two subsequent studies, however, using data from a driving simulator task found that while brain impaired subjects were consistently slower than controls, higher order cognitive functions of planning and flexibility were unimpaired (Schmidt et al., 1996; Van Wolffelaar, Brouwer, & Van Zomeren, 1990). It is therefore recommended that the role of previous driving experience, both in terms of exposure (kilometres driven per year) and previous crash and violation records, be investigated further to determine its predictive value in individuals who have sustained brain impairment.

4.4.3 On-Road Driving Performance

With regard to the fourth research question, concerning driving performance during the on-road evaluation, the highest number of mean driving errors were made in the driving categories of observation, planning and judgement and vehicle positioning. Slowed reaction time was not a significant source of driver error, confirming that slowed reaction time alone does not preclude safe driving, as it can be compensated for by increased anticipatory driving (Van Zomeren, Brouwer, & Minderhoud, 1987). Errors in planning and judgement, errors in vehicle positioning and the number of instructor interventions were correlated with the final on-road result. However, errors in reaction time, errors in speed control and errors in observation were not correlated with final on-road result. The total number of driving errors was significantly associated with the final on-road result, accounting for 15% of the variance in the final on-road result. This finding of a relationship between an objective scoring of driving according to prespecified criteria and an expert rating of driving performance is consistent with several previous studies in which a standardized driving assessment was used (Brooke et al., 1992; Odenheimer et al., 1994; Sivak et al., 1981). The question of why the total number of driving errors and the expert rating of driving performance were not perfectly correlated is interesting. Perhaps the expert's rating of driving performance is a relatively unreliable measure, because of subjective elements of the rating, such as the perceived seriousness of the driving error. Potential consequences of driving errors differ, and this may influence the rater. For example, expert raters may place greater importance on speeding on a road with other traffic or near a school, than on speeding on a road without other traffic nearby, even though the same number of speeding errors may be committed. Concerning the fifth research question posed in this study, the occupational therapist and driving instructor's ratings of driving performance were associated with the objective scoring of the standardized on-road driving test, sharing 15% common variance.

The total error score and the number of instructor interventions were significant predictors of the final on-road result, with an overall correct classification rate of 73%. The significant association found between instructor interventions and the final on-road result raised the question of whether subjects who required instructor intervention were less likely to pass the driving assessment. No interaction effect on the final on-road result was detected in a logistic regression analysis of total driving errors by number of instructor interventions. This suggests that the number of instructor interventions made an independent contribution to the final global evaluation by our expert judges. This finding confirms that of Hartje and colleagues (1991) who suggested that when the driving instructor was required to intervene to prevent danger, there was an additional influence on the final evaluation of driving performance.

Reliability analysis of the on-road driving assessment indicated that it was a consistent, reliable test, thus addressing the fourth research question of this study. This reliability may be attributable in part to standardization of the test, in terms of route and component driving tasks. This finding of reliability is consistent with the Cronbach's alpha reported in previous studies in which a standardized driving task was employed (Brooke et al., 1992; Odenheimer et al., 1994). One difficulty when examining the reliability of the on-road driving test is presented by the fact that one of four different driving test routes was used for each subject. The driving test routes were representative of a range of difficulty. Subjects were allocated to a route on the basis of the occupational therapist's judgement of the subject's driving experience and any physical disability. Data regarding which driving test route was employed were not recorded and hence it is not possible to examine the effects of driving test route on outcome. It is possible that the driving test route had no effect on outcome, as despite the variation in driving test routes, high reliability and internal consistency measures were found in this study. The possible contribution of driving test route to variance requires further investigation. In order to treat the scores from the driving tests as equal, the driving test routes need to be identical in terms of complexity and traffic density. In the present study, the partial rather than complete standardization of the driving assessment test route represents a methodological weakness, and it is recommended that future driving assessments employ completely standardized routes, and that all subjects be assessed on the same or equivalent routes, so that the effect, if any, of the driving test route may be determined.

While the reliability of this on-road driving test was confirmed, establishing the criterion validity of this test is more difficult. The same is true of all driver assessment and driver licensing tests. Evans (1991) distinguished driver performance (what the driver can do), from driver behaviour (what the driver actually does). It is likely that in the structured setting of an on-road driving test what is actually being assessed is driver performance; that is, what the driver does in a test situation with a driving examiner seated beside them. Clearly, subsequent driver behaviour is not related in a straight forward way to performance on a driving test. This is exemplified by crash data showing that drivers do not always drive as they did during their licence test, suggesting deficient predictive validity for driver licence tests (Mihal & Barrett, 1976). Furthermore, if one considers a) that driver training and education have not been shown to significantly alter crash rates; b) that drivers with optimal perceptual-motor skills and interest in driving (young males) have the highest crash rates; and c) that high skill drivers such as professional racing drivers have above average crash rates (Evans, L., 1991), it is apparent that the validity of driver testing requires further investigation. One method to examine the validity of driving tests would be to track subsequent driver behaviour by way of crash or violation records. However, a rigorous study would require the examination of subsequent driver behaviour of all drivers assessed, including those judged unsafe to drive. In other words, all drivers, including those judged unfit, would be required to drive for a period after the driving assessment. Clearly, this is ethically unacceptable. Moreover, privacy considerations may preclude access to such data, even in the case of drivers judged to be fit to drive. Permission to screen the subsequent driving records of the subjects in this study, in a manner in which individual subjects could not be identified, was denied by a statutory body, the New South Wales Privacy Committee.

4.4.4 Performance of a Subgroup of CVA Subjects After Remedial Driving Training

For sixty subjects, all with a diagnosis of CVA, data were available from both the initial driving assessment and a subsequent driving assessment which followed remedial driving training and on which the final judgement of driving competence was based. Significant decreases in the number of errors were noted in only two driving categories (observation and vehicle positioning), but this was sufficient to engender a significant decrease in the total number of driving errors. The absence of significant decreases in the number of errors in the other driving categories raises the interesting question of how the final evaluation of driving competence was made for these 60 subjects. With significant decreases in the total number of driving errors, but decreases evident in only two of the five driving categories, on what basis did the 'expert raters' determine that a sufficient improvement in driving performance had occurred in the 55% who passed the test?

4.5 Conclusions

In summary, in terms of the first research question posed in this study, the doctor's prediction of driving performance, when considered with all other variables, was not a significant predictor of the outcome variable, final on-road result. Moreover, in relation to the second research question, medical variables, with the exception of finger-nose coordination, were not significantly associated with the final on-road result. The criteria on which the doctor's prediction of on-road driving was based were unclear. Diagnosis was a significant predictor of outcome, and an examination of the results suggests that subjects with a right hemisphere CVA were least likely to be successful in the driving assessment. These results do not support the use of a medical assessment alone as a means of determining fitness to drive for people with brain impairment. The third research question concerned the predictive validity of a neuropsychological assessment for driving on-road. Three neuropsychological tests were significant predictors of final on-road result (Judgement of Line Orientation, Trail Making Test B and Block Design), although the neuropsychologist's prediction of driving performance was not. The results suggest that with knowledge of the diagnosis and the duration of the diagnosis, together with the administration of three neuropsychological tests and a coordination task, 78% of subjects with brain impairment could be correctly classified as safe or unsafe to drive. Conversely, 22% of subjects would be incorrectly classified, which may be an excessive error rate for practical use on an individual basis and may preclude substitution of an off-road assessment for an on-road assessment. With regard to the fourth research question, reliability analysis confirmed that the on-road driving assessment was a consistent and reliable test. Finally, the occupational therapist and driving instructor's rating of driving performance were significantly associated with the objective scoring of the standardized on-road driving test, sharing 15% common variance.

These results highlight the need for a standardized on-road evaluation of driving performance, in order to reliably distinguish competent and safe drivers from incompetent, unsafe drivers. While off-road approaches to driver assessment may allow the screening of clearly incompetent drivers prior to on-road testing, they lack sufficient predictive validity, sensitivity and specificity to correctly identify subjects who are indeed safe.

CHAPTER 5

DEMENTIA AND DRIVING: A SURVEY OF CLINICAL PRACTICE IN AGED CARE ASSESSMENT TEAMS IN NEW SOUTH WALES AND THE AUSTRALIAN CAPITAL TERRITORY*

5.1 Introduction

The previous chapter discussed research that examined the predictive validity of both medical and neuropsychological assessment for on-road driving performance, and the on-road driving assessment of a group of drivers with non-progressive acquired brain impairment. The results of the research suggested that a standardized on-road evaluation of driving performance was required to reliably distinguish competent and safe drivers from incompetent, unsafe ones. An issue frequently encountered in the setting of aged care services is the ability of individuals with a diagnosis of dementia, including Alzheimer's Disease (AD), to continue to drive safely. This issue not only encompasses competent operation of a motor vehicle, but more importantly, safe participation in traffic, which impacts upon the safety of others.

Lucas-Blaustein and colleagues (1988) examined 53 current or former drivers with dementia (Senile Dementia of the Alzheimer's Type, Multi-Infarct Dementia, and other forms of dementia) using a brief neuropsychological screen and a questionnaire completed

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by caregivers concerning crash history. Since the onset of dementia, 30% of the drivers had been involved in a crash and a further 11% were reported to have caused crashes. At the time of the study, 30% of the drivers were still driving, and those still driving were as likely as those who were no longer driving to have been involved in a crash, although they performed better on mental status examination and naming tasks. Friedland and colleagues (1988) studied 30 patients with Alzheimer's disease (AD) and 20 healthy age matched controls. As in the Lucas-Blaustein (1988) study, crash data were gathered retrospectively from relatives. Forty-seven percent of the AD patients experienced at least one crash while driving, whereas only 10% of the control subjects had been involved in a crash in the previous five years. In 77% of the DAT patients, a deterioration in driving performance was noted and 63% of the patients had ceased driving. However only 42% of the DAT patients who stopped driving had ceased before a crash occurred. Both the Lucas-Blaustein and the Friedland studies recommended that patients with a diagnosis of dementia (DAT and Multi-Infarct Dementia) should not drive.

O'Neill (1992) reported that a significant minority of patients with a DSM III-R diagnosis of dementia showed no deterioration in driving skills. While ultimately all individuals with a diagnosis of progressive dementia will become incapable of driving, the rate of deterioration and the pattern of deficits show marked variability. It has been argued that a diagnosis of dementia should not in itself be an automatic indication for the cessation of driving, but rather that the cessation of driving should be based on a demonstration of impaired driving competence (Drachman, 1988; Drachman & Swearer, 1993). As driving competence has not been clearly associated with measures of cognitive function in patients with a diagnosis of dementia, some authors have recommended a focus on functionally based measures, such as on-road tests (Odenheimer, 1993; O'Neill, 1992).

In Australia, the guidelines available to medical practitioners to assist in determining the fitness to drive of patients with dementia are unclear and potentially contradictory. For example, the Australian national guidelines for medical practitioners (1988) state that early symptoms of dementia should be sought in the examination of the patient, and that their presence should exclude the patient from driving. By contrast the New South Wales (NSW) Roads and Traffic Authority (RTA) Medical Guidelines (1993) do not preclude patients with dementia from driving, but do recommend careful assessment, without offering further specific guidance as to the nature of the assessment. Similarly, the Queensland and Victorian Guidelines also recommend careful evaluation or referral to driver assessment centres, without providing specific advice as to the appropriate type of assessment (Queensland Transport, 1994; VicRoads, 1994). More recently, the Austroads (1998) guidelines suggested that drivers with cognitive impairment and dementia should not drive if significant memory deficit, disorientation or cognitive impairment are present. Odenheimer (1993) considers performance based guidelines for driving competence essential, but these are not contained in the advice available to medical practitioners in the documents mentioned above (Queensland Transport, 1994; Roads and Traffic Authority, 1993; VicRoads, 1994).

This study outlines the results of a survey conducted in early 1994, to determine the current state of clinical practice concerning the determination of fitness to drive in individuals with a diagnosis of probable dementia (AD, Multi-Infarct and other forms), in Aged Care Assessment Teams (Assessment Teams) in NSW and the Australian Capital Territory

(ACT) with a geriatrician on staff. Aged Care Assessment Teams are specialist, community based geriatric care teams staffed by medical, nursing and allied health professionals. The selection of Assessment Teams with a geriatrician on staff was made because in NSW only medical practitioners were legally indemnified to report potentially unsafe drivers to the Roads and Traffic Authority (RTA). The questionnaire was devised on the basis of the literature concerning driver assessment (discussed in Chapter 1), and the assessment procedure used at the Coorabel Driving Assessment and Training Program of Royal Rehabilitation Centre Sydney (see Chapter 2).

5.2 Method

The survey questionnaire was developed by a neuropsychologist active in the assessment of driver competence (the author of this thesis). The survey was piloted by being administered to five doctors completing advanced training in Rehabilitation Medicine at the Royal Rehabilitation Centre Sydney. The pilot process resulted in alterations in the phrasing of some questions but no changes were made in the content. The survey questions and responses are shown in Table 5.1. The survey was designed to obtain a picture of current clinical practice in specialist teams involved in the care of the elderly, with regard to driving by individuals with dementia. Specifically, since doctors are legally indemnified to report unsafe drivers to the RTA, and are responsible for signing the medical reporting forms which are forwarded to the RTA, it was of interest to ascertain which members of the Assessment Team were involved in the assessment of driver fitness. The nature of the assessment procedure was investigated, including the manner in which the severity of dementia was assessed, whether other medical conditions in addition to dementia or medications were considered, and whether the assessment included a driving test. The follow up actions after assessment were also investigated, for example whether restricted licences were recommended or assessments repeated, and to whom the results of the assessment were reported. Given a previous finding of reluctance to discontinue driving among patients with Alzheimer's Disease (Friedland et al., 1988), the survey questioned whether the Assessment Teams had encountered clients who continued to drive despite advice to the contrary, and any action that had been taken as a result. Finally, in light of the different alternative transport options available in the urban and rural settings, it was of interest to investigate whether clinical practice reflected a consideration of the relatively fewer transport options for the rural elderly.

All Assessment Teams in NSW and ACT with a geriatrician as a member of staff (42 of the 48 Assessment Teams) were contacted by telephone for inclusion in the survey. The survey consisted of a questionnaire administered by telephone, with 14 closed questions for which a series of response options were provided, and one open question concerning clinical practice in the assessment of fitness to drive in clients with the diagnosis of dementia. Each respondent was also provided with an opportunity for further comment. Thirty-eight of the 42 Assessment Teams (90.5%) participated in the survey. The majority of the telephone interviews were conducted by a neuropsychologist (26 cases), with the remainder conducted by a doctor (12 cases). In 32 of the 38 participating teams, the geriatrician was interviewed. In the remaining six cases, the geriatrician was not available, and another member of the team involved in the determination of driver fitness (an occupational therapist, psychologist or nurse) was interviewed.

As the data collected were frequency data, Chi-square analysis was used for statistical analysis. All statistical analyses were performed using SPSS/PC+ 4.0.

5.3 Results

The results are summarised in Table 5.1. Of the 38 Assessment Teams surveyed, 19 were located in city areas, mainly in and around Sydney, and 19 were located in rural areas. Twenty-six (68.4%) Assessment Teams were found to have an assessment procedure to evaluate fitness to drive in clients with a diagnosis of dementia. In 15.8% of rural Assessment Teams driving was felt to be a right (as distinct from a privilege), although this view was not expressed by any of the city Assessment Teams. Twenty-three (60.5%) of respondents expressed the view that society should be protected from unsafe drivers. Five (13.2%) respondents considered a diagnosis of dementia sufficient to conclude that a client was no longer fit to drive.

In the majority of teams the geriatrician was active in the assessment of fitness to drive (92.1%), often assisted by an occupational therapist who conducted an off-road test (65.8%), at times accompanied by a driving instructor (18.4%). Almost 16% of Assessment Teams routinely had access to a neuropsychologist for driver evaluation. This was more common among city teams although the difference was not statistically significant (21.1% of city Assessment Teams; 10.5% of rural Assessment Teams; $\chi^2(2)=1.699$, $p<.43$). Sixteen (42.1%) Assessment Teams included an on-road driving evaluation to examine vehicle control, traffic participation and knowledge of traffic rules. In both city and rural units the geriatrician had primary responsibility for the final decision about driver fitness (55.3%) although 28.9% of Assessment Teams also reported referring clients to other centres with on-road testing facilities. The determination of fitness to drive was then made by the agency conducting the on-road assessment. Use of RTA guidelines to assist in determination of driver fitness was reported by 52.6% of respondents, with a trend for less frequent use by rural Assessment Teams (χ^2 (2)=4.271, p<.12). As part of their assessment procedure, 57.9% of respondents indicated that information was sought from the client or carer regarding current licence status, and 71.1% sought information regarding driving history.

The severity of dementia was most commonly (94.7%) assessed by means of the Mini Mental Status Examination (MMSE), and was usually accompanied by a clinical examination by the geriatrician (94.7%), including an assessment of visual acuity, as well as a review of medications and identification of comorbid disease. While a cut-off score on the MMSE was not utilised by any of the city Assessment Teams for determination of driving fitness, 10.5% of the rural Assessment Teams reported using a cut-off score.

Generally Assessment Teams tended to classify clients as either safe or unsafe drivers (44.7%), although in some cases restricted licences were recommended. The most frequently reported restrictions were limiting driving to residential areas only (15.8%), or to daytime driving in residential areas only (15.8%). Fewer rural Assessment Teams restricted their decision to one of safe versus unsafe (36.8% of rural Assessment Teams used this classification compared with 52.6% of city Assessment Teams), although the difference was not significant (χ^2 (4)=2.196, p<.70).

In most instances (94.7%) the decision regarding the clients fitness to drive was communicated to the client, the relatives or carers (89.5%) and the client's local doctor (86.8%). The results of the assessment were not always reported to the RTA. This seemed to vary with the philosophy of the Assessment Teams involved. Twenty-five (68.4%) respondents felt it was their responsibility to inform the RTA, particularly in the case of an unsafe driver. Those who did not, cited concern for the relationship with the client and the desire not to breach confidentiality as the reasons for not reporting. Usually the Medical Advice Form of the RTA was used for notification.

Twenty-eight (73.7%) Assessment Teams reported having had clients that they had judged unsafe to drive, who had ignored their advice and continued to drive. Eighteen teams reported dealing with this by discussing possible solutions with relatives or carers (47.4%), and five by talking with both relatives and the client (13.2%). The police were contacted in this situation by two Assessment Teams, while two took no action.

Assessment Teams typically had received referrals from medical practitioners (81.6%), from hospitals (57.9%), from relatives of the client (57.9%), and from community service agencies (42.1%). Driving evaluations were repeated by 36.8% of Assessment Teams, to follow any longitudinal changes in driving competence. Fewer rural Assessment Teams reported repeating assessments (31.6% of rural compared with 42.1% of city Assessment Teams), however this was not statistically significant (χ^2 (2)=.4870, p<.78).

5.4 Discussion

This survey highlights some inconsistencies surrounding the assessment of driver fitness by Aged Care Assessment Teams. For example, while the Assessment Team members surveyed indicated that they felt responsible for assessing the driving competence of their clients who drove, not all inquired about or recorded their client's current driving status or driving history. This information is useful for determining whether functional driving problems have occurred. Examples of functional driving problems include becoming lost, being involved in crashes, or causing traffic problems because of inappropriate speed (Odenheimer, 1993).

Amongst the Assessment Teams surveyed, evaluation of fitness to drive was largely a medically based procedure in both city and rural settings. This was not unexpected given that in NSW only doctors were indemnified for notification of unsafe drivers to the RTA. Most Assessment Teams indicated using an assessment procedure generally consisting of a clinical examination by a geriatrician (which included administration of the MMSE), and an interview with relatives or carers. Less than half the Assessment Teams conducted functional evaluations of actual driving competence, via on-road assessment. This may be attributable to a lack of appropriately trained staff, such as occupational therapists trained in driver assessment. The referral of clients to centres with facilities for on-road assessment should be encouraged by improving awareness of these centres and the programs they offer.

In determining the severity of dementia and its impact on safe driving, nearly all Assessment Teams reported use of the MMSE (95% of Teams surveyed), although few utilised any cut-off score. The predictive validity of the MMSE for driving competence has not been demonstrated in previous research, although a lower MMSE score has been associated with cessation of driving (Dubinsky et al., 1992; Gilley et al., 1991; Logsdon, Teri, & Larson, 1992). In two retrospective crash rate audits, MMSE scores did not distinguish between patients with dementia who had had accidents, and those who had not (Friedland et al., 1988; Lucas-Blaustein et al., 1988). Thus caution is recommended with the use of the MMSE as a criterion for driving competence. The survey results indicate that Assessment Teams regard a diagnosis of dementia alone as an inappropriate criterion for determining driving ability, consistent with Drachman's view (Drachman, 1988).

Drachman and Swearer (1993) have suggested that rather than trying to determine fitness to drive, it may be more appropriate for doctors to inquire about the presence of specific incompetent driving behaviours and to advise patients and their families of the increasing risk of continuing to drive as the duration of the dementia lengthens. Drachman and Swearer described a two to three year time course of decline in driving ability following a diagnosis of dementia, based on crash rates, and suggested a cessation of driving during this time frame (Drachman & Swearer, 1993). However, while problems with validity and standardization persist, an operational (on-road) test remains a better measure of actual driving competence, preventing the revocation of licences held by safe, competent drivers thus allowing them to maintain their autonomy for as long as possible, while at the same time identifying unsafe drivers (Drachman, 1988; Odenheimer, 1993).

The use of restricted licences remains a somewhat contentious issue. Restricted licences are permitted in NSW, and tend to be more frequent in rural areas. There is evidence that while older drivers voluntarily restrict their driving by decreasing mileage and restricting driving to daylight hours and optimal road conditions, they still experience a relatively high crash rate, when age-specific crash rates are corrected for miles driven (Reuben, Silliman, & Traines, 1988b). Thus the provision of licences that restrict driving to daylight hours, or to a short distance from home, may not achieve the desired intention of protection for all road users. Moreover, compliance with restricted licences may be reduced in drivers with dementia, because of limited appreciation of potential driving risk and the reduced likelihood of the demented driver implementing risk minimising behaviour (Kaszniak, Keyl, & Albert, 1991). Rather than issuing restricted licences, alternative modes of transport for those no longer able to drive are required. At the present time it is unlikely that available transport resources, particularly in remote or rural areas, can necessarily accommodate a person's lifestyle or desire for mobility.

The experience of clients continuing to drive against advice has also been reported elsewhere (Kaszniak, Keyl, & Albert, 1991; Odenheimer, 1993). With regard to management, Odenheimer (1993) has suggested the discouragement of driving through the establishment of viable alternatives, explanation of the risk to others, and explanation of the legal and insurance ramifications. If necessary, more authoritarian options may be considered, such as confiscating car keys, or moving or disabling the car.

Given the commonly progressive nature of most dementias, there is a need for centres to follow up clients who are found at first assessment to be safe to drive. The need for review, and the likelihood that the client will at some time in the future become unfit to drive, must be discussed with both the client and their relatives or carers. The lower frequency of repeated assessments by rural Assessment Teams may reflect a reluctance on the part of the client to travel long distances for review, or insufficient resources to accommodate regular reassessment.

Concern was expressed regarding client confidentiality and notification of driving incompetence to the RTA, together with the need for clarification of the responsibility of the team when the client continues to drive against the advice of the team. Many Assessment Teams also expressed the need for clear-cut guidelines regarding to fitness to drive to be provided by the RTA.

The results of this survey indicate that among Aged Care and Assessment Teams in NSW and ACT there is a strong reliance on medical assessment for the determination of driving competence in clients with a diagnosis of dementia, even though there is little scientific evidence that a physician's evaluation can correctly identify the safe older driver (Reuben, 1993). In the previous chapter, the results of a study of 153 drivers with neurological impairment and a mean age of 57.4 years were discussed. Although the range of ages for this group was very wide (17 to 84 years), a large proportion of clients were young to middle aged, with relatively few elderly clients. Findings from that study indicated that while none of the medical variables were significantly associated with final on-road driving test result, the physician's prediction of driving performance and the diagnosis were significantly correlated with on-road driving performance. No studies of the predictive validity of a physician's evaluation for on-road driving performance in elderly drivers, including those with a diagnosis of dementia, were located in a literature search.

Despite the reported limitations in the discriminant ability of the MMSE in predicting driving performance in elderly individuals with a diagnosis of dementia (Fitten et al., 1995; Odenheimer et al., 1994), the majority of Assessment Teams reported using the MMSE to measure the severity of dementia, as a means of determining the impact of the dementia on the ability to drive safely. Given the frequency of use of the MMSE by Assessment Teams, it may be useful to specifically examine the predictive validity of MMSE for on-road driving performance in a group of drivers diagnosed with dementia.

Given the progressive nature of many dementias, a judgement of safe performance on any assessment of driving competence is valid as an indicator of fitness to drive for a limited time only. Thus it is recommended that all drivers with a diagnosis of dementia be reviewed regularly. Further research is required to establish the optimal frequency of review of driving ability for these drivers.

The findings of this survey of Aged Care and Assessment Teams and driving assessment raise several questions for further research. These questions could best be addressed by investigating the on-road driving performance of a group of drivers diagnosed with dementia (specifically Alzheimer's Disease), following a medical examination (including the administration of the MMSE), and a neuropsychological evaluation. A further study was therefore planned in which the predictive validity of a medical examination for a group of drivers with Alzheimer's Disease, could be investigated by requiring the physician conducting the medical evaluation to predict on-road driving performance prior to a standardized on-road driving test. Similarly, the predictive validity of the MMSE, included as part of the medical examination, could be explored by analysing the association between the MMSE score and on-road driving performance. The relationship between driving competence and measures of cognitive function in drivers with a diagnosis of Alzheimer's Disease could be studied by comparing performance on a range of neuropsychological tests and on a standardized driving test, and by requiring the neuropsychologist administering the tests to predict on-road driving performance. Finally, the on-road performance of the drivers with Alzheimer's Disease could be systematically reviewed to identify any patterns of deficiencies in driving, and the nature of driving errors.

TABLE 5.1 Frequency of responses to questionnaire on assessment of fitness to drive in patients with dementia, by all ACAT (n=38), city ACAT (n=19) and rural ACAT (n=19).

QUESTIONS AND RESPONSES	ALL n=38 %	CITY n=19 %	RURAL n=19 %
1. Which disciplines are routinely involved in the assessment of fitness to drive? (may be more than one)			
Geriatrician	92.1	94.7	89.5
Neuropsychologist	15.8	21.1	10.5
Occupational Therapist	65.8	68.4	63.2
Driving Instructor	18.4	15.8	21.1
2. Who makes the final decision regarding fitness to drive in patients with the diagnosis of dementia?			
Geriatrician	55.3	63.2	47.4
Team	13.2	15.8	10.5
Referred on elsewhere	28.9	21.1	36.8
3. Do you use the guidelines of the RTA as an aid in your decision making?			
Yes	52.6	68.4	36.8
4. On what basis do you make decisions regarding the fitness to drive in patients with dementia?			
Assessment procedure	68.4	73.7	63.2
Clinical experience	71.1	84.2	57.9
Particular incidents	42.1	42.1	42.1
Assumption of driving as a right	7.9	0.0	15.8
On the assumption that assessment serves as a protection for society against unsafe drivers	60.5	57.9	63.2
Diagnosis of dementia alone	13.2	10.5	15.8
5. If a decision is made on the basis of as assessment procedure, what are the components of the assessment?			
Medical evaluation	97.4	97.4	97.4
Neuropsychological evaluation	21.1	21.1	21.1
On-road test	42.1	36.8	47.4
Off-road test	42.1	42.1	42.1
Interview relatives	68.4	68.4	68.4
6. What kind of information is sought during the assessment?			
Current licence status	57.9	57.9	57.9
Driving history	71.1	78.9	63.2
Mental Status	100.0	100.0	100.0
Knowledge of traffic rules	28.9	31.6	26.3
Car Adaptations	15.8	15.8	15.8
Control of car	34.2	26.3	42.1
Traffic participation	39.5	31.6	47.4

QUESTIONS AND RESPONSES	ALL n=38 %	CITY n=19 %	RURAL n=19 %
7. How is the severity of dementia assessed?			
Mini Mental Status Examination	94.7	100.0	89.5
Neuropsychological evaluation	21.1	26.3	15.8
Medical examination	68.4	68.4	68.4
8. If the MMSE is used, is a cut-off score employed?			
Yes	5.3	0.0	5.3
9. Do you consider:			
Visual capacity	92.1	94.7	89.5
Concomitant diseases	94.7	94.7	94.7
Medications	94.7	94.7	94.7
10. Final recommendations:			
Safe versus unsafe only	44.7	52.6	36.8
Restricted licences:			
Residential area only	15.8	10.5	21.1
daylight and residential	15.8	10.5	21.1
daylight, residential and car adaptation	7.9	10.5	5.3
11. Is the assessment repeated after some interval?			
Yes	36.8	42.1	31.6
12. Where do referrals come from?			
Relatives	57.9	57.9	57.9
Local Doctor	81.6	89.5	73.7
RTA	5.3	10.5	0.0
Hospitals	57.9	57.9	57.9
Community Services	42.1	42.1	42.1
13. To whom do you report the results of the assessment?			
Client	94.7	100.0	89.5
Carers	89.5	94.7	84.2
Local Doctor	86.8	89.5	84.2
RTA	68.4	63.2	73.7
14. Have you had the experience of clients continuing to drive against your advice?			
Yes	73.7	73.7	73.7
15. What was your action in the case of (14)?			
Counsel client	2.6	0.0	5.3
Talk to relatives	47.4	68.4	26.3
Talk to relatives and client	13.2	15.8	10.5
Contact RTA	5.3	5.3	5.3
Contact police	5.3	0.0	10.5
Contact relatives, police and RTA	13.2	0.0	26.3
No action	5.3	10.5	0.0
Any further remarks or comments?			

CHAPTER 6

ALZHEIMER'S DISEASE AND DRIVING: PREDICTION AND ASSESSMENT OF DRIVING PERFORMANCE*

6.1 Introduction

The number of older drivers and their yearly mileage continues to increase (Ball et al., 1998). Alzheimer's Disease (AD), the most common cause of dementia, has been estimated to affect as many as 11.6% of those aged 65 and older, and 47.8% of those aged 85 and older (Evans, D. A. et al., 1989). Thus the number of older drivers with AD may also be increasing. AD is steadily progressive and is characterised by a variety of abnormalities of cognitive function, which may have a negative impact on everyday activities, including driving. Competence in driving a motor vehicle has implications for the safety of the individual affected by AD and for other road users. Accordingly, two questions frequently encountered by health care providers are whether individuals with dementia are able to continue to drive safely, and when they should stop driving.

The actual public health risk posed by drivers with AD is unknown. While it has been observed that drivers with dementia generally drive fewer miles and frequently cease driving voluntarily, there is also evidence that some AD drivers have insufficient self monitoring to cease driving when they are demonstrating at risk driving behaviours

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(Morris, 1997). Self regulation may not sufficiently reduce the crash risk among drivers with more severe functional impairments, and driving cessation may be a safer option (Ball et al., 1998). Tests of visual acuity and peripheral vision, as used in driver licensing, are insufficient to identify which individual older drivers are more likely to be involved in crashes (Ball, 1997), although state mandated tests of visual acuity at licence renewal have been found to be associated with a reduced risk of fatal crashes among elderly drivers (Levy, Vernick, & Howard, 1995).

Several retrospective surveys concerning driving and AD have suggested that many patients diagnosed with AD continue to drive and have a higher risk of crashes, but are reluctant to give up driving (Dubinsky et al., 1992; Friedland et al., 1988; Gilley et al., 1991; Logsdon, Teri, & Larson, 1992; Lucas-Blaustein et al., 1988; Tuokko et al., 1995). As reported in the previous chapter, a survey of Aged Care Assessment Teams in NSW and ACT found that 73.7% of the Assessment Teams had been confronted by the issue of clients continuing to drive after being judged unsafe to do so. It is noteworthy that two retrospective studies found that only 50% of drivers with AD had ceased driving within three years of the onset of dementia (Drachman & Swearer, 1993; Friedland et al., 1988), beyond which time crash risk increases substantially. A recommendation that a diagnosis of AD preclude the continuation of driving has come from two retrospective studies (Friedland et al., 1988; Lucas-Blaustein et al., 1988). However, both of these studies suffered the limitations of retrospective design, reliance on informants' reports for crash histories, and a paucity of data regarding the nature of driving exposure. More recently, Tuokko and colleagues examined driving records (insurance claims) of 165 drivers with dementia, and found that they had approximately 2.5 times the crash rate of a cohort of matched controls (Tuokko et al., 1995).

A recent study of neuropathological findings in 98 older drivers killed in traffic accidents showed that 33% had neuritic plaque scores indicating certain AD, and in a further 20%, findings were suggestive of AD (Johansson et al., 1997). This raises the possibility that more accidents are attributable to AD than previously thought. In contrast, in a study using Michigan State records, road crash and violation rates among AD patients did not differ significantly from those of matched controls (Trobe et al., 1996). However this study did not control for the mileage driven, and the reduced driving exposure of AD patients may have kept their crash rate equal to that of control subjects. Drachman and Swearer (1993) investigated crash rates for 130 patients with AD over a ten year period. They also did not control for mileage driven, but found that although the AD patients had fewer reported crashes than 16-24 year old drivers, they had more than twice as many as matched controls in the years following the onset of their AD.

Drachman (1988) has suggested that the potential loss of driving privileges may lead many people with mild or potentially treatable cognitive impairments to refrain from seeking medical advice about continuing to drive (Drachman, 1988). O'Neill (1992) points out that studies such as those by Friedland and colleagues (1988) and Lucas-Blaustein and colleagues (1988) showed that a substantial minority of patients with AD at the time of assessment had suffered no deterioration in driving skills, thus supporting Drachman's (1988) view that a diagnosis of AD alone is insufficient to preclude driving. Moreover, there may be considerable variation in both the manifestations of the disease and the rate of disease progression in AD, particularly in the earlier stages, and therefore the use of a diagnosis of AD alone as a basis for a decision regarding driving cannot be recommended.

As discussed in the previous chapter, among NSW and ACT Aged Care Assessment Teams, the Mini Mental Status Examination (MMSE) was frequently used (by almost 95% of Assessment Teams surveyed) as a measure of severity of dementia as part of their assessment of driving competence. There are several studies in which the MMSE has been used as a measure of dementia severity in the assessment of driving competence, either alone or as part of a neuropsychological test battery (Fitten et al., 1995; Gilley et al., 1991; Hunt et al., 1993; Logsdon, Teri, & Larson, 1992; Lucas-Blaustein et al., 1988; Odenheimer et al., 1994). Cessation of driving has been associated with lower MMSE scores (Dubinsky et al., 1992; Logsdon, Teri, & Larson, 1992; Lucas-Blaustein et al., 1988), although in two retrospective crash rate audits the MMSE did not distinguish those AD patients who had had crashes from those who had not (Friedland et al., 1988; Gilley et al., 1991; Lucas-Blaustein et al., 1988). Ball and Owsley (1991) found that a mental status exam was a significant predictor of accidents, particularly of intersection accidents, in a group of older drivers (mean age = 70, range 57-83 years). Odenheimer and colleagues (1994) reported a strong correlation between MMSE and driving performance in a group of 30 elderly drivers, of whom six were diagnosed with dementia. However, there was considerable overlap in the range of MMSE scores of those who had achieved a pass in the global rating of driving performance, and those who failed. As a result, Odenheimer and colleagues (1994) suggested that the MMSE alone was an inadequate predictor of driving performance. Similarly, Fitten and colleagues examined the correspondence between performance on several cognitive tasks and a road test, and noted limitations for the

MMSE's discriminating power (Fitten et al., 1995). At the upper end of the MMSE range, MMSE score did not correlate with the driving score, suggesting that this test is of limited usefulness as a driver screening device. In the study of 153 drivers with acquired brain impairment described in Chapter 4, MMSE score was found to be significantly associated with the final on-road result when one outlier score was excluded from the analysis. However, there was an overlap of MMSE scores between those subjects who passed the on-road driving test, and those who failed. It was therefore suggested that the MMSE may lack sufficiently precision to enable individual predictions of driving safety.

The relationship between performance on cognitive tasks and driving ability in people with dementia has been investigated in several studies (Fitten et al., 1995; Hunt et al., 1993; Kapust & Weintraub, 1992; Odenheimer et al., 1994). However, a clear relationship between cognitive impairment and driving performance has not been demonstrated. In a study by Hunt and colleagues, neither subject self-assessment nor caregiver perceptions of driving ability consistently predicted driving performance (Hunt et al., 1993). Attention, language and visuoperceptual abilities were found to be correlated with driving performance although the on-road test in this study was only partly standardized.

While the data increasingly show risks to individuals and the community associated with driving by people with dementia, there are few guidelines to assist medical practitioners in determining who can and cannot drive, even though physicians are frequently involved in the determination of driving competence for both the elderly and individuals with dementia. A review of North American procedures for driver licensing and medical review (Poser, 1993) reported that 13 jurisdictions require physicians to report potentially dangerous drivers, 11 protect the physician by law from legal action by the driver, and in 20 jurisdictions the reports are confidential. A further 12 jurisdictions give statutory authorisation for physicians to report such drivers but do not require them to do so. Since 1988, physicians in California have been required to report dementia cases to their local health departments, who then forward the information to the Department of Motor Vehicles (Reuben & St George, 1996). In the United Kingdom the relevant Act requires the licence holder (that is, the patient) to notify the licensing authority by of a diagnosis of a disability likely to affect safe driving (King, Benbow, & Barrett, 1992). Under Australian national uniform driver licensing laws, any person who, in good faith, reports a driver to the relevant authority because of doubt about the driver's fitness to drive, is protected from civil and criminal liability (Austroads, 1998).

Reuben has suggested that scientific evidence is lacking to support a physician's examination as a means of correctly identifying safe older drivers (Reuben, 1993). In the study of subjects with acquired brain impairment such as TBI and CVA, detailed in Chapter 4, the doctor's prediction of driving performance, when considered with all other variables, was not a significant predictor of the outcome variable, the final on-road result. Moreover, medical variables, with the exception of finger-nose coordination, were not significantly associated with the final on-road result. In the case of drivers with dementia, a review of the literature revealed little attention to the investigation of the efficacy of medical assessment in correctly distinguishing safe from unsafe drivers, even though in most countries this task legally remains the responsibility of doctors. For elderly drivers comorbidity is an important issue, as cognitive dysfunction may co-exist with motor or visual dysfunction for example, with potentially cumulative risks for driving. Thus while many doctors have a legal responsibility to assess the safety of their patients to drive, there is a lack of information to assist them in this process. Moreover, as driving situations are complex and constantly changing, the validity of isolated physiological testing must be questioned as a predictor of ability to drive safely (Reuben, Silliman, & Traines, 1988).

Actual driving performance of individuals with AD has received little systematic scrutiny. As described in Chapter 2, Odenheimer and colleagues (Odenheimer et al., 1994) developed a road test with a fixed route and use of the same vehicle, conducted at a prescribed time of day in clear weather. The elderly subjects, some with diagnoses of dementia, were given driving instructions as single step commands, and were not required to find their own way. In another example of a standardized road test, assessment was conducted on a hospital campus road network to ensure consistent low level traffic conditions (Fitten et al., 1995). The road test consisted of a six-stage driving course, 2.7 miles long, with each stage presenting a different degree of driving complexity. As discussed in Chapter 2, Fitten and colleagues obtained collision and moving violation records for all older participants, for the two year period prior to their involvement in the study. A trend was noted for a negative association between the driving score and number of collisions and moving violations per thousand miles driven (Fitten et al., 1995).

As reported in Chapter 5, 92% of the Aged Care and Assessment teams surveyed responded that a geriatrician was involved in the assessment of fitness to drive. However, the predictive validity of a medical examination for on-road driving ability in subjects with a diagnosis of AD has not been examined. Likewise, the predictive validity of neuropsychological assessment for on-road driving ability assessed by means of a standardized driving test, in subjects with a diagnosis of AD, has received little attention.

The prospective study described in this chapter was designed to investigate the relationship between medical variables, MMSE score (Folstein, Folstein, & McHugh, 1975) and open road driving performance in drivers diagnosed with probable AD. A second area of investigation was the relationship between neuropsychological variables and open road driving performance in individuals diagnosed with probable AD. Thirdly, this study sought to examine actual open road driving competence on a standardized road test in a group of drivers diagnosed with probable AD. The research questions in this study were similar to those of the study described in Chapter 4, although the sample was drawn from a different population.

6.2 Method

This study was a prospective investigation; approved by the Medical Ethics Committee of Royal North Shore Hospital, Sydney. The study was conducted in the Coorabel Driver Assessment Centre within the Royal Rehabilitation Centre Sydney. Subjects were recruited from specialist Dementia Clinics situated in, or associated with, teaching hospitals in Sydney. The referring agencies were responsible for the diagnosis and ongoing management of subjects. All of the referring agencies used contemporary and accepted international criteria for the diagnosis of AD (McKhann et al., 1984), and were requested to note the year of diagnosis of AD on the referral form. Informed written consent to participate in the study was obtained from all subjects, and also from caregivers where subjects were accompanied to the assessment. Nineteen consecutively referred subjects, two female and 17 male, with a diagnosis of probable AD (McKhann et al., 1984) were assessed by a physician and a clinical neuropsychologist. All subjects then underwent an on-road driving assessment. The total duration of assessment was approximately three hours, conducted over two mornings. All staff involved in the driver evaluation were blinded to the results of other portions of the driving assessment, but not to diagnosis. With one exception, all subjects were still driving, and all wished to continue to drive.

6.2.1 Medical Assessment

The medical assessment, conducted by a doctor completing specialist training in Rehabilitation Medicine, was standardized. During the course of data collection, four doctors were sequentially involved with the Driver Assessment Program and performed the medical examinations. The medical assessment involved obtaining a medical and driving history, administration of the MMSE (Folstein, Folstein, & McHugh, 1975) according to standard instructions (see Appendix 5), and a clinical medical examination consistent with the NSW RTA Medical Guidelines (Roads and Traffic Authority, 1993). Accompanying caregivers, or if unaccompanied, the subjects themselves were asked about the incidence of accidents in the period since the diagnosis of AD.

In the medical examination a range of sensory and motor abilities were rated as either normal or abnormal. These included visual attention, sensory attention, tone and reflexes, clonus, power, sensation, coordination, diplopia, and nystagmus. Visual attention was assessed by presentation of visual stimuli to the left field, the right field and then simultaneously to both fields, with inattention being recorded when failure to respond to simultaneous stimulation was evident. Sensory attention was assessed by sensory stimulation of the left hand, the right hand and then both hands, with inattention being recorded upon failure to respond to both. Visual acuity was assessed with normal correction using Snellen's chart. Visual fields were assessed by confrontation. The doctor recorded any potential contraindications to driving in accordance with the RTA Medical

Guidelines (1993). Finally, for the purpose of the study, the doctor was required to make a prediction regarding driving performance based on the medical assessment, in the same manner as in the study reported in Chapter 4. The forced choice rating scale was pass, fail or borderline. A 'Pass' was defined as a prediction of safe, competent driving performance. A 'Fail' was defined as a prediction of clearly unsafe, incompetent on-road performance. 'Borderline' was defined as a prediction of errors being made on-road with the potential to compromise safety. The ratings were not based on a score, but instead were based on a gestalt derived from the physical examination and the MMSE. A standardized medical assessment form was used to record all the information required for the study. This form is reproduced in Appendix 2.

6.2.2 Neuropsychological Assessment

A clinical neuropsychologist administered a brief, standardized battery of tests to all subjects, using the same battery as that employed in the study described in Chapter 4. The specific tests were selected on the basis of previous reports of the predictive qualities of psychological tests for driving (Schweitzer et al., 1988; Sivak et al., 1981). The tests included the Visual Form Discrimination Test, a multiple choice test of visual recognition (Benton et al., 1983); the Judgement of Line Orientation Test, examining perception of angular relationships (Benton et al., 1983); TMT A and B, tests of visual, conceptual and visuomotor tracking (Reitan, 1958); the Benton Visual Retention Test, a visual recall test (Benton, 1974); and the Wechsler Adult Intelligence Scale-Revised subtests Picture Completion, Block Design and Digit Symbol Substitution, tests of perceptual organisation and attention (Wechsler, 1981). The clinical neuropsychologist was also required to predict the outcome of on-road driving evaluation using the ratings of pass, borderline or fail, as in the medical assessment. The rating was based on a gestalt from the neuropsychological profile.

6.2.3 On-Road Assessment

All subjects underwent an on-road assessment conducted in a vehicle with automatic transmission, power steering, dual brakes and an engine cut-off switch. All road tests were conducted by the same professional driving instructor and the same occupational therapist. The driving instructor provided directions to the subject and maintained safe passage of the vehicle, and the occupational therapist recorded driving performance according to a standardized protocol. Driving performance was evaluated over a route in traffic standardized for traffic density and required a range of driving operations, based on the Driver Performance Test described by Jones (1978), and discussed in Chapter 2. Each subject was evaluated in daylight over the same route in suburban Sydney, in light to moderate density traffic. The scoring protocol and route used for the standardized road test are shown in Appendix 4. The occupational therapist rated the subject on 138 predetermined actions at specified locations along the route, using a two-point scale. Rather than scoring entire manoeuvres, only part of a manoeuvre was scored at a given time, to simplify observation requirements and enhance observer reliability. Because of prevailing traffic conditions and incorrectly executed test actions, not all subjects were able to complete all 138 test actions. The proportion of correct actions, expressed as a percentage of the total number of attempted actions, was calculated for each of the categories of driving actions. These categories were: driver observations, including appropriate scanning of the environment for vehicles and pedestrians, traffic signals, mirror use, and acceptance of gap; car control, including maintenance of path and speed of vehicle;

judgement, including approach and following distance; and other tasks such as U-turns and pre-operation tasks such as adjusting the seat and mirrors, and fastening the seat belt. The mean percentage of correct actions was calculated across all categories, to derive the total driving score. In addition, the number of instructor interventions, prompts, evasive actions by other drivers, evasive actions by the subject (both appropriate and inappropriate) and dangerous manoeuvres were recorded. Finally, after a discussion by the driving instructor and the occupational therapist (our 'expert raters'), a consensus global rating of driving performance of either pass or fail was made. This was referred to as the final on-road result. The 'borderline' rating was not used by the expert raters, so that unambiguous feedback could be provided to the referring agencies about the safety and competence of the drivers. The criteria for a pass rating of driving performance were based on Jones' (1978) data on the driving performance of elderly drivers over a similar course, and on RTA driver licence testing criteria (Roads and Traffic Authority, 1993). The result of the evaluation was forwarded to the referring agency. This study differs from the one described in Chapter 4 in terms of the subjects' age and diagnosis, as well as in the use of a fully standardized driving test and scoring protocol.

Statistical analyses included correlational analyses (Pearson's (r_p), Spearman's (r_s) and Point Biserial (r_{pb})), reliability analysis and logistic regression. The rationale for the selection of these statistical analyses is the same as that given in Chapter 4. All statistical analyses were performed using SPSS/PC+ 4.0.

6.3 Results

The mean age of the subjects in this sample was 74.3 (SD=6.4), with a range of 59-84 years. The mean number of years since diagnosis of AD was 4.0 (SD=2.0), with a range of 2.0 to 8.0 years. Five subjects reported having had one accident since the diagnosis of AD, and one subject reported two accidents. The remaining 13 subjects reported no accidents. Seven (36.8%) subjects passed the on-road assessment, while 12 (63.2%) failed. A detailed discussion of the data is provided below. Results for the medical variables and an examination of the relationship between the doctor's prediction of on-road performance and final on-road result will be presented, followed by results for the neuropsychological variables and the relationship between the neuropsychologist's prediction of driving performance and final on-road result. In the third section, the on-road assessment variables and reliability analysis will be presented.

6.3.1 Medical Assessment and Relationship to On-Road Result

Three subjects were judged in the medical assessment to have possible contraindications for driving according to RTA criteria, and these three subjects also failed the on-road assessment. With regard to the medical variables, there were few occurrences of abnormal motor or sensory abilities (14 occurrences in 247 ratings or 5.7%). No significant correlational was found between the medical variables and the doctor's prediction of driving performance. The mean MMSE score was 21.3 (SD=2.75). The range of MMSE scores among the subjects who passed the on-road test was 20 to 25, and 15 to 26 among the subjects who failed. A significant association between the doctor's prediction and the MMSE score was observed (r_s = -.53, p=.021). The mean number of medications prescribed was 1.7 (SD=1.53), with a range of 0-5. Neither the number of medications

(r_p = -.31, p=.202) nor the subject's age (r_p = -.23, p=.349) were significantly associated with percent total correct driving score, which was termed the total driving score. However, both the MMSE score (r_p = .63, p=.004) and the doctor's prediction of outcome (r_s = -.63, p=.004) were associated with total driving score. No significant relationships were observed in point biserial correlation between any of the medical variables and the expert rating of driving competence, referred to as the final on-road result. The duration of disease (r_{pb} = -.17, p=.477), number of medications (r_{pb} = -.28, p=.25) and age (r_{pb} = .09, p=.711) were also not associated with the final on-road result.

Using a forward stepwise logistic regression model, MMSE score was found to be a significant predictor of the final on-road result (estimated coefficient = -.536, standard error = .289). In terms of goodness of fit, 71.43% of subjects were correctly predicted to pass and 83.33% correctly predicted to fail (-2 log likelihood = 19.73, df=17, significance = .289). An examination of MMSE scores plotted against final on-road result for the 19 subjects showed that a cut-off MMSE score of 22 would result in the lowest number of false positive and false negative results, with a score greater than 22 associated with a likelihood of passing the on-road driving test, and a score of less than or equal to 22 suggesting failure. The doctor's prediction of driving competence was not found to be significantly associated with the final on-road result, using a logistic regression model. The predictions of the neuropsychologist and the doctor for final on-road result were not associated with each other (r_s = .21, p=.379).

6.3.2 Neuropsychological Assessment and Relationship to On-Road Result

The subjects' performance on cognitive tasks is illustrated by the mean, standard deviation and range for the neuropsychology test scores, as shown in Table 6.1.

TABLE 6.1 Neuropsychological test performance and association with neuropsychologist's prediction of driving performance for all subjects (n=19).

Neuropsychological Test	Mean	SD	Range	Spearman's r	p
VFDT correct	22.84	6.11	9-32	-.823	<.001
JLOT correct	23.37	6.69	5-30	-.619	.005
TMT A seconds	125.79	84.57	34-353	.577	.010
TMT B seconds	324.37	214.42	0-648	.410	.081
BVRT correct	3.16	1.50	1-7	-.567	.011
BVRT errors	13.53	3.66	6-21	.569	.011
WAIS-R PC raw score	9.00	4.90	1-16	-.463	.046
WAIS-R BD raw score	12.16	9.86	0-31	-.695	<.001
WAIS-R DSS raw score	18.68	10.62	3-38	-.780	<.001

Performance on these tests was generally poor relative to age norms, with the exception of the Judgement of Line Orientation Test (Benton et al., 1983). The neuropsychology test scores were all significantly associated with the neuropsychologist's prediction of on-road performance, in the expected direction, with the exception of Trail Making Test B (see Table 6.1). That is, poor performance on neuropsychological tests was associated with a prediction of incompetent driving performance by the neuropsychologist.

Only one neuropsychological test (Block Design, r_p = .54, p=.017) was significantly associated with total driving score. The neuropsychologist's prediction of driving performance was associated with the total driving score (r_s = -.45, p=.051), although this association was not statistically significant. None of the neuropsychology test scores were significantly associated with the final on-road result. Using a forward stepwise logistic regression model, the neuropsychologist's prediction of driving performance was not found to be a significant predictor of final on-road result.

6.3.3 On-Road Evaluation

The mean total driving score was 60.76 percent (SD=14.19), with a range of 36.4 percent to 86.2 percent. The mean, standard deviation and range of component percent correct scores for each category of driving actions, together with correlations between the component percent correct scores and total driving score, are shown in Table 6.2.

TABLE 6.2 Mean, standard deviation and range of component percent correct scores, and Pearson's correlation between component scores and total driving score.

Component % Scores	Mean (%)	SD	Range (%)	Pearson's r	p
Observation	62.88	13.07	36.6 - 84.2	.770	<.001
Gap	72.66	17.78	25.0 - 100.0	.470	.042
Mirror	17.19	14.71	0.0 - 55.0	.520	.022
Path	62.55	20.70	30.0 - 90.6	.897	<.001
Speed Turns	71.83	19.94	31.3 - 93.8	.790	<.001
Speed Through	79.53	23.56	14.3 - 100.0	.311	.194
Limit Line	56.88	40.20	0.0 - 100.0	-.109	.658
Approach	68.55	18.60	33.3 - 100.0	.662	.002
Following	67.03	39.61	0.0 - 100.0	.593	.007
U turn Location	56.52	45.99	0.0 - 100.0	.698	<.001
U turn Backing	60.87	45.12	0.0 - 100.0	.475	.040
Pre-operation	47.83	51.08	0.0 - 100.0	.534	.019
Shutdown	65.22	48.70	0.0 - 100.0	.254	.294

Ten of the thirteen component percent correct scores were significantly correlated with the total driving score. An analysis of the internal reliability of the component percent correct scores from the on-road evaluation showed a Cronbach's alpha of .82, indicating an internally reliable test (Anastasi, 1982). The final on-road result, a consensus rating by the expert judges, was significantly associated with the objective measure of total driving score (r_{pb} = .53, p=.019). That is, the expert rating of driving competence shared 28% common variance with the total performance score derived from the objective evaluation.

To examine the quality of the driving performance, particularly the occurrence of potentially dangerous events, certain driving action categories (that of prompts required, instructor interventions, and dangerous manoeuvres) were analysed in terms of their relationship to final on-road result (see Table 6.3).

TABLE 6.3 Occurrence of potentially dangerous events in on-road test, and correlation with final on-road result and total driving score, for all subjects (n=19).

Event	Mean	SD	Range	Final On-Road Result	Total Driving Score
Instructor prompts	5.42	4.75	0-18	r_{pb}=-.16, p=.50	r_p=.12, p=.61
Instructor intervention	5.37	4.76	0-15	r_{pb}=-.51, p=.03	r_p=-.56, p=.01
Dangerous manoeuvres	2.58	2.22	0-8	r_{pb}=-.26, p=.30	r_p=.11, p=.67
Evasive action others	0.68	1.10	0-4		
Evasive action subject-appropriate	0.00	0.00	0		
Evasive action subject-inappropriate	0.12	0.46	0-2		

Evasive actions by the subject or by others were not included in the analysis because of their infrequency. The number of dangerous manoeuvres was not associated with either the final on-road result (r_{pb} = -.26, p=.30), or with total driving score (r_p = .11, p=.67). Similarly, the number of instructor prompts was not related to either the final on-road result (r_{pb} = -.16, p=.50), or the total driving score (r_p = .12, p=.61). However, the number of instructor interventions was significantly associated with both the final on-road result (r_{pb} = -.51, p=.03) and with the total driving score (r_p = -.56, p=.01).

6.4 Discussion

With one exception, the subjects were still driving, and all wished to continue driving. However, 12 subjects failed the on-road evaluation and were judged unsafe to drive. The remaining seven subjects were rated by our expert judges to be safe to drive within the test conditions, suggesting that a diagnosis of AD alone may not be a sufficient criterion by which to determine a person's inability to drive safely (Drachman, 1988; Drachman & Swearer, 1993; O'Neill, 1992). Given the likely progression of AD, a judgement that an individual with AD is safe to drive may be valid for a limited period of time only, and reassessment may be required. It is noteworthy that four subjects who passed the on-road evaluation, subsequently failed on re-assessment six months later.

None of the specific medical variables other than MMSE score was related to the either the final on-road result or to the doctor's prediction. This may be attributed to the low frequency of abnormal medical variables. The total number of medications was also not related to the final on-road result. A better assessment of any effect of medication use may require an examination of the types of medication rather than total number, such as sedatives or hypnotics, neuroleptics, antidepressants and so forth. A significant association between the MMSE and the doctor's prediction was observed, which raises the question of the extent to which the MMSE influenced the outcome of the medical evaluation. The doctor's prediction of on-road driving performance was not significantly associated with the consensus global judgement of driving competence made by the expert judges. In Chapter 4, in which a study of a larger sample of subjects with non-dementia brain impairment was described, it was noted that the doctor's prediction of driving performance was significantly associated with the outcome measure. However a much higher incidence of abnormal medical variables was detected in that larger group. Hence, reliance on medical evaluation to determine fitness to drive may not be justified except in those instances where medical factors preclude, or impact upon, driving, as in the case of a visual field defect, for example. In the current study only three subjects were judged by the doctor to demonstrate possible contraindications to driving according to NSW RTA Medical Guidelines (1993), all of whom failed the on-road test. Yet an additional nine subjects failed the on-road evaluation, suggesting that these guidelines are not sufficient to identify unsafe drivers. A similar result was obtained with the larger group of subjects with brain impairment, described in Chapter 4.

The MMSE score was found to be associated with the on-road result. In the study described in Chapter 4, MMSE score was also significantly associated with the final on-road result, after exclusion of a single MMSE outlier score of 7. In the present study, a lower MMSE score predicted both the likelihood of a rating of failure of the on-road test and a lower total driving score on the on-road evaluation. However, in both this present study and that of Odenheimer and colleagues (1994), the sensitivity and specificity of the MMSE were not sufficient for the effective prediction of individual driving performance. Similar to the results of the study reported in Chapter 4, there was an overlap between the range of MMSE scores for those subjects who passed the on-road driving test (MMSE score range of 20 to 25), and those who failed (MMSE score range of 15 to 26). Analysis of the MMSE scores for the 19 AD subjects suggests that a MMSE cut-off score of 22 would result in the lowest number of false positive and false negative predictions of the on-road result. A MMSE score greater than 22 would suggest the likelihood of passing an on-road driving test, while a score of less than or equal to 22 would suggest the likelihood of failure. Clearly, use of a MMSE cut-off score for screening purposes requires further research with a larger number of subjects. In a previous study (Logsdon, Teri, & Larson, 1992), it was suggested that AD subjects scoring lower than 18 on the MMSE, and demonstrating impaired visuospatial ability, were likely to have difficulty driving. In our study only three subjects scored 18 or less on the MMSE, all of whom failed the on-road evaluation. Fourteen subjects scored between 19 and 24 on the MMSE, of whom eight failed the on-road evaluation. Thus a MMSE cut-off score of 18, as previously recommended, may be too low to reliably identify unsafe drivers.

Hunt and colleagues (1993) found, in a study of subjects with mild AD, that the presence of aphasia was associated with poor road test performance, as this was dependent in part on the ability to follow verbal commands. Although their sample consisted largely of elderly drivers rather than drivers with dementia, Odenheimer and colleagues (1994) also reported a relationship between memory and language abilities and driving, which they suggested might reflect difficulty comprehending instructions rather than inherent difficulty with the driving task. Another study (Hartje et al., 1991) reported that driving behaviour was impaired in a significantly higher proportion of aphasic than non-aphasic patients. Additionally, a significant interaction was reported between the presence of aphasia, advanced age, and on-road driving performance, such that aphasic patients of advanced age tended to fail the driving test. It is possible that in the present study the association noted between MMSE score and final on-road result may in part reflect the effect of verbal impairment which compromises the ability to follow commands, thereby diminishing performance on the driving test.

The duration of disease was not related to the final result of the driving test, which is consistent with the findings of a previous study of subjects with dementia (Logsdon, Teri, & Larson, 1992). This contrasts with the significant correlation ($r = -.19$, $p<.01$) found between the duration of diagnosis and outcome in the study of subjects with non-dementia brain impairment, discussed in Chapter 4. This may reflect a difference in subject numbers between the two studies, and the consequent difference in power. While the occurrence of crashes in AD subjects has not been found to be related to disease duration, an increase in risk of crashes for each year of driving following onset of AD has been reported (Drachman & Swearer, 1993; Friedland et al., 1988). Since there is a marked variability in the degree of disability due to AD and in its progression, it is not recommended that predictions of driving safety be based on the duration of AD alone (Drachman & Swearer, 1993; Haxby et al., 1992).

In contrast to the findings of the study of non-dementia brain impaired subjects described in Chapter 4, the Alzheimer's Disease group study found that neither the neuropsychology test scores nor the neuropsychologist's prediction of driving performance were associated with the final on-road result. However the neuropsychologist's prediction and the score on a timed neuropsychology test (Block Design) were associated with the total driving score. These results might be interpreted as suggesting that the neuropsychological evaluation used in this study is not a reliable means of determining driver competence in people with dementia, an interpretation consistent with a previous report which included a small sample of two subjects (Kapust & Weintraub, 1992). An alternative explanation may be that the sample size included in the Alzheimer's Disease study (n=19) may have been insufficient to enable the detection of a relationship between neuropsychological test performance and driving test performance. Interestingly, neuropsychological measures have also been reported as failing to distinguish between AD subjects who had crashes and those who did not (Friedland et al., 1988).

The neuropsychology test battery included tasks involving speed of information processing, mental tracking, visual memory and visuospatial abilities. A number of subjects did poorly on these tasks and were predicted to fail the on-road evaluation by the neuropsychologist, yet were subsequently passed on the driving evaluation and judged to be safe. Interestingly, Lambert and Engum (1992) also reported older drivers being judged better in on-road testing than would have been expected on the basis of psychological test results, suggesting a poor positive predictive value of psychological tests for driving ability. The absence of a relationship between neuropsychological test performance and driving test performance in the present study of subjects with AD, could be interpreted as indicating that visuospatial and information processing abilities are not important for the task of driving. However, in the study described in Chapter 4, with a larger sample of drivers with brain impairment, two neuropsychological tests, Judgement of Line Orientation Test and Trail Making Test B, were found to be significant predictors of the final on-road result. An alternative explanation might be that in the structured environment of an on-road test, where the planning and judgement demands on the subject are reduced, those subjects judged as safe may be demonstrating relatively preserved, overlearnt driving skills. These overlearnt driving skills, based on procedural knowledge, would be elicited via environmental cues (Brouwer & Ponds, 1994). Potential interaction effects arising from the demands of planning and monitoring a route, and dealing with immediate traffic contingencies, could not be observed in the driving test used in this study. A more complex driving task with some route finding requirements may be necessary to elicit deficits in information processing, memory and visuospatial abilities. This would result in a road test more complex than the general licensing test in most countries, which might be considered as discriminating against the elderly driver.

While the explicit basis for the expert judges' final decision on driving performance was the total driving score, it was of interest also to examine whether there was an implicit effect of the number of instructor interventions, prompts or dangerous manoeuvres. While neither prompts nor dangerous manoeuvres were associated with the final result of the driving test, the number of instructor interventions was associated with the final on-road result, suggesting that the expert judges may have been influenced by the need for the instructor to intervene during the driving test. Similarly, in the earlier study of 153 subjects with brain impairment described in Chapter 4, the number of instructor interventions was found to be a significant predictor of the final on-road result. In the present study however, the number of instructor interventions was also associated with the total driving score, so that a higher number of instructor interventions may simply reflect poor driving performance that impinged on driving safety. Nevertheless, this finding of an association between the number of instructor interventions and the final on-road result, is consistent with that of Hartje and colleagues (1991) who noted that the necessity to intervene almost inevitably influenced the rating of driving performance.

In the present study, the on-road test was a reliable and internally consistent measure. Few previous studies have evaluated the internal consistency of on-road driving tests conducted in subjects with a diagnosis of dementia, although one recent study reported a similar internal consistency figure of .84 (Odenheimer et al., 1994). The final rating by our expert judges was related strongly to the objective score of total driving actions, suggesting that the expert judges' overall rating was largely based on their observation of the subject's performance on each of the driving actions. The reliability of the on-road test, and the association between the expert rating and the objective correct driving actions score, suggest that a road evaluation is a valid means of determining driving competence in people with AD. It is interesting to note, when contrasting the study described in Chapter 4 and the present study, that the amount of common variance between the expert rating of driving performance (the final on-road result) and the driving error score from the on-road test increased from 15% to 28% in the present study, despite a substantially smaller sample size. This increase might be attributed to the further standardization of the on-road driving test. The ways in which the test was standardized included the use of a standard route with the same driving manoeuvres required of each candidate, and the rating of each component of a manoeuvre rather than of the entire manoeuvre, against precise criteria, rather than simply noting when a manoeuvre was performed incorrectly.

The use of a standardized on-road evaluation, in preference to neuropsychological examination, medical examination, or mental state examination alone, is recommended for the determination of driver competence in individuals with AD. In this study, approximately one third of the subjects were found to be safe drivers. An on-road evaluation is therefore recommended as the most reliable means of determining who should no longer be driving, without unnecessarily restricting the driving privileges of those who are safe to drive. At an individual level however, each subject judged as 'safe' could only be considered as safe in certain traffic conditions, as not all traffic conditions can be sampled in a single driving evaluation. While a judgement of 'safe' on the driving test cannot be taken to imply that the subject is safe in all possible traffic conditions, the same limitation is true of ordinary licence testing. On-road driving assessment of all AD drivers would require substantial resources, and hence it may be more pragmatic to offer on-road evaluation only to those for whom continuation of driving privileges is a realistic goal, for example, those with an adequate MMSE score. The judgement of safety in this population is a temporary one however, and regular re-evaluation may be required.

CHAPTER 7

CONCLUSION

The central research issue of this thesis was described in Chapter 1 as the investigation of the most appropriate method of determining which individuals should be advised to cease driving following brain impairment. Previous studies suggest that approximately half of the patients with cognitive impairment in rehabilitation settings might be expected to resume driving and to therefore require assessment of their driving competence (Hopewell & Price, 1985; Quigley & DeLisa, 1983; Shore, Gurgold, & Robbins, 1980). Another group of drivers with cognitive impairment who may require assessment of their driving competence are those with a progressive dementing illness such as Alzheimer's Disease (AD). The prevalence of AD increases at an exponential rate after age 65 and has been estimated as high as 47% in those aged 85 years and older (Bylsma, 1997). Many patients with AD continue to drive, and even after adjusting for mileage driven, drivers with dementia have a higher crash rate than elderly normal drivers (Dubinsky et al., 1992; Friedland et al., 1988). Thus a potentially large group of patients with cognitive impairment, both static and progressive, may require assessment of their ability to drive.

7.1 Literature Review

7.1.1 Models of Driving

As detailed in Chapter 1, a review of the literature highlighted the lack of a comprehensive model of driving behaviour, from which testable hypotheses could be generated. Much of the research has focused on accident-causing behaviours and crash risk, rather than on everyday driving, and consequently valid predictors of safe driving have not been identified. Early models of driving emphasised the hypothesised construct of 'driving skill', based on perceptual motor and psychomotor abilities. However, empirical data fail to support such a model. Driver training has not been shown to significantly alter accident rates, high skill drivers such as professional racing car drivers have above average accident rates, and young male drivers with optimal perceptual motor skills also have above average accident rates (Evans, L., 1991). Despite lacking empirical support, the skill based model of driving provides the basis for nearly all state driver licensing examinations (Hopewell & Van Zomeren, 1990). It is not surprising then, that licence examinations appear to have less than optimal predictive validity, and accident statistics indicate that drivers do not always drive as they did during their licence test (Mihal & Barrett, 1976). Other approaches to modelling driving behaviour have looked for predictors of accident involvement, despite inherent difficulties with retrospective accident data, such as a low frequency of accidents and a multiplicity of causes. Although one group found that a component of visual attention, termed the Useful Field of View, was a significant predictor of retrospective accident involvement in older subjects (Ball & Owsley, 1991), the finding is not sufficient for a model of driving behaviour, as elements such as the dynamics of control of driving cannot be addressed.

Arising from a functional rather than skill based perspective, motivational models of driving focus on observed driving behaviour rather than driver capabilities, and assume that the main factors influencing driver behaviour are the risks drivers are willing to tolerate, and the goals and expectations of the journey (Ranney, 1994). A problem with such models is the difficulty in generating testable hypotheses, making validation complex. Another model of driving, termed the 'cybernetic model', included aspects of the skill and motivational models of driving, and demonstrated some of the weaknesses of both types of models, including a lack of specification of control mechanisms for the dynamic aspects of driving (Galski, Bruno, & Ehle, 1992). Moreover, attempts to validate the cybernetic model were difficult because of an insufficient number of subjects for each predictor in the regression analysis (Brouwer & Withaar, 1997).

Michon has proposed a descriptive model, with a three level hierarchy underlying the cognitive control of driving, in which driving is characterised as involving concurrent activity at each of the three levels, necessitating multitasking (Michon, 1979, 1989). The three levels are termed the strategic level, the tactical level and the operational level, and each has an associated level of risk. The strategic level incorporates the planning stage of a trip, including the determination of the trip goal, route and vehicle choice, and an evaluation of the costs and risks involved. At this level, the subjective evaluation of risk in traffic is specified in terms of the probability of a danger occurring during a particular time interval. Behaviour and decisions in traffic are encompassed within the tactical level, and the associated level of risk is described as risk taking, or actively engaging in behaviour that increases the probability of a danger becoming manifest. The operational level involves the basic skills of driving, such as steering, braking and so forth, and the associated risk involves coping with threat by information intake, decision making and the performance of evasive manoeuvres aimed at avoiding acute, perceived danger (Michon, 1979). Uncertainty has been proposed as the mechanism for eliciting compensatory behaviour, with the resultant reallocation of cognitive resources (Ranney, 1994). Thus Michon's model offers both provision for switching control between the levels of driving and a mechanism for switching. Michon's hierarchical model of driving was utilised in this research as a reference point from which to consider approaches to the assessment of driving competence in individuals with brain impairment.

7.1.2 Medical Assessment of Driving Competence

While physicians generally have a legal responsibility to assess whether their patients with brain impairment are able to resume driving safely, there is a lack of information to assist them in this process. Although guidelines have been published by state licensing authorities to aid physicians in assessing the fitness of their patients to drive safely (for example, the Roads and Traffic Authority of NSW, 1993), these are lacking in specific instructions or advice on methods of assessing fitness to drive. Moreover, a literature review failed to locate any studies that had examined the efficacy of medical assessment in correctly distinguishing safe from unsafe drivers with brain impairment. Thus the predictive validity of a medical examination of driver fitness in individuals who have sustained brain impairment has received little attention.

7.1.3 Psychological Test Performance and On-Road Driving

The literature concerning the relationship between performance on psychological tests and on-road driving for individuals having incurred brain impairment was reviewed in detail in Chapter 1. The studies reviewed indicate that a clear and consistent relationship between psychological test performance and on-road driving is lacking. Various studies have reported certain psychological tests as having either good or poor predictive ability for on-road driving. The studies varied considerably in terms of subject characteristics, such as the duration of brain impairment and prior driving experience, whether the subjects had resumed driving before the driving assessment, the cognitive measures used, and the manner in which driving was assessed. Some of the driving tests used may have been superior measures of driving competence relative to other tests. This diversity in methodology between studies may in part explain the absence of a consistent relationship between psychological test performance and driving. Moreover, some of the studies which reported a relationship between psychological test performance and driving ability may be criticised on methodological grounds, such as having insufficient numbers of subjects for the number of predictors examined in regression or discriminant analyses (Galski, Bruno, & Ehle, 1993; Nouri, Tinson, & Lincoln, 1987).

A small number of studies have examined the relationship between psychological variables and driving performance in elderly subjects, including those with a diagnosis of dementia. An association between Mini Mental Status Examination (MMSE) score and driving performance has been reported, although the specificity of the MMSE was insufficient for individual predictions of driving performance (Fitten et al., 1995; Odenheimer et al., 1994). Performance on other psychological tasks has not been found to be closely related to on-road driving in subjects with dementia.

7.1.4 Driving Simulators

Commercial driving simulators have not been reported as reliable predictors of on-road driving performance in subjects with brain impairment. This lack of predictive validity may be attributed to the poor face validity of the simulator task for many subjects, and the simulator's limitation to very basic operational aspects of driving, with no consideration of the broader demands of driving in traffic. More complex driving simulators have been developed, incorporating aspects of the interactive driving environment, but these have not yet been fully evaluated in terms of their predictive validity for on-road driving (Brouwer

& Van Zomeren, 1992). Furthermore interactive driving simulators are costly. The potential benefits of simulating the driving environment, rather than directly testing driving performance, require evaluation. At this point in time, there is little convincing evidence of the predictive validity of driving simulators for subjects who have incurred brain impairment, and therefore there is currently little justification for substantial financial investment in the further development of interactive, 'virtual environment' driving simulators.

7.1.5 Closed Course Driving Assessment

Some studies have evaluated the driving performance of subjects with brain impairment over a closed course, where no interaction occurs with other traffic. In studies in which the performance of a group of subjects with brain impairment was contrasted with that of a control group, the brain impaired subjects were noted to be slower, and their driving performance was rated as inferior (Schweitzer et al., 1988; Sivak et al., 1981; Stokx & Gaillard, 1986). Several studies, however, have found that a closed course evaluation yielded little useful or predictive information for on-road driving in subjects with brain impairment or in elderly subjects (Galski, Ehle, & Bruno, 1990; Odenheimer et al., 1994; Wilson & Smith, 1983). It is likely that a closed course driving test is not sufficiently complex to test the integration of skills required for safe driving in traffic, although it may be useful in determining whether a subject meets minimum standards of competence for an open road driving assessment.

7.2 On-Road Driving Assessment

A review of the literature concerning open road driving assessments for subjects with brain impairment indicated that there has been little attention given to issues such as the reliability and standardization of on-road driving assessments. Noteworthy is a study that examined the reliability and standardization of an on-road driving test in normal subjects (Jones, M. H., 1978). In this study a set route was used, with specified driving manoeuvres required of each subject, which an observer then assessed against previously determined competence criteria. The test was found to be a reliable instrument for the evaluation of driving performance in both novice and experienced drivers. However, this driving assessment protocol does not appear to have been widely adopted by researchers examining the driving performance of individuals with brain impairment.

On-road assessment of subjects with brain impairment has typically been utilised either as an outcome measure to validate the predictive validity of off-road assessment techniques, or to examine the driving performance of different diagnostic groups. In both cases, a gradual progression towards the use of standardized driving tests is evident. Where standardized driving tests were used, high inter-rater reliability was observed (Fitten et al., 1995; Odenheimer et al., 1994). Many studies included a final rating of driving competence, although frequently the basis of the final rating was unclear (Galski, Bruno, & Ehle, 1993; Nouri & Lincoln, 1992), or the overall rating of driving performance did not relate well to an objective driving error score (Van Zomeren et al., 1988). In fact, it has been suggested that the explicit scoring of driving performance may not enhance the validity of assessment unless more complex aspects of traffic behaviour are incorporated into the driving test (Van Zomeren et al., 1988). In contrast, other authors have reported that an overall rating of driving was significantly related to a quantified driving score (Brooke et al., 1992). Reported correlations between the rater's global evaluation of driving and objective driving scores obtained during the on-road test, have ranged from .74 to .83 (Odenheimer et al., 1994; Sivak et al., 1981). Additionally it has been argued that any direct intervention by the driving examiner to prevent danger may have an additional influence on the final rating of driving performance (Hartje et al., 1991). The effect of the driving instructor being required to intervene during an on-road test requires further investigation. The criterion validity of a standardized on-road assessment of driving performance in subjects with brain impairment requires further development, just as is also required for driver licence testing of normal subjects. Moreover, there is a need for the development of guidelines for the interpretation of on-road driving errors in the derivation of a final judgement regarding driver competence.

A series of studies, described below, were conducted to address some of these experimental questions in subjects with brain impairment.

7.3 Retrospective Audit of the Coorabel Driver Assessment Program

A retrospective audit of the first 129 consecutive referrals to the Coorabel Driver Assessment Program was conducted to examine the program's success in achieving its aim of undertaking reliable and thorough assessment of driver competence in people with disability. The audit reviewed the assessment process, methodology and success rates for various subject groups, and examined the variables age, chronicity (time since diagnosis), sex and diagnosis in relation to both the final outcome and the result of each stage of assessment. As a retrospective audit of clinical data, this study failed to satisfy many of the criteria for a standardized, controlled examination of driving assessment procedures. However, it was considered valuable as a pilot study, enabling the gathering of information about the subjects, and the examination of aspects of the assessment procedure and the performance of subjects at each stage of the assessment process.

Outcome data were collected from a medical assessment, a neuropsychological assessment and an on-road driving assessment. The medical assessment involved a general neurological examination including testing of visual fields. Subjects were judged as pass, borderline or fail. Those judged to have failed the medical assessment were not permitted to continue with the assessment program. Those judged as borderline were considered to have demonstrated a deficit that required neuropsychological and/or on-road assessment to clarify its significance to driving. Neuropsychological assessment involved the administration of a short battery of neuropsychological tasks, during which both quantitative and qualitative aspects of performance were noted. Subjects were again judged as pass, borderline or fail; those judged to have failed the neuropsychological assessment were not permitted to continue with the program. The on-road assessment was conducted in a dual control vehicle on one of four standard driving routes. The nature and frequency of errors were recorded, and driving performance was rated as pass, borderline or fail by an occupational therapist and driving instructor. In the case of a borderline result, remedial driving training was offered, with subsequent re-assessment of driving performance.

The results showed that of 129 subjects, seven (5.4%) were judged to have failed the medical assessment, and 25 (19.4%) to have failed the neuropsychological assessment. These subjects were therefore precluded from continuing to the on-road assessment. Of the 97 subjects who continued to the final stage, 57 (44.2%) passed the on-road assessment, 24

(18.6%) failed and the remaining 16 (12.4%) subjects withdrew from the program. Subjects were predominantly male (76.0%), and more than half (57.0%) were aged 60 or more years. Subjects aged 70 or more years were noted to be less likely to pass the assessment program. Most subjects (79.0%) were more than six months post diagnosis when referred to the program. Among subjects with brain impairment, diagnosis was not associated with outcome, and furthermore, no significant difference in failure rates between left and right cerebrovascular accident groups was found.

In this study, false negative error rates could not be examined because subjects who failed the medical or neuropsychological stages of assessment were not permitted to continue to the on-road assessment. This limitation is present in other uncontrolled clinical studies where some subjects did not have the opportunity to proceed to an on-road driving assessment (Jones, R., Giddens, & Croft, 1983; Simms, 1985). Despite this methodological shortcoming, an examination of the results suggested that medical assessment alone may not be a reliable means of judging driver competence, because in 47 cases (36.0%) the physician was unable to make a judgement regarding driving ability. Moreover, 12 of the 75 subjects who passed the medical assessment subsequently failed the on-road driving test. Medical assessment may therefore provide an inadequate basis for judging fitness to drive safely for individuals with brain impairment, as comprehensive testing of all abilities relevant to driving, particularly cognitive abilities, is not routinely included in a medical assessment. Although there was a small number of false positive results (3 of 52 cases) from neuropsychological assessment, the lack of information regarding false negative error rates for neuropsychological assessment precluded consideration of relationship with outcome.

In order to address these methodological shortcomings, a prospective study was designed in which the raters were blinded to the ratings from other stages of assessment, and in which all subjects proceeded to on-road driving assessment. This study aimed to examine the predictive validity of both medical and neuropsychological examinations for driving performance, and the validity and reliability of on-road assessment itself.

7.4 Predicting Driving Performance After Brain Impairment

The retrospective audit of clients of the Coorabel Driving Assessment Program, discussed above, raised several questions about the assessment of driving competence in clients with brain impairment. Specifically, both the validity of a medical assessment and the validity of a neuropsychological assessment for predicting driving performance required further investigation. The reliability and validity of an on-road driving test for examining driving performance in subjects with brain impairment also warranted attention. Further issues for investigation were the association between diagnosis and driving performance, the predictive validity of the MMSE for driving performance, and the nature of driving errors committed by drivers with brain impairment during an on-road evaluation.

In this study, 153 subjects with a mean age of 57.4 years (range 17 - 84 years) were assessed. Each subject belonged to one of the following diagnostic groups: Brain Injury, Left CVA, Right CVA, Other CVA and Other Neurological Illness. All subjects undertook standardized medical, neuropsychological and on-road driving assessments, except those subjects found to have deficits that legally prohibited them from driving. Staff involved with each stage of assessment were kept blinded to the results of other stages of assessment. The physician and the clinical neuropsychologist were each required to make a prediction of on-road driving performance based on their respective clinical assessments, using a rating scale of pass, borderline or fail.

Seventy-five (49%) subjects passed the on-road assessment, while the remaining 78 (51%) failed, a success rate for driving following brain impairment similar to that reported in previous studies (Hopewell & Price, 1985; Shore, Gurgold, & Robbins, 1980). Concerning the variables examined in the medical assessment, no association was found between the age of the subjects and the presence of abnormalities, suggesting that the occurrence of abnormal medical variables was not simply a function of increasing age. The presence of abnormalities on medical examination was found to be associated with a prediction of failure by the doctor for all variables except visual attention, presence of diplopia or nystagmus, tone-reflexes and toe-tap coordination. MMSE scores ranged from 7 - 30, although 95% of MMSE scores were 20 or greater. A significant association between the doctor's prediction of driving competence and the MMSE score was observed. No association was observed between subject's age and the doctor's prediction of driving competence. These results suggest that the doctor's prediction of driving competence may have been based on the medical variables and the MMSE score. However, correlational analysis showed that neither the MMSE score, when all MMSE scores were included, nor any of the medical variables were associated with the final on-road result, whereas the doctor's prediction of driving competence was correlated with the final on-road result. Perhaps the doctor's predictions of driving competence were influenced by a variable not measured in this study, such as 'clinical experience'. On the basis of these results it is difficult to make recommendations concerning the appropriate content of a medical examination for the determination of driving competence in subjects with brain impairment.

All neuropsychology tests were correlated with the neuropsychologist's prediction in the expected direction (that is, a poor test performance was associated with a prediction of incompetent driving). It therefore seems reasonable to conclude that the neuropsychologist's prediction of driving performance was based on the subject's performance on the neuropsychological tests. Correlational analysis showed that the neuropsychology test results (except the Visual Form Discrimination Test) and the neuropsychologist's prediction of driving performance, were all associated with the final on-road result.

To formulate an 'expert model' of prediction of driving performance, all background, medical and neuropsychological variables were entered into a forward, stepwise logistic regression with the final on-road result as the dependent variable. The variables diagnosis; duration of diagnosis; Judgement of Line Orientation Test, Trail Making Test B, and Block Design test scores; and Finger/Nose Coordination were found to be significant predictors of the final on-road result, independent of other variables. This model suggests that with knowledge of diagnosis and duration of diagnosis, administration of a coordination task and three neuropsychological tests, 80.6% of successful subjects would be correctly classified as 'pass', and 75.4% of unsuccessful subjects would be correctly classified as 'fail'. However, the concomitant incorrect classification rates may be too high to permit the use of the off-road tests in this model for the determination of individual driving competence in subjects with brain impairment.

An examination of the diagnosis variable showed that the diagnostic groups Right CVA and Other Neurological illness were least likely to be successful in the driving assessment program. When the groups Right CVA and Left CVA were directly compared, the Right

CVA group was found to be less likely to be successful in the driving assessment. This finding of a significant difference in failure rates between Right CVA and Left CVA groups contrasts with the earlier finding of no difference in failure rates in the retrospective audit study discussed above. The different failure rates between the Right and Left CVA groups in the present study may in part be attributable to the fact that in this study all subjects progressed to an on-road driving test, thereby reducing the potential for false negative errors. In the retrospective audit subjects who performed badly on the medical and neuropsychological evaluations were precluded from attempting the on-road driving test, and it was therefore not possible to know whether some of these subjects would have passed the on-road driving test if they had been given the opportunity. In the present study all subjects had the opportunity to attempt the on-road driving test.

In terms of the nature of driving errors committed by subjects, the mean number of errors was greatest in the categories Observation, Planning and Judgement, and Vehicle Positioning. Furthermore, the number of errors in Planning and Judgement and Vehicle Positioning were significantly correlated with the final on-road result, with an increase in errors being associated with an increased likelihood of failure. The total number of errors made in the driving assessment was significantly associated with the age of the subject, with increased age being associated with a higher number of driving errors. This result supports a finding of the retrospective audit study, where increased age was associated with a decreased likelihood of passing the on-road driving test. To examine the predictive value of the objective error scores for the expert rating of driving performance, the predictor variables of total error score, number of instructor interventions, and the number of errors in each of the categories of observation, speed, planning and judgement, vehicle positioning and reaction time were included in a forward stepwise logistic regression with the final on-road result as the dependent variable. The total error score and the number of instructor interventions were found to be significantly associated with the final on-road result, with an overall correct classification rate of 73%. The number of instructor interventions made a contribution to the final global rating by the expert judges, independent of the number of driving errors. This result supports Hartje's (1991) suggestion that direct intervention by the instructor to prevent danger has an additional influence on the final rating of driving performance.

The on-road driving test was confirmed as a consistent, reliable test. The final on-road result, a consensus rating of driving performance made by the expert judges, was highly associated with the total objective error score from the driving assessment. The expert rating of driving performance shared 15% common variance with the total error score. The total number of driving errors made by subjects who passed the driving assessment was significantly lower than that of subjects who were considered to have failed.

The administration of a standardized on-road driving test is therefore recommended as the best means of ascertaining the competence of individuals with brain impairment to drive safely. The main findings of this study can be discussed in terms of the five research questions, which arose from a consideration of the results of the retrospective audit. The first question concerned whether doctors are able to make accurate predictions of driving performance on the basis of medical examinations. The results of this study indicate that although the doctor's prediction of driving performance was correlated with the final on-road result, it was not found to be a significant predictor of the final on-road result, independent of other variables, in a logistic regression model. Additionally, the criteria of the NSW Roads and Traffic Authority for identification of possible contraindications to driving do not appear to be sufficiently stringent to identify individuals at risk of unsafe driving. The second research question concerned the relationship between medical and background variables and driving performance. The results indicated that the variables of diagnosis, duration of diagnosis and finger-nose coordination were significant predictors of the final on-road result, and were included in an 'expert model' of prediction of driving performance. The MMSE was not a significant predictor of the final on-road result. Other background variables, including age, were also not predictive of the final on-road result, although the total number of driving errors was positively associated with age. The third research question concerned the predictive validity of neuropsychological assessment for on-road driving performance. The results showed that the neuropsychology test scores and the neuropsychologist's prediction of on-road driving performance were correlated with the final on-road result. However, although the individual neuropsychological tests Judgement of Line Orientation Test, Trail Making Test B and Block Design were found to be significant predictors of final on-road result independent of other variables in a logistic regression model, the neuropsychologist's prediction was not.

An 'expert model' for prediction of driving competence following brain impairment was derived from a consideration of all the variables in a logistic regression model. This 'expert model' for prediction of driving performance included the variables diagnosis, duration of diagnosis, finger-nose coordination, Judgement of Line Orientation test, Trail Making Test B and Block Design, and achieved an overall correct classification rate of 78.03%. While this model is helpful, the incorrect classification rate is probably too high for the model to be considered appropriate for individual assessments of driving competence following brain impairment. The 'expert model' may instead be useful as a screening tool, to identify, for example, individuals at risk of unsafe driving who could then undergo driving assessment on a closed course rather than open road.

The fourth research question concerned the reliability of the on-road driving test. As discussed above, the driving test was found to be both consistent and reliable. Following on from the issue of the reliability of the driving test, the fifth question concerned the relationship between the expert judges' rating of driving performance and the objective scoring of the standardized driving test. The results indicated an association between the expert judges' rating and the objective scores, with 15% common variance.

One weakness of this study was that four different routes were used for the driving test, and it was not possible to control for effect, if any, of the selected test route. There may have been differences in the degree of difficulty of the routes. As the route undertaken by each subject was not recorded, it was not possible to examine the data for an effect. Clearly it would be preferable to eliminate such a source of variance by using one standardized driving test route only. Another weakness common to many studies that have employed an on-road driving test is that the criterion validity of the on-road driving test has not been established. In fact, the criterion validity of learner driver licensing tests have similarly not been confirmed, because, by definition, those who fail the driver licensing test are not permitted to drive. It may be argued that since licence tests have not been validated and the false negative rate is unknown, it would be useful to put all drivers on the road following a driving test to evaluate their driving performance, and then validate the driving test by examining the subsequent driving behaviour (crash risk and number of violations). Ethically and politically this methodology may be difficult to justify, however, particularly since the false negative rate for learner driver licence examinations in the normal population is likely to be low, and many individuals who fail a driver licence examination repeat the examination until they are successful. The number of individuals who attempt a driver licence test but are unable to ever pass the examination is probably very small. In contrast, the problem of false positive errors on driver licence tests is important, as exemplified by the relatively high crash rate for young recently licensed male drivers (Evans, L., 1991; Mihal & Barrett, 1976).

One possible method for examining the relationship between performance on a driving test and subsequent driver behaviour might be to rate driving performance on a continuous scale rather than on a dichotomous (pass/fail) scale. Subsequently, driving behaviour in terms of crashes and violations could be tracked and examined with regard to a possible relationship between the rating of driving test performance and rates of crashes or violations. The difficult ethical issue of putting potentially unsafe drivers on the road might be minimised by designating those who achieve the lowest grade as clearly unsafe and incompetent and therefore not recommended to drive on-road. The finding of a positive predictive relationship between a test rating and the subsequent driving record may confirm the construct validity of the driving test.

Unlike driver licence testing, most drivers entering a driver rehabilitation program following brain impairment have previous driving experience. It has been argued that previous driving experience, in terms of years of driving, may be predictive of performance on a driving test following brain impairment (Korteling & Kaptein, 1996; Van Zomeren, Brouwer, & Minderhoud, 1987). This suggestion is based on the observation that drivers with longer driving experience seem to perform the operational aspects of driving with some automaticity, and consequently may have greater residual attentional capacity available for the development and use of compensatory strategies. The driving record prior to brain impairment, described by the number of crashes or violations, may also be predictive of subsequent on-road driving performance. In other words, drivers who were previously risk takers or relatively unsafe drivers may display similar driving habits after suffering brain impairment. In a recent study it was suggested that the higher crash rate of a group of drivers with TBI, compared to the state population, might be due to pre-injury driving habits as well as to direct injury effects (Boake et al., 1998). Thus, issues for future research include the relationship between the driving test rating and subsequent driving performance, and also the relationship between years of driving experience and prior driving record, and driving performance following brain impairment. It may be possible to validate an on-road driving test procedure by investigating the association between previous driving record and driving test rating of performance.

Sixty CVA subjects in this study underwent remedial driving training following their initial driving test, and then completed a second driving test. Although a significant decrease in the total number of driving errors was evident between the initial and subsequent driving tests, only two of the five driving categories (observation and vehicle positioning) showed significant decreases in the number of errors. This raises the question of how the raters determined that sufficient improvement in driving performance had occurred for a rating of pass to be given to more than half of the 60 subjects. In other words, the question remains as to what specific changes in driving test performance, if any, indicated to the raters that driving competence had reached an acceptable standard.

Another important area for further research is the possible remediation of specific deficits in driving performance following brain impairment through appropriate retraining. Van Zomeren, Brouwer and Minderhoud (1987) have suggested that remedial driver training for drivers with brain impairment should concentrate on defensive and anticipatory driving (involving the tactical level of Michon's (1989) model of driving), and on the sensible use of automobiles (the strategic level of Michon's model), rather than on driving skills at the operational level. There is already evidence that drivers are to some degree able to compensate for difficulties with driving at the operational level, for example by driving more cautiously to compensate for slowed reaction times. In the present study, it is unclear what aspect of remedial training affected driving performance on subsequent reassessment. Perhaps other factors were involved, such as the driving instructor's increased exposure to the subjects, as the remedial training was provided by the same driving instructor who rated driving performance in the driving tests. The effect of remedial training on driving performance by individuals with brain impairment is also an area for future research.

7.5 Dementia and Driving: A Survey of Clinical Practice in Aged Care Assessment Teams

The previous study, conducted in a group of drivers with non-progressive acquired brain impairment examined the predictive validity of both medical assessment and neuropsychological assessment for on-road driving performance, and also examined the on-road driving test itself. A question frequently encountered within aged care services concerns the ability of clients with progressive dementias, including Alzheimer's Disease (AD), to continue to drive safely. This present study involved a survey of current clinical practice with regard to the determination of fitness to drive in subjects with a diagnosis of probable dementia (AD, Multi-Infarct and other forms), in Aged Care Assessment Teams with a geriatrician on staff, in New South Wales (NSW) and the Australian Capital Territory (ACT). The survey questionnaire was devised on the basis of the literature concerning driver assessment (see Chapters 1 and 2) and on the assessment procedure used at the Coorabel Driving Assessment and Training Program of the Royal Rehabilitation Centre Sydney (see Chapter 3). Thirty-eight of 42 (90.5%) Assessment Teams participated in the survey. Half of the assessment teams surveyed were in city areas and half in rural areas.

The results of the survey indicated that the evaluation of fitness to drive by the Assessment Teams was generally a medically based procedure in both city and rural settings. This result was not unexpected since only medical practitioners were indemnified for notification of unsafe drivers to the relevant authorities. There is little scientific evidence that a medical evaluation can correctly identify the safe older driver, and therefore consideration of additional mechanisms for driving evaluation, such as on-road assessment, is recommended. Less than half of the Assessment Teams conducted functional evaluations of actual driving, via on-road assessments and this may be attributable to a lack of staff trained in driver assessment. Referrals to centres with on-road assessment facilities should be encouraged, for example by increasing awareness of the programs these centres offer.

More than half of the Assessment Teams sought information about licence status and driving history. This information can bring to light useful information concerning difficulties with driving, such as getting lost, crashes, reluctance of passengers to travel with the driver and so forth. This information is important for identifying drivers who should undergo further assessment of their driving ability. Obtaining information about driving history and driving record is recommended as part of the driving assessment procedure for elderly drivers.

Severity of dementia was usually assessed (95%) by means of the Mini Mental Status Examination (MMSE), although few teams reported using a cut-off score on the MMSE for the determination of driving fitness. The predictive validity of the MMSE in determining driving competence has not been conclusively demonstrated in previous research. In the study described in Chapter 4, involving subjects with non-dementia brain impairment, when an outlier score was excluded, the MMSE score was found to be correlated with the final on-road result. However, the MMSE score was not associated with the total driving error score, and was not a significant predictor of the final on-road result when all variables were included in a logistic regression analysis. Caution is therefore recommended with use of the MMSE score as a criterion for determining driving competence, and use of the MMSE for screening purposes in elderly drivers requires further investigation.

The Assessment Teams communicated the results of the driving assessment to the client (95%), the relatives or carers (90%) and the client's local doctor (86%), but not always to the relevant authorities. Approximately one third of the teams indicated that they did not report unsafe drivers to the authorities because of concern about their relationship with the client and their desire to maintain confidentiality. Indeed, many Assessment Teams indicated a desire for clear guidelines on their responsibilities regarding drivers with dementia, particularly concerning reporting and confidentiality, and clients who continue to drive against advice. Around three quarters of the Assessment Teams experienced clients disregarding the advice of the team and continuing to drive despite being judged unsafe at assessment, confirming previous reports of this behaviour (Kaszniak, Keyl, & Albert, 1991; Odenheimer, 1993).

Approximately one third of Assessment Teams repeated driving evaluations to follow longitudinal changes in driving competence. Given the commonly progressive course of dementia, Assessment Teams should continue to monitor clients who at first assessment are found to be safe to drive, and re-evaluate driving competence where there is evidence of cognitive deterioration or at regular time intervals, such as six months. Moreover, the likelihood that the client will at some time in the future become unsafe to drive, should be discussed with both the client and the relative or carers. Interestingly, no statistically significant differences in practice of driver assessment were found between city and rural Teams. Some trends were evident, perhaps reflecting the different role of driving, and the limited alternatives available in rural areas. Specifically, a trend for more frequent use of restricted licences was noted in rural areas, and fewer rural Assessment Teams reported repeating the driving evaluation.

Further investigation is required of the predictive validity of a medical examination, the MMSE and neuropsychological tests for driving competence in drivers with dementia. Additional research may assist in establishing guidelines for the optimal frequency for reviewing driving ability in drivers with dementia. The on-road driving performance of drivers with dementia could also be studied for any evidence of systematic driving errors, including an examination of the driving environments, traffic situations, and intersection types in which errors most frequently occur. This information may be useful for evaluating whether limitations on driving, such as restricted licences, might permit clients to continue driving for a period without increased risk.

7.6 Alzheimer's Disease and Driving: Prediction and Assessment of Driving Performance

In light of the findings of the survey of clinical practice among Aged Care and Assessment Teams discussed above, and in view of the paucity of data on actual driving behaviour of drivers with Alzheimer's Disease, an experimental study was conducted with drivers diagnosed with probable Alzheimer's Disease. This study sought to examine the relationship between medical examination, inclusive of administration of the MMSE, and open road driving performance, and between neuropsychological examination and open road driving performance. A further objective was to observe the open-road driving behaviour of drivers diagnosed with probable AD. The present study further developed the research questions investigated in Chapter 4, but with a different subject group. The study detailed in Chapter 4 dealt with predicting driving ability after acquired brain impairment subsequent to traumatic brain injury, CVA, and other diagnoses. The predictive validity of both medical and neuropsychological assessments for determining driving competence were examined, together with the reliability of an on-road driving assessment. Subjects included in the study described in Chapter 4 had suffered acquired brain impairment, which by the time of driving assessment was static in terms of level of severity. In contrast, the subjects included in the study described in Chapter 6 had been diagnosed with probable Alzheimer's Disease (AD), a progressive dementia, and thus deterioration in driving ability could reasonably be anticipated. Again the central research questions in the study described in Chapter 6 concerned the predictive validity of a medical assessment and a neuropsychological assessment for driving competence for subjects with AD, and the reliability of a standardized on-road driving assessment for subjects with AD.

In this prospective study, 19 consecutively referred subjects (17 male, 2 female), with a mean age of 74.3 years and a diagnosis of probable AD, were assessed by a doctor and a clinical neuropsychologist and then underwent an on-road driving test. All staff involved in the driver evaluation were kept blinded to the results of other portions of the driving assessment, but not to the diagnosis. With one exception, all subjects were still driving, and all wished to continue to drive. A standardized medical assessment was conducted, including administration of the MMSE. For the purposes of the study, the doctor was required to make a prediction (of pass, borderline or fail) regarding on-road driving performance based on the medical assessment. The clinical neuropsychologist, who was required to predict the outcome of the on-road driving evaluation using the same rating scale, administered a brief, standardized battery of tests. On-road driving performance was evaluated on a fully standardized route in suburban traffic by an occupational therapist, who rated 138 predetermined driving actions at specified locations along the route, using a two point scale. Scores obtained included the percentage correct of the total attempted driving actions in each category, total percentage of correct actions across all categories (called the total driving score), the number of instructor interventions and the number of dangerous manoeuvres. A global rating of driving performance of either pass or fail, was made by the driving instructor and occupational therapist, and was referred to as the final on-road result.

The results indicated that there were few occurrences of abnormal motor or sensory abilities. Mean MMSE score was 21.3; the range of MMSE scores for those subjects who passed the on-road driving test was 20 to 25, and 15 to 26 for those subjects who failed. An inspection of the MMSE scores suggested that a cut-off score of 22 would result in the fewest false positive and false negative predictions for on-road driving. An MMSE score of more than 22 would result in a prediction of passing an on-road driving test, while a score of less than or equal to 22 would result in a prediction of failure of an on-road driving test. This cut-off score is based on a small sample however (n=19), and prior to adoption of a cut-off score, repeating this aspect of the study with a much larger sample is recommended. Using a forward stepwise logistic regression model, MMSE score was found to be a significant predictor of the final on-road result, with 71.4% of subjects correctly predicted to pass and 83.3% correctly predicted to fail. With regard to the neuropsychological tests, with the exception of the Judgement of Line Orientation Test (Benton et al., 1983) performance was generally poor relative to age norms. None of the neuropsychological test scores were significantly associated with the final on-road result, nor was the neuropsychologist's prediction of driving performance found to be a significant predictor of the final on-road result. Seven out of the 19 (36.8%) subjects passed the on-road assessment, a success rate lower than in the acquired brain impairment study reported in Chapter 4. The mean total driving score was 60.76 percent, and in ten of the thirteen categories the percent correct scores were significantly correlated with the total driving score. Internal reliability analysis of the component percent correct scores showed a Cronbach's alpha of .82, indicating an internally reliable test. The final on-road result, the consensus rating by the expert judges, was significantly associated with the objective measure of total driving score, sharing 28.5% common variance.

Although all but one of the subjects in this study were still driving, and all wished to continue to drive, 12 subjects failed the on-road evaluation and were judged unsafe to drive. Conversely, seven subjects were rated as safe to drive within the test conditions, thus supporting the contention that a diagnosis of AD alone may be an inadequate criterion for determining inability to drive. Given the likely progression of disease, a judgement that an individual with AD is safe to drive is valid for a limited time only, and reassessment may be required.

In this study there was a low frequency of abnormal medical variables, and the doctor's prediction of on-road driving performance was not a significant predictor of the outcome measure. Thus reliance on a medical examination for the determination of fitness to drive in individuals with AD may not be justified except in those instances where medical factors other than the diagnosis of AD preclude or impact upon driving. Although the MMSE score was found to be associated with the final on-road result, in contrast to the acquired brain impairment study reported in Chapter 4, the overlap in MMSE scores between those subjects passing and those subjects failing the on-road driving evaluation suggested that the MMSE was not sufficient for effective individual prediction of driving performance. A ceiling effect may also exist for performance on the MMSE, such that individuals scoring highly on the MMSE might still be unsafe to drive. A ceiling effect may have been a factor in the absence of a relationship between MMSE and final on-road result in the acquired brain impairment study described in Chapter 4. The duration of disease was not related to the final result of the driving test, and basing predictions of driving safety on the duration of AD alone is not recommended. Neither the neuropsychological test scores nor the neuropsychologist's prediction of driving performance were associated with the final on-road result, suggesting that the neuropsychological evaluation used in this study was not a reliable means of determining driving competence in people with dementia. Additionally, the relatively small number of subjects in this study may have resulted in insufficient power to detect any predictive effect of neuropsychological tests for driving. Difficulty in recruiting elderly subjects or subjects with dementia for studies of driving ability has been reported elsewhere, and may reflect a feeling of insecurity among potential participants about their driving ability, leading to a failure to volunteer (Hunt et al., 1997).

The on-road test was reliable and internally consistent. The final rating of driving competence related strongly to the objective score of total driving actions, suggesting that the expert judges based their rating on their observation of subjects' performance of the required driving actions. The reliability of the on-road test, and the association between the expert rating and the objective correct driving actions score, together suggest that an on-road evaluation is a valid means of determining driving competence in people with AD. Despite the relatively small sample size, the common variance between the expert rating of driving performance (the final on-road result) and the driving percent correct score was 28%, higher than that reported in the study described in Chapter 4 (15%) which involved a larger sample of brain impaired drivers. This increase in the percentage of shared variance between final on-road result and total percent correct driving score in the Alzheimer's Disease study represents a small to medium effect size (Cohen, 1988). The higher common variance may be attributable to the increased standardization of the on-road driving test and the increased preciseness of scoring, by rating the components of a manoeuvre rather than the entire manoeuvre, against precise criteria.

In preference to a medical examination, MMSE or a neuropsychological examination, a standardized on-road driving evaluation is recommended for the determination of driver competence in individuals with AD. A road driving test is a reliable means of determining who should no longer be driving, without unnecessarily restricting the driving privileges of those who are safe to drive, such as the subjects in this study who were found to be safe drivers at the time of testing. Thus, for the examination of drivers with AD, competence based tests are required which are fair, cost effective and appropriate for experienced older drivers. An appropriate test is one that is standardized, does not discriminate against older drivers, distinguishes 'bad habit' driving errors from dangerous driving errors, and includes some complex traffic situations. A recent study reported that the occurrence of hazardous errors was found to discriminate between impaired drivers and age matched controls, and therefore it is recommended that hazardous errors be recorded during an open road driving test (Dobbs, Heller, & Schopflocher, 1998). The present study of the on-road driving behaviour of patients with dementia indicated that older drivers with a range of cognitive abilities can be safely and reliably evaluated by a road test, with validity equal to that of driver licence tests.

However, given the large implications for both costs and service provision inherent in the on-road testing of all drivers with AD, the development of a screening protocol is urgently required to identify drivers at risk. Positive cases could then undergo further assessment. Recent studies suggest that screening procedures for drivers with AD or other forms of dementia should include visual attention measures, such as the Useful Field of View (Ball, 1997), visual search tasks (Duchek et al., 1998), a Traffic Sign Naming test (Carr et al., 1998), or on the basis of this study, the MMSE. Screening could be conducted by licensing agencies at the time of licence renewal, or by physicians or other health professionals. Screening by licensing agencies might be more effective if the time period between licence renewals was decreased, particularly for older drivers, as proposed by Waller (1988). Ideally, drivers who perform poorly on the screening protocol could then be referred for assessment of actual driving behaviour during an on-road driving test. The appropriate agency to conduct the on-road driving assessment is unclear and requires further consideration. It is likely that driver licensing agencies will not have sufficient resources to conduct large numbers of on-road driving tests. Useful information can also be obtained from family members or caregivers, as part of the screening process. This may include any incidences of getting lost, perplexity while driving, or requiring prompts from passengers or other motorists. The introduction of restrictions on driving for individuals with AD, such as driving in daylight only, or within a certain distance of home, has been suggested as a means of implementing a graduated driving reduction program. One problem with this approach is that there is no evidence that a driver with AD is any safer driving near their home or on familiar roads, than they are elsewhere. Restricted licences cannot be recommended on the basis of empirical findings.

The regular review of drivers with AD is essential. Six months may be an appropriate time frame, unless an increase in disease severity indicates the need for earlier review. If assessment demonstrates that driving should be ceased, the patient and family should be involved in discussion of alternatives to driving, such as assistance from family or friends, or community transport options, so that activities may be continued. The provision of counselling about lifestyle changes and future planning of transportation may be critical to compliance as well as to psychological wellbeing of the patient, as driving cessation may be associated with depressive symptoms.

7.7 Recommendations for Assessment of Driving Competence and Directions for Future Research

The research described in the preceding chapters investigated aspects of the process of determining driving competence in individuals with brain impairment. The impetus for this research came from questions arising from clinical practice, and the studies described are clinical in nature. The subjects included in the studies detailed in Chapters 3, 4 and 6 were clients of a driver assessment program at a rehabilitation facility. All subjects wished to resume or continue driving. Although each subject participated in the research with full and informed consent, their individual goals were not research related, but rather were focused on the resumption of driving.

The first aim of this research was to examine two methods of off-road assessment of driving competence, specifically medical assessment and neuropsychological assessment, with regard to their relationship to the outcome measure of on-road driving ability, as rated by two 'expert judges'. Secondly, the reliability of on-road assessment was examined, together with the nature of driving errors incurred by different subject groups. The effects of increasing the standardization of the on-road driving test were investigated. In the retrospective audit study described in Chapter 3, non-standardized driving routes were used. In the prospective study of drivers with acquired brain impairment, described in Chapter 4, each subject underwent driving assessment on one of four standardized routes. Unfortunately, data regarding the route on which subjects were tested were not available, and hence it was not possible to examine for the variance contributed by particular driving test routes. The study of drivers with AD, described in Chapter 6, utilised one driving test route that had been standardized for the traffic density, driving manoeuvres required and degree of difficulty. Reliability analysis indicated that this driving test was a reliable and consistent measure. Moreover, the increase in the standardization of the driving test route was associated with higher common variance between the expert judges' rating of driving performance and the objective driving error scores. It can therefore be concluded that the driving test route and the content of the driving test, in terms of the driving manoeuvres required, do make a contribution to the variance. Standardization of the driving test is a means of reducing extraneous variance. It is recommended that in future driving assessment tests be standardized in terms of route, traffic density and complexity of driving manoeuvres. During the course of the studies described, there were no crashes or major safety problems, and so it may be concluded that the on-road assessment of driving skills for people with brain impairment is not overly dangerous.

The results of these studies will be discussed with reference to two categories of subjects: those with acquired brain impairment, such as TBI and CVA, and those with progressive brain impairment, such as AD. From the results of these studies it may be concluded that neither a medical assessment, a neuropsychological assessment nor the MMSE can reliably predict on-road driving performance at an individual level, for either subject category. A standardized on-road driving assessment has been demonstrated with both subject categories to be consistent, reliable, and at least as valid as a learner driver test.

7.7.1 Individuals with Acquired Brain Impairment

In the study of drivers with acquired brain impairment described in Chapter 4, approximately half the subjects passed an on-road driving assessment. An 'expert model' of prediction of on-road driving performance was developed from logistic regression analysis of off-road variables. The variables diagnosis, duration of diagnosis, the medical variable finger/nose coordination, and three neuropsychological variables, the Judgement of Line Orientation Test, Trail Making Test B and Block Design, were identified as significant predictors of the final on-road result, independent of other variables. Although this model correctly classified 78% of subjects, the concomitant incorrect classification rates may be too high to allow the recommendation of the use of these off-road criteria for the individual determination of driving competence in people with acquired brain impairment. The 'expert model' variables may however be useful as off-road screening measures. For example, all driving candidates could be administered a driving test, but on the basis of the on-road driving performance predicted by the 'expert model', those candidates thought to be at risk of unsafe driving could commence their driving test on a closed course, with clearly unsafe, incompetent drivers completing assessment at that point, rather than endangering other traffic.

It is noteworthy that the variable MMSE score was not included as part of this 'expert model'. Although the MMSE score was correlated with the final on-road result when an outlier score was excluded from the analysis, it was not a significant predictor of the outcome measure in the logistic regression analysis. Additionally, the overlap in MMSE scores between those subjects who passed and those who failed demonstrates the inadequate sensitivity and specificity of the MMSE as a predictor of driving competence in individuals with acquired brain impairment. Although the variables diagnosis, finger-nose coordination, and the three neuropsychological test scores, were included in the 'expert model', neither the doctor's prediction of driving performance nor the neuropsychologist's prediction of driving performance were significant predictors of the final on-road result. These results suggest that neither a medical model nor a psychological test based model of driving are sufficiently comprehensive. Driving is a complex functional behaviour, and thus a behavioural model of driving may be most appropriate. However, it is difficult to cognitively model simple behaviours, and likely to be very difficult to cognitively model complex behaviours such as driving.

With regard to the on-road driving examination of subjects with acquired brain impairment, a significant association between the expert judges' rating of driving performance and the objective error scores was detected. However, both total driving error score and the number of instructor interventions were found to be predictive of the final on-road result. This finding suggests that the need for direct intervention by the instructor had an additional influence on the judges' overall rating of driving performance, separate to that of the number of driving errors. The recording of hazardous errors committed during driving assessment is recommended.

As previously discussed, a methodological weakness of the study of subjects with acquired brain impairment was that four different driving routes were used for the on-road driving assessments. Records of the driving test routes employed for each subject were not retained, and so the level of variance contributed by the driving test route could not be examined. A further methodological weakness, common to other studies that have investigated on-road driving ability, is that the criterion validity of the on-road driving test requires further research. Criterion measures other than post-assessment accident rate require exploration. As crashes are statistically rare events, the crash rate following assessment is not likely to be a useful measure for providing an operational definition of safe driving. An alternative to investigating a relationship between a dichotomous pass/fail outcome on a driving test and subsequent driving record, might be to grade driving test performance on a seven point scale for example, and examine for a relationship between test grade and subsequent driving record of crashes and violations. Another means of validating an on-road driving assessment might be to include normal control subjects, a high proportion of whom could be expected to pass the driving test. A similar approach was used in the development of the driving test utilised in the study described in Chapter 6, and discussed further below. Finally, the driving record and driving exposure prior to brain impairment should be investigated further as predictors of driving performance after brain impairment.

On the basis of the best available evidence, a standardized on-road driving assessment is recommended for determining the driving competence of individuals with acquired brain impairment. The driving assessment should examine not only basic component skills, but also complex executive skills, related to the tactical and strategic levels of driving described in Michon's model of driving, such as those required in traffic or at complex intersections (Michon, 1979).

7.7.2 Individuals with Progressive Brain Impairment

As described in Chapter 5, a survey of community based aged care assessment teams, with clients requiring driver assessment, showed that the determination of driving competence was typically a medically based procedure, and that less than half of the assessment teams used an on-road driving test. However from the results of the study of drivers with acquired brain impairment described in Chapter 4, in which medical assessment was not found to be associated with the reliable prediction of on-road driving competence, it was questionable whether the assessment of drivers with progressive brain impairment should be medically based. An investigation of assessment methods for drivers with AD, described in Chapter 6, showed that the doctor's prediction of driving competence was not associated with the rating of driving performance on a standardized on-road driving test. Moreover, neither neuropsychological test scores nor the neuropsychologist's prediction of driving competence were associated with driving performance. In contrast to the clinical practice of Aged Care Assessment Teams reported in Chapter 5, for whom the determination of fitness to drive was predominantly a medically based decision, findings from the AD driver study suggest that neither medical assessment nor neuropsychological assessment can be recommended as sole methods for determination of driving competence. MMSE score was found in the AD driver study to be predictive of driving performance, albeit with insufficient precision for individual decisions regarding driving competence. This result contrasts with the failure to find a significant association between MMSE and final on-road result in the acquired brain impairment study, even though the acquired brain impairment group was substantially larger. It is noteworthy that 63% of the AD subjects failed the on-road driving test, even though they were still driving. Conversely, 37% of subjects passed the on-road driving test, suggesting that a diagnosis of AD alone is not sufficient criterion for the cessation of driving. An on-road driving assessment is recommended as the optimal approach to determining driving competence in drivers with progressive cognitive impairment.

Drivers with probable AD or other progressive dementias differ from drivers with acquired brain impairment in several respects. Firstly, as their condition is progressive, a deterioration in driving competence can realistically be anticipated. Secondly, some drivers with early dementia and consequent deterioration in driving skills may not yet have been diagnosed with dementia, and may not be aware of their declining driving performance.

Furthermore, such individuals may not have come to the attention of relevant health professionals. A recommendation of on-road driver assessment for all individuals with AD or related disorders would not be sufficient to identify all drivers at risk of unsafe driving. This is because many drivers with early dementia may not yet have been diagnosed, and thus may not yet be in the care of appropriate health professionals able to monitor their driving competence. Unsafe and incompetent driving behaviour may therefore go undetected by the relevant authorities. People with mild cognitive impairment are unlikely to present to a specialist centre for driving assessment, although they may already be unsafe to drive. It may therefore be useful to screen drivers in other settings, such as at licence renewal. Different settings will require different screening measures because the prevalence of the index condition, which is inability to drive safely will vary. In the specialist dementia clinic, where the prevalence of dementia related driving incompetence is likely to be greater, highly specific tests with low false positive rates, and moderate sensitivity, would be especially useful when results are positive (Baldessarini, Finklestein, & Arana, 1983). Conversely, highly sensitive tests with low false negative rates and moderate specificity are powerful when the results are negative and the prevalence of incompetent driving is low, such as in a screening program conducted at licence renewal.

In the AD driver study, the MMSE score was found to be a significant predictor of on-road driving performance, with 71% of subjects correctly predicted to pass and 83% of subjects correctly predicted to fail. The MMSE test may be useful as a screening measure in a dementia clinic setting, where a high true negative rate is desirable. Drivers identified as 'at risk' by the MMSE test could then undergo further on-road driving testing to determine driving competence. In terms of how 'at risk' might be defined in relation to MMSE score, data from the 19 subjects detailed in Chapter 6 suggest that a cut-off score of 22 would result in the fewest false positive and false negative results, with a score greater than 22 consistent with the likelihood of passing an on-road driving test, and a score of less than or equal to 22 suggestive of failure of an on-road driving test. In the licence renewal setting, there are constraints regarding the type of testing possible, the time available, the number of individuals requiring testing and the personnel available to administer the tests. In this setting a brief screening test with high sensitivity is desirable. The Traffic Signs Naming Test, discussed by Carr and colleagues (Carr et al., 1998) may be useful in this setting and should be further investigated for this purpose.

The standardized driving test employed in the Alzheimer's Disease study described in Chapter 6 was based on a learner driver test for which reliability analyses had been conducted with groups of both young learner drivers and older experienced drivers, and which had previously been partially validated through the administration of the test to normal, non -brain impaired drivers. The use of this standardized, reliable driving test was associated with an increase in common variance between the expert rating of driving performance and driving score. The validation of on-road driving tests for drivers with brain impairment by administration to normal controls drivers appears promising and worthy of further research attention.

To reiterate, some issues identified for further research from the above studies include:

1. Establishing the criterion validity of the on-road driving test. Suggested methods include administering the driving test to normal control drivers; examining past driving experience and past driving record of drivers with brain impairment as

predictors of driving test performance; rating driving in an on-road driving test on a continuous rather than dichotomous scale, and then examining for a relationship between test driving performance and subsequent driving record.

2. The development of screening protocols for drivers with dementia. These are likely to differ according to the setting and the incidence of dementia, for example a specialist dementia clinic and a driving licence renewal centre.

3. The identification of risk factors for unsafe driving by drivers with brain impairment, such as occurrence of hazardous errors during an on-road driving test.

Several important findings concerning the assessment of driving competence in individuals with brain impairment are evident from the studies described in this thesis. With regard to the central research question concerning the most appropriate method for determining who should be advised to cease driving following brain impairment, a standardized on-road driving assessment is recommended. The driving assessment should examine not only basic component skills, but also complex executive skills, which are required for safe participation in traffic. The reliability of the standardized on-road driving test, and the association found between the expert ratings of driving performance and the objective score of correct driving actions, which strengthened with increased standardization of the driving test, indicate that a standardized on-road driving evaluation is a valid means of determining driving competence for people with both acquired and progressive brain impairment. The driving behaviours sampled by the driving test must be sufficient in terms of duration and complexity to allow the observation of several driving situations and manoeuvres. The test should not be seen as discriminating against disabled drivers, and hence should not be so difficult as to contrast unfavourably with ordinary licence testing. The driving test should, however, remain sufficiently challenging to allow the demonstration of any cognitive and perceptual sequelae of brain impairment incompatible with safe traffic participation, and the elimination of unacceptable levels of risk. Given the finding that the need for intervention by the driving instructor to prevent danger had an influence on the expert judges' rating of driving performance, the driving test should include the recording of hazardous errors.

Neither medical nor neuropsychological assessment were well correlated with on-road driving performance, and hence, used alone, these approaches cannot be recommended. The MMSE was found to be a significant predictor of on-road driving performance for drivers with AD, with a cut-off score of 22 resulting in the fewest false positive and false negative errors. Although using the MMSE for individual determination of driving competence cannot be supported because of insufficient sensitivity, this test shows promise for use as a screening tool for the identification of at-risk drivers within a setting such as a dementia clinic. The 'expert model' of prediction of on-road driving performance for drivers with acquired brain impairment, described in Chapter 4, is similarly promising for off-road screening of drivers with non-progressive brain impairment.

The overall goal for providers of rehabilitation services to people with brain impairment who wish to resume driving should be the provision of a valid, reliable assessment of driving competence. Currently this is best achieved by observing an adequate sample of driving behaviour in real traffic, over a standardized route, with predetermined driving manoeuvres. Driving performance should be evaluated according to pre-defined criteria, and the judgement regarding competence should be closely related to this objective measure. These criteria are recommended as the minimum requirements for the assessment of driving competence in people with brain impairment.

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APPENDIX 1

Occupational Therapist Checklist for Driving Test

ON-ROAD CHECKLIST

NAME: DATE: TIME:

ASSESSOR: INSTRUCTOR:

DRIVING ROUTE: ASSESSMENT NO:

CONDITIONS:

BEFORE STARTING SEAT ADJUSTMENT	MIRROR ADJUSTMENT	SEATBELT

STARTING ENGINE START	BRAKE APPLICATION	GEAR SELECTION	OBSERVATION

DRIVING PROCEDURE MIRROR USE	BLINDSPOT CHECK	SIGNALLING

OBSERVATION	SPEED CONTROL	PLANNING & JUDGEMENT	VEHICLE POSITIONING	REACTION TIME

INSTRUCTOR; BRAKE WHEEL	3 POINT TURN EMERGENCY STOP	REVERSE PARK 1 REVERSE PARK 2

DRIVING PROCEDURE MIRROR USE	BLINDSPOT CHECK	SIGNALLING

OBSERVATION	SPEED CONTROL	PLANNING & JUDGEMENT	VEHICLE POSITIONING	REACTION TIME

	3 POINT TURN EMERGENCY STOP	REVERSE PARK 1 REVERSE PARK 2

APPENDIX 2

Standardized Medical Assessment Form

MEDICAL ASSESSMENT FOR DRIVER ASSESSMENT PROGRAM

PATIENT HISTORY:

Name: ______________________________ MRN: ______________

Age: ________ years Sex: M / F Dominant hand: L / R

Diagnosis (if CVA, note underlying pathology and right or left hemispheric): ______________________________

____

______________________________ Date of Diagnosis: ___/___/___

Fitting? Yes / No ______________________________

Medications: ______________________________

____

Driving prior to onset of disability? Yes / No

____

Driving after onset of disability? Yes / No

____

Motor vehicle accidents since onset of disability? Yes / No

If yes, Number: ______ Details: ______________________________

____

PHYSICAL EXAMINATION:

Mini Mental State Examination Score: /30

Visual Attention	[ ] Normal	[ ] Abnormal
Sensory Attention	[ ] Normal	[ ] Abnormal
Visual Fields	[ ] Normal	[ ] Abnormal
Tone/Reflexes	[ ] Normal	[ ] Abnormal
Clonus	[ ] Normal	[ ] Abnormal
Power	[ ] Normal	[ ] Abnormal
Sensation (including proprioception)	[ ] Normal	[ ] Abnormal
Co-ordination: finger/nose	[ ] Normal	[ ] Abnormal
supination/pronation	[ ] Normal	[ ] Abnormal
toe tap	[ ] Normal	[ ] Abnormal
heel/toewalk	[ ] Normal	[ ] Abnormal
Ocular Motility Diplopia	[ ] Present	[ ] Absent
Ocular Motility Nystagmus	[ ] Present	[ ] Absent

Visual Acuity (corrected): Left _____ Right _____ Both _____

CONCLUSION:

Contraindication to driving as per RTA Guidelines? Yes/No

If Yes, detail contraindication: ______________________________

____

If No, do you believe patient will be a:

[ ] safe driver [ ] unsafe driver [ ] borderline driver

Name (please print): ______________________________

Signature: ______________________ Date: ____/____/____

BINDING MARGIN - NO WRITING

ON TRIAL JULY - SEPT 1991

APPENDIX 3

RTA Medical Report Form

Medical Report

Roads and Traffic Authority NSW

RTA

Any fee charged for the examination is payable by the licence holder and not the RTA.

Always complete questions 1 and 2 then complete the relevant questions (3 to 12) by ticking the box to indicate disorders suffered by the patient. (N = Normal ABN = Abnormal)

Please comment on any abnormal findings and disabilities likely to affect driving.

1 How long have you treated this patient? Years ______ Months ______

2 **History** (brief, relevant, especially loss of consciousness, awareness, giddiness)

______

______

______

3 **Vision**

Are glasses/ lenses worn (distance) . . . . No ☐ Yes ☐

Visual acuity	R	L	Together
Uncorrected	6/___	6/___	6/___
With glasses	6/___	6/___	6/___

- Fields of vision . . . . . N ☐ ABN ☐
- Cataracts . . . . . No ☐ Yes ☐
- Glaucoma . . . . . No ☐ Yes ☐
- Other disorder . . . . . No ☐ Yes ☐

4 **Cardio-Vascular Disorder**

- Heart (incl. angina) . . . . . N ☐ ABN ☐
- Blood pressure . . . . . ______
- Cardiac decompensation . . . . . No ☐ Yes ☐
- Cerebral vessels . . . . . N ☐ ABN ☐
- Other vessels . . . . . N ☐ ABN ☐

5 **Diabetes**

- Controlled by: diet ☐ oral ☐ insulin ☐
- Significant hypo. periods? . . . . . No ☐ Yes ☐
- Well controlled? . . . . . No ☐ Yes ☐
- Familiar with hypos & control? . . . . . No ☐ Yes ☐

6 **Epilepsy**

- Type ______
- Cause (if known) ______
- Date of onset ______
- Date of last seizure ______
- Attacks occur whilst awake ☐ asleep ☐

If last seizure within 2 years, describe:

- Was there loss of consciousness? . . . . . No ☐ Yes ☐
- Was there loss of awareness? . . . . . No ☐ Yes ☐
- EEG . . . . . N ☐ ABN ☐
- Any contributing factor (omission, or change of treatment, intercurrent illness etc)? ______

7 **Nervous System Disorder**

- Diagnosis ______
- Consciouness/Awareness . . . . . N ☐ ABN ☐
- Attention (confusion, response) . . . . . N ☐ ABN ☐
- Intellect (memory, retardation) . . . . . N ☐ ABN ☐
- Perception (delusions, hallucinations) . . . . . N ☐ ABN ☐
- Personality (aggression, emotion) . . . . . N ☐ ABN ☐
- Reaction time . . . . . N ☐ ABN ☐
- Equilibrium (balance, vertigo) . . . . . N ☐ ABN ☐
- Paralysis, paresis . . . . . No ☐ Yes ☐
- Muscular co-ordination . . . . . N ☐ ABN ☐
- Psych. Hospital (last 2 years) . . . . . No ☐ Yes ☐
- Sleep Apnoea . . . . . No ☐ Yes ☐
- Medication, incl. effect on driving ______

8 **Musculo-Skeletal Disorder**

- Diagnosis ______
- Dysfunction likely to affect driving ______

9 **Drugs likely to affect driving**

- Prescribed drugs . . . . . No ☐ Yes ☐
- Ethanol (signs of abuse) . . . . . No ☐ Yes ☐
- Non-prescribed drugs . . . . . No ☐ Yes ☐

Comments (Please comment on abnormal findings)

10 **Additional Comments** (including alcohol abuse or other medical condition which may affect driving) ______

______

11 Do you consider the person fit for the licence applied for? Fit ☐ Unfit ☐ If unfit, state medical disorder ______

12 Do you consider the licence holder fit for a less demanding licence? No ☐ Yes ☐ Licence Class ______

13 Sign the Medical Certificate before you send the report to the RTA.

Class of Licence
Licence Number
Licence Expires
Date of this letter

Reason for Medical

Instructions to Licence Holders

To confirm you are fit to drive, you need to have a medical examination for the reason shown at the top of this letter.

If the words "driving test" appear next to the reason, you need to take a driving test after you pass the medical.

Please complete the "Medical Report Authorisation" below for your doctor to carry out the examination.

The doctor should complete the Doctor's Certification, on the right, and the Medical Report on the reverse.

The doctor will either send the form directly to the RTA or hand the completed form to you to post or take to a motor registry.

Any fees for this and other medical examinations are your responsibility.

Medical Report Authorisation

I authorise the doctor named below to examine me and if necessary, forward this report to the Medical Officer, RTA. I also authorise the Medical Officer to approach the doctor named below, at my expense, should further clinical information be required.

Doctor's name ____________________

Licence holder's signature

____

Date ____________________

Instructions to Examining Doctor

Please complete the Doctor's Certification and the Medical Report (on the reverse), paying particular attention to the medical condition stated above.

If you consider the licence holder **unfit** to hold a licence or requires further assessment, send the completed form to: Medical Officer, Roads and Traffic Authority NSW, Box 28 GPO, Sydney 2001.

Otherwise hand the form to the licence holder who can deliver it to a motor registry.

Doctor's Certification

I certify that I have examined the above licence holder who is considered by me to be:

- ☐ Medically FIT to hold the Class of Licence indicated above with normal review
- ☐ Medically FIT with recommended licence condition ____________________
- ☐ Medically FIT to hold the Class of Licence indicated above and there is no need for further review
- ☐ Medically FIT to hold the Class of Licence indicated above with a restriction to drive no more than -
  - ☐ 10 kilometres from their residence
  - ☐ 20 kilometres from their residence
  - ☐ 50 kilometres from their residence
- ☐ Referred case history to Medical Officer, RTA or appropriate specialist for assessment
- ☐ Medically **UNFIT** to hold a licence

Doctor's Name ____________________
block letters please

Address ____________________

____

Telephone Number ____________________

Doctor's Signature

____

Date ____________________

RTA 1008 (9/91)
Cat No 45070085

APPENDIX 4

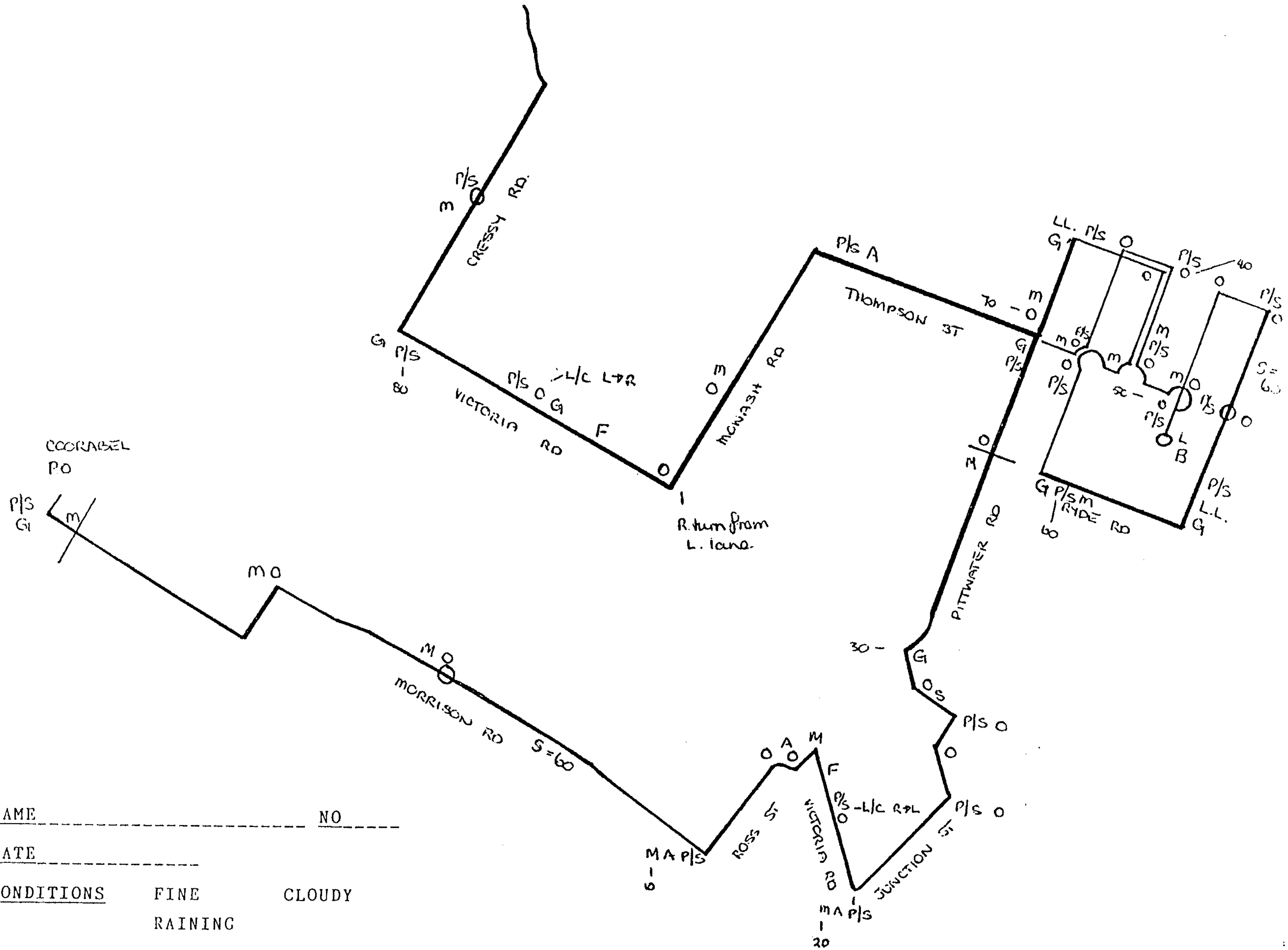
Route for Standardized Road Test and Scoring Protocol

Standardized On-Road Assessment Score Sheet
Name: Number:

1 PO	2 P/S	3 G	4 M	5 M
6 O	7 M	8 O	9 S	10 M
11 A	12 P/S	13 O	14 A	15 O
16 M	17 F	18 P/S	19 O	20 M
21 A	22 P/S	23 P/S	24 O	25 O
26 P/S	27 O	28 S	29 O	30 G
31 M	32 O	33 P/S	34 G	35 M
36 O	37 P/S	38 0	39 P/S	40 O
41 M	42 P/S	43 O	44 M	45 O
46 P/S	47 L	48 B	49 P/S	50 O
51 O	52 P/S	53 O	54 5	55 O
56 P/S	57 LL	58 G	59 M	60 P/S
61 G	62 P/S	63 O	64 M	65 O
66 P/S	67 LL	68 G	69 M	70 O
71 A	72 P/S	73 M	74 O	75 O
76 F	77 G	78 O	79 P/S	80 P/S
81 G	82 M	83 P/S	84 A	85 P/S
86 O	87 M	88 P/S	89 O	90 F
91 G	92 M	93 O	94 M	95 O
96 S	97 M	98 O	99 O	100 P/S

101 O	102 P/S	103 M	104 O	105 M
106 A	107 P/S	108 O	109 S	110 M
111 O	112 P/S	113 O	114 G	115 O
116 P/S	117 P/S	118 G	119 F	120 M
121 O	122 P/S	123 O	124 G	125 M
126 O	127 S	128 S	129 O	130 F
131 B	132 P/S	133 O	134 P/S	135 S
136 O	137 P/S	138 SD		

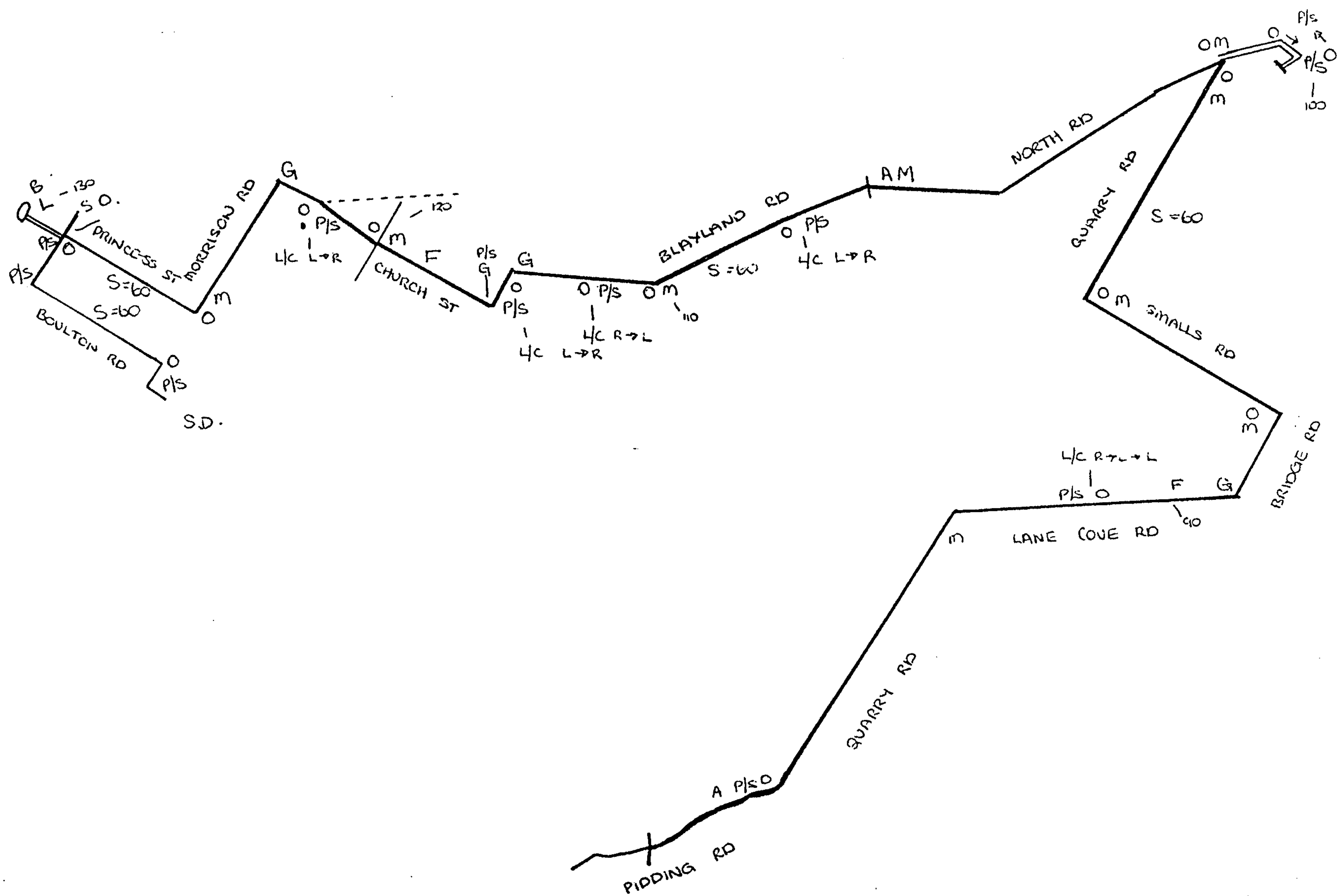
Key: P/S = Path and Speed
G = Gap acceptance
LL = Limit Line
M = Mirror Check
A = Approach
O = Observation
P = Path
S = Speed
PO = Pre-operation check
SD = Shut Down



NAME ______________________ NO _____

DATE ______________

CONDITIONS FINE CLOUDY RAINING


PRINCESS ST
S=60
BOULTON RD
S=60
S.D.
MORRISON RD
CHURCH ST
BLAYLAND RD
S=60
4C L→R
4C R→L
4C L→R
AM
NORTH RD
QUARRY RD
S=60
SMALLS RD
BRIDGE RD
LANE COVE RD
L/C R→L→L
QUARRY RD
PIDDING RD

APPENDIX 5

MMSE Protocol

DELEGATION OF NURSING HOME ADMISSION APPROVAL, PILOT PROJECT

MINI-MENTAL STATE EXAMINATION

Date ______________

SURNAME: ______________ GIVEN NAMES: ______________ UNIT NUMBER: ______________

(Add points for each correct response)

			Score	Points
Orientation				
1.	What is the	Year?	—	1
		Season?	—	1
		Date?	—	1
		Day?	—	1
		Month?	—	1
2.	Where are we?	State?	—	1
		Suburb	—	1
		City?	—	1
		Hospital? If at home, house number and street	—	1
		Floor?	—	1
Registration				
3	Name three objects, taking one second to say each. Then ask the patient all three after you have said them. Give one point for each correct answer. Repeat the answers until patient learns all three.		—	3
Attention				
4.	Serial sevens. Give one point for each correct answer. Stop after five answers. Alternate: Spell WORLD backwards.		—	5
Recall				
5.	Ask for names of three objects learned in Q.3. Give one point for each correct answer.		—	3
Language				
6.	Point to a pencil and watch. Have the patient name them as you point.		—	2
7.	Have the patient repeat 'No ifs and/or buts'.		—	1
8.	Have the patient follow a three-stage command: 'Take this paper in your right hand. Fold the paper in half. Put the paper on the floor.'		—	3
9.	Have the patient read and obey the following: 'CLOSE YOUR EYES'. (See back of sheet)		—	1
10.	Have the patient write a sentence of his or her choice in the space on back of sheet. (The sentence should contain a subject and an object, and should make sense. Ignore spelling errors when scoring.)		—	1
11	Have the patient copy the design on back of sheet below the design. (Give one point if all sides and angles are preserved and if the intersecting sides form a quadrangle.)		—	1
				= Total 30

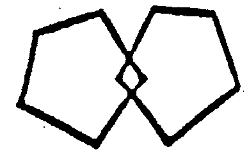
NOTE: Level of consciousness

Alert   Drowsy   Stupor   Coma

Estimate the patient's level of sensorium along a continuum, from alert on the left to coma on the right.

Signature ______________

CLOSE YOUR EYES



INSTRUCTIONS FOR ADMINISTRATION OF THE MINI-MENTAL STATE EXAMINATION

ORIENTATION

(1) Ask for the date. Then ask specifically for parts omitted, e.g. "Can you also tell me what season it is?" One point for each correct.

(2) Ask in turn "Can you tell me the name of this hospital?" (State, City, Suburb, etc.) One point for each correct.

REGISTRATION

Ask the patient if you may test his memory. Then say the names of 3 unrelated objects, clearly and slowly, about one second for each. After you have said all 3, ask him to repeat them. This first repetition determines his score (0-3) but keep saying them until he can repeat all 3, up to 6 trials. If he does not eventually learn all 3, recall cannot be meaningfully tested.

ATTENTION AND CALCULATION

Ask the patient to begin with 100 and count backwards by 7. Stop after 5 subtractions (93, 86, 79, 72, 65). Score the total number of correct answers.

If the patient cannot or will not perform this task, ask him to spell the word "WORLD" backwards. The score is the number of letters in correct order, e.g. DLROW – 5, DLORW – 3.

RECALL

Ask the patient if he can recall the 3 words you previously asked him to remember. Score 0-3.

LANGUAGE

Naming: Show the patient a wrist watch and ask him what it is. Repeat for pencil. Score 0-2.

Repetition: Ask the patient to repeat the sentence to you. Allow only one trial. Score 0 or 1.

3 Stage Command: Give the patient a piece of plain blank paper and repeat the command. Score 1 point for each part correctly executed.

Reading: Show the patient the sentence "Close your eyes" printed above. Ask him to read it and do what it says. Score 1 point only if he actually closes his eyes.

Writing: In the space at the top of this page ask him to write a sentence. Do not dictate a sentence, it is to be written spontaneously. It must contain a subject and verb and be sensible. Correct grammar and punctuation are not necessary.

Copying: Ask the patient to copy the design of intersecting pentagons drawn above. All 10 angles must be present and 2 must intersect to score 1 point. Tremor and rotation are ignored.

ERRATUM

In Chapter 6, which considered prediction and assessment of driving performance for drivers with Alzheimer's Disease, the neuropsychological test data reported included scores on Trail Making Test B . It was reported that the range of scores on Trail Making Test B for all subjects was 0 to 648 seconds, with a mean performance of 324.37 seconds and a standard deviation of 214.42 seconds. Re-examination of the raw test data indicates that two of the 19 subjects, were given a score of 0 for Trail Making Test B, after being unable to complete any of the test. However, giving these two subjects a score of 0 after they were unable to complete any of the test is potentially misleading and difficult to interpret, particularly since a lower score is generally associated with a better performance. Since there were only two subjects in this situation, it may be preferable to have scored those subjects unable to complete any of the Trail Making Test B as 'missing value' or 'missing data', and subsequently exclude them from data analysis involving Trail Making Test B.

Therefore, if the two subjects who were unable to complete any of Trail Making Test B are coded as Missing Value for the test, re-analysis of the data shows the following:

1. Trail Making Test B (n=17; missing value=2)
   Mean =362.53 seconds
   Standard deviation = 192.41 seconds
   Minimum score = 112 seconds
   Maximum score = 648 seconds

2. Association between Trail Making Test B performance and neuropsychologist's prediction of driving performance (n=17)
   Spearman's r = .696, p=.002.
   Therefore, following exclusion of the two subjects with missing data, a statistically significant association between Trail Making Test B performance and neuropsychologist's prediction of driving performance was found. With this result, all neuropsychology test scores were significantly associated with the neuropsychologist's prediction of on-road performance, in contrast to the previously reported finding of all neuropsychology test scores except Trail Making Test B, being significantly associated with the neuropsychologist's prediction.

3. Association between Trail Making Test B score and total driving score (n=17)
   Pearson's r = -.535, p=.027.
   With this result, the number of neuropsychological tests significantly associated with the total driving score would increase to two, with Block Design being the other test.

4. Association between Trail Making Test B score and final on-road result (n=17)
   Spearman's r = .122, p=.641.
   As previously, no association between neuropsychological test scores and final on-road result was found.