damage. In view of these findings the association between the SDSA subtests (Compass Cards, Road Sign Recognition and Dot Cancellation) and known measures of executive abilities, attention, visuospatial skills and memory would explain the SDSA's predictive validity for driving (Nouri et al., 1987; Nouri and Lincoln, 1992).

This study set out to establish the nature of cognitive abilities tested by the Stroke Drivers Screening Assessment. It has determined that the SDSA is predominantly a measure of executive abilities and attention, which incorporates visuospatial abilities and memory. The fact that these skills are known determinants of safe and unsafe driving in people with brain damage supports these findings and confirms that the SDSA is an important diagnostic measure of driving ability in stroke patients.

Chapter 3

PREDICTIVE VALIDITY OF THE STROKE DRIVERS SCREENING ASSESSMENT FOR PATIENTS WITH AN ACQUIRED NEUROLOGICAL DISABILITY (other than stroke).

3.1 Aim

To determine whether the SDSA, either alone or in conjunction with other cognitive tests, can be used to predict driving ability in people with an acquired neurological disability other than stroke.

3.2 Introduction

The assessment of patients who wish to resume or continue driving is often time consuming and complex. It is well recognised that is difficult to assess fitness to drive in patients with dementia (Lundberg et al., 1994; Odenheimer, 1993; O'Neill, 1992), Parkinson's disease (Dubinsky et al., 1995; Madeley et al., 1990), head injury (Brouwer and Withaar, 1997) and other neurological conditions. Physical impairment can usually be compensated for by providing car adaptations, though impairments such as visual field loss preclude driving. Many patients with neurological disability have cognitive impairments and it is these, which cannot be overcome and limit the person's fitness to drive.

The assessment of cognitive impairment in relation to driving ability is of recognised importance (McKenna, 1998, Simms, 1994, Simms and O'Toole, 1994) but there is little consistency between different centres in the procedures

that are used (Frye, 1995). There is also conflicting evidence about which cognitive impairments need to be assessed and which are predictive of driving outcome. Van Zomeren et al., (1987) reviewed the assessment of driving following brain damage and highlighted many problems with the procedures used. Some investigators demonstrated cognitive tests, which predict on-road driving performance (Engum et al., 1988; 1989; 1990; Fattal et al., 1998; Fitten et al., 1995; Johannsen et al., 1996; Lundqvist et al., 1997; Mazer et al.,1998; Odenheimer et al., 1994), others indicated that simulated evaluations also had value and considered aspects not assessed by the cognitive tests (Galski et al., 1997; Lundqvist et al., 1997, 2000).

Nouri (1994) developed a cognitive assessment, the Stroke Drivers Screening Assessment (SDSA), which was found to be predictive of on the road performance in stroke patients (Nouri et al., 1987). This was also shown to be a more accurate predictor of road test performance than the judgement of general practitioners or the DVLA (Nouri and Lincoln, 1993). This assessment was only validated on stroke patients. However, it may have a role in the assessment of fitness to drive in patients with other acquired neurological disabilities. The purpose of this study was to evaluate the predictive validity of the Stroke Drivers Screening Assessment in patients with a range of acquired neurological conditions.

3.3 Method

3.3.1 Subjects

Subjects were recruited from the waiting list for assessment at the Derby Regional Mobility Centre (DRMC). This includes patients referred for assessment by Motability, DVLA Medical Branch, Solicitors or by themselves and those advised to seek assessment by a medical consultant, GP, therapist or psychologist involved in their care. Onset or change in a medical condition, which may affect the individual's ability to drive safely, usually triggers the need for assessment. The waiting time is approximately three months. According to a medical form completed by the subject's GP, all had an acquired neurological disability other than stroke. Subjects were excluded according the criteria below.

Exclusion Criteria;

- live in excess of fifty miles radius of Nottingham or Derby
- no 'recent' driving experience i.e. more than two years break from driving
- novice i.e. less than two years driving experience
- history of previous stroke
- refused consent

3.3.2 Procedure

In addition to demographic details, a record was kept of the onset date of sudden onset conditions such as head injury or surgical procedures and of the date of diagnosis in chronic disabling conditions such as multiple sclerosis and Parkinson's disease. The number of years driving experience was recorded

together with 'time since driven' where stopping driving was as a direct result of the subject's diagnosis e.g. head injury. Subjects' occupation and whether or not this was driving related, was also recorded. This information was taken from records held by DRMC.

Subjects were initially contacted by letter (see Appendix 3.0) and asked if they would be willing to participate in a study to find out which factors affect a person's ability to drive. They were told that if they agreed to take part, the cost of their assessment at the DRMC would be met in full. Consenting subjects were visited at home by the researcher and assessed on a series of cognitive tests. Cognitive assessment was carried out before the driving assessment at the DRMC. This was to ensure the researcher was unbiased when carrying out the cognitive tests and to prevent subjects found 'unfit to drive' by the DRMC withdrawing from the study

3.3.3 Cognitive assessment

Patients were assessed on;

1. The Stroke Drivers Screening Assessment (SDSA) (Nouri and Lincoln 1994). Details of the SDSA are given in chapter 2.

The SDSA was supplemented by additional cognitive tests chosen to assess those cognitive problems (such as attentional deficits, memory and reasoning abilities) that are recognised as important features of the neurological disabilities represented in this study and which are thought to be measures of skills required for driving. Some of the cognitive tests had been used by researchers carrying out similar research (Smith, 1980) and some had been found to be predictive of driving

ability (Sivak et al., 1981). The tests were chosen following discussions with clinical psychologists, for their availability and ease of administration.

The supplementary cognitive assessments used were: -

2. Paced Auditory Serial Addition Test [PASAT] (Gronwell 1977; Gronwell and Sampson 1974).

The PASAT is a serial addition task selected to assess speed of information processing and sustained attention (Spreen and Strauss, 1991). It has been widely used to measure attentional disorders in people who have suffered traumatic brain injury (TBI); has been found sensitive to deficits in information processing ability (Ponsford and Kinsella 1992) and is considered useful in detecting subtle attentional deficits in mild brain damage (Lezak 1995).

In the version used in this study (NTBIS, 1998) subjects are given a tape recording of 61 numbers, from 1 to 9, presented randomly. They are instructed to add pairs of numbers, so that each number is added to the one immediately before. i.e. the first number is added to the second, the second to the third, the third to the fourth and so on. A repetition task is used at the beginning to check numeracy and subjects' ability to articulate numbers. A sheet of ten randomly selected numbers (Fig. 3.1), presented in a horizontal row, is placed before the subject. Subjects are then asked, " If I were to ask you to add 6 and 2, you would say ?, 2 and 7 ?,7 and 4 ?....." . At the same time, the researcher points to the corresponding numbers on the sample sheet. This continues across the row with the subjects adding consecutive numbers and giving a verbal response, until the researcher is confident that the subject can count and articulate numbers.

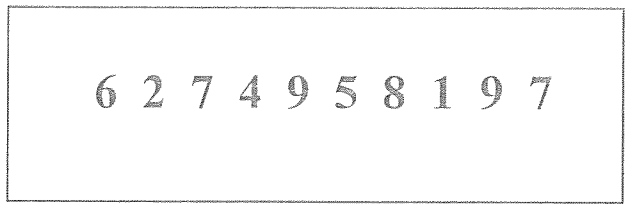


Fig. 3.1 Number sample from the PASAT

Subjects are then told. "This test requires you to add pairs of numbers together, just as you did before. However, this time the numbers will be called aloud, like this." The researcher then reads aloud the numbers on the sample sheet with a four-second time interval between each number. Subjects are instructed, "What I would like you to do is to add each new number to the one immediately before it, *not* to your answer. So for example, if I were to say '6', '2', you would say '8'. If I then said '7', you would say '9'; adding the '7' to the '2', not to the '8' which was your answer." The researcher checks to ensure the instructions have been understood before proceeding to the two practice trials. In the first (un-paced) practice, ten digits are read aloud by the researcher. In the second, a recording of ten digits is presented at four-second intervals. Subjects are told " This time the numbers have been recorded onto a tape. I would like you to add each new number to the one immediately before it, *not* to your answer". Subjects then complete the paced practice trial. A demonstration recording of the second practice trial is then played back to the subject, giving the right answers. The practice series are followed by two consecutive trials of 61 digits. The first is read

at four-second intervals, the second at two-second intervals. Subjects are asked to respond in the same way. The demands on information processing abilities are increased with the speed of presentation (Spreen and Strauss, 1991). Each trial is scored out of a possible sixty correct answers. To be correct responses must be made before presentation of the next stimulus.

Performance on the PASAT has been shown to decline with age (Brittain et al., 1991) and may be related to general intelligence and numerical ability in normal subjects (Egan, 1988). One weakness of the PASAT is the demand it places on fast speech responses which precludes the assessment of dysarthric or other speech impaired subjects (Weber, 1986). It was chosen as a measure of information processing ability and sustained attention and because of it's sensitivity to deficit in mild brain injured subjects.

3. The Stroop Neuropsychological Screening Test [SNST] (Trennery et al., 1989).

A detailed description of this test is given in Chapter 2.

The Stroop was chosen as a measure of selective attention, frontal lobe function and high level concentration (Shum et al., 1990). It appears to measure specific higher cognitive function - the ease with which a person can shift between verbal response modes to conform to changing demands. Subjects must suppress a habitual response in favour of an unusual one. The Stroop has been used in studies of psychiatric and brain damaged patients. It has been found to discriminate brain damaged subjects from their normal controls (Nehemkis and Lewinsohn, 1972), between brain damaged and psychiatric patients (Golden, 1976) and to be sensitive

to dementia severity (Koss et al., 1984). It was selected for use in this study because of its suitability for use among subjects with brain damage due to different causes.

4. Test of Motor Impersistence (Kertesz et al., 1985)

Motor Impersistence is the term introduced by Miller Fisher (1956) to describe the inability to sustain certain discrete voluntary motor acts on command. It is considered by Joynt and colleagues (1962) to be associated with advancing age, mental impairment and disorientation. Although most common in patients with damage to the right hemisphere or bilateral cortex (Kertesz et al., 1985), it can also be seen in patients with left hemisphere damage (Lezak, 1995). Inability to persevere may result from distractibility, when the patient's behaviour is distracted by something going on around them or from impaired self-control often associated with frontal lobe damage. It may present as a loss of interest, slowing down or giving up which is internally driven (Lezak 1995).

The Motor Impersistence test (Kertesz et al., 1985) comprises eleven subtests, originally derived from the neurological examination. These are:-

1) Eye Closure. Subjects are asked to close both eyes and keep them closed for 20 seconds.

2) Tongue protrusion. Subjects are asked to stick their tongue out for 20 seconds and keep it out. If the tongue recedes beyond the back of the bottom lip the trial is terminated.

3) Mouth opening. Subjects are asked to open their mouth for 20 seconds. If the teeth or lips close fully then the trial is terminated.

4) Right lateral gaze fixation. The subject is told to fixate for 20 seconds, on the examiner's finger held in the subject's right visual field, at 45 degrees from the plane between the examiner and patient midlines. The trial was terminated if the gaze deviated in either direction.

5) Left lateral gaze fixation. This is the same procedure as for 4 but to the opposite side.

6) Central gaze fixation. Subjects are asked to fix their gaze directly ahead. They are allowed to blink but must not avert the gaze for 20 seconds.

7) Head turning to the right. Subjects are required to identify which of their fingers, numbered 1-5, (where thumb =1) of their left hand are tapped by the administrator, whilst keeping the head turned in the opposite direction for 20 seconds

8) Head turning to the left. This is the same procedure as for 7 but to the opposite side.

9) Vocalisation. The subject is asked to take a deep breath and say "aah" as long as possible.

10) Hand grip. Subjects were asked to squeeze the researcher's index fingers as hard as they could and to keep squeezing for 20 seconds. In the event of unilateral weakness only the preferred hand was used.

11) Arm extension. Subjects were told to hold the arms out at shoulder height while closing the eyes and keeping them closed. The trial was not terminated if the eyes opened but the subject was asked to close them again. Downward arm drift

resulted in termination of the trial. In the event of unilateral weakness only the unaffected arm was used.

The test of Motor Impersistence was chosen as a short test of the inability to persevere as a result of distractibility or impaired self control associated with frontal lobe damage.

5. Adult Memory and Information Processing Battery (AMIPB) Form 2

The AMIPB (Coughlan and Hollows, 1985) is a battery of memory and information processing tasks. There are two versions, (Form 1 and Form 2) each comprising six tests, two 'verbal' memory tests (story recall and list learning) and two 'visual' memory tests (figure recall and design learning) and two tests of information processing, both of which involve cancellation tasks. Verbal and visual refer to the modality of presentation and do not infer exclusive processing in either verbal or visual memory systems. Form 2 was selected for use in this study, when subjects participating in a pilot study and who lived in the vicinity of Sheffield and Rotherham, were found to be familiar with Form 1.

The Story Recall test is designed to assess the immediate recall of verbal information and the amount retained after a delay. Subjects are read a short passage, which they are asked to recall immediately and after a period of 27-33 minutes. The test is derived from the Logical Memory passages of the WMS (Beddoe-Rees, 1970; Powell, 1979) but has a shorter delay (Coughlan and Hollows, 1985). The Figure Recall test assesses immediate and delayed recall of visual information. The subject has to copy a complex 2-D figure, then reproduce it immediately and after a 27-33 minute delay. This test is based on the Rey-

Osterrieth figure copy and recall, which has a 40-minute delay (Beddoe-Rees, 1970; Powell 1979). The Figure Recall test includes an immediate recall in addition to the copy, so that the percentage retained over time can be accurately assessed (Coughlan and Hollows, 1985).

The List Learning test assesses rote learning of verbal information and susceptibility to interference. The subject is read a list of 15 words at the rate of one word per 2 seconds, which he/she has then to recall. This is repeated over five trials. A new list of words is then presented once. After recalling the new list, the subject's susceptibility to interference is assessed by asking them to recall the original list. This is an adaptation of the Rey Auditory Learning Task (Rey, 1964; Lezak, 1995) but uses a slower rate of presentation.

In the Design Learning test the subject is asked to reproduce a small design over five consecutive trials. In each trial the design is shown for ten seconds and then removed. Interference is again tested by presenting the subject with a second design, then asking for recollection of the first one. This test was developed for the AMIPB as a visual modality equivalent of the List Learning task because no such task was available.

There are two Information Processing tasks, included as measures of 'mental activity variables', which encompass attention, concentration, conceptual tracking, alertness and speed of cognitive activity (Lezak, 1995). Both involve cancelling out a target in a series of items. In the first (Task A) subjects are required to cancel out the second highest 2-digit number in a row of five 2-digit numbers (i.e. one item). In the second (Task B), the subject has to cancel out the new digit in each

item containing a 4-digit and a 5-digit number, where the 5-digit number is a rearrangement of the 4-digit number with a new one added. Four minutes are allowed for each task. The tasks are scored according to the number of correctly cancelled items in the given time. The tasks also involve a test of motor speed, where the subject is required to cancel out a list of identical figures as fast as they can. This is so that motor speed and mental activity components may be separately assessed. The tasks have been found to be sensitive to generalised cerebral dysfunction (Coughlan and Hollows, 1985).

The AMIPB was chosen to assess memory and information processing abilities. It is not known which, if any aspects of memory are important in driving, therefore tests that measure a range of memory deficits and detect problems in subjects from different diagnostic groups have been chosen. Conflicting reports about the role of memory in driving (Fitten et al., 1995; Fox et al., 1997; McKenna, 1998; Odenheimer et al., 1994) support the need for clarification.

The AMIPB provides a broad range of age related norms (18-75 years) and is standardised on a population within which normal age related changes are likely to occur. It also gives specific background data (IQ, social class and academic achievements) on the standardisation population, so that decisions may be made about subject resemblance to the standardisation population.

In the present study, drivers with a range of neurological disabilities such as head injury, dementia and Parkinson's disease were assessed and it was envisaged that subjects would encompass a broad age range. The incidence of conditions such as dementia and Parkinson's disease in older age groups indicated a need for tests

with norms representative of the study sample. It was chosen as a standardised version of tests that are in everyday clinical use and are therefore meaningful to clinical psychologists asked to comment on patients' 'fitness to drive'.

The cognitive tests were administered within two to three weeks of the date for attendance at the DRMC, except where the DRMC date was postponed. For example when patients or DRMC staff were ill or due to adverse weather conditions.

Results of the cognitive assessment were not given to the DRMC. This was to ensure that the DRMC and the driving instructor who conducted the public road assessment, made independent ratings of the subjects' 'fitness to drive'.

3.3.4 Driving Assessment

Following completion of the cognitive assessment, subjects attended the DRMC for routine assessment of their 'fitness to drive'. This consisted of an interview with a medical consultant to check the relevant medical history. Visual acuity and visual fields were assessed using the Snellen chart, number plate test (ability to read a registration mark fixed to a vehicle at a distance of 20.5 metres) and the Goldmann Perimeter. Visual inattention was tested by confrontation. This was followed by assessment on a 'static rig' (sometimes referred to as a driving simulator or reactometer) by a technician. This included assessment of sitting tone, power and speed of movement on the pedals, reaction time of all four limbs, pedal misses, involuntary movements and proprioception. The rig assessment allowed the technician to determine which, if any modifications needed to be made

to the subject's car, for example whether a car with automatic or manual transmission would be best or whether the accelerator and brake could be adequately controlled with either the left or right foot, or whether hand controls were required. Many other modifications could be made to adapt the car to the subject. They included extensions to foot pedals, levers, adapted switch controls, modified seat belts, steering knobs and powered steering (Barnes, 1997). The rig allowed the technician to record adaptation options and take the required measurements for their installation to the subject's vehicle. It also allowed him to determine whether the client had sufficient power to control a vehicle with the appropriate controls, i.e. whether they had sufficient torque to control the steering and sufficient braking force to brake with either the lower or upper limbs. If the subject had inadequate power or reaction speed to control a vehicle with any of the possible adaptation options, then the assessment was terminated and 'failed rig assessment' was recorded.

Subjects then underwent a test drive in an area with no traffic to assess their ability to steer, position the car, stop and use speed appropriately. This took place with the technician on the centre's test track. They then progressed to an area with light traffic. This took place in the grounds of the hospital where the DRMC is located. Their ability to make quick decisions, cope with time pressure or divided attention tasks such as lane merging and observation ability was recorded on a standard form. In addition, their reaction to the environment, ability to anticipate and judgement were assessed. Faults were classified as minor or dangerous.

The DRMC's vehicles were used for the assessments. They were:-

- Ford Escort, 1600cc, 3 door, automatic transmission with 'ultralite' power assisted steering
- Renault Clio, 1390cc, 3 door, automatic transmission with power assisted steering
- Peugeot 106, 1100cc, 5 door, manual transmission

All vehicles were dual controlled and could be adapted to suit driving with hand controls.

3.3.4.1 Public Road Assessment

Patients were then tested on the public road by a Department of Transport approved driving instructor (ADI) in a dual controlled car. Subjects were given the choice of being assessed in a vehicle with manual or automatic transmission. Choice was given to avoid discriminating against subjects with no experience of driving an automatic car and because there was no typical pattern of disability evident across all diagnostic conditions (as is found in stroke patients) which would make assessment in an automatic vehicle easier for all subjects. Assessments took place in the Ford Escort for those who preferred automatic transmission or in the Renault Clio or Peugeot 106 for those who preferred manual transmission. Subjects were not given the choice of manual vehicle. This depended on availability (vehicles were used simultaneously during different stages of the assessment procedure). The public road assessment (PRA) followed on from the DRMC assessments, on the same day. The ADI was asked to make an independent assessment of the subjects' 'fitness to drive'. Strict instructions were

given to the medical consultant, technicians and staff at the DRMC not to communicate information about patients to the ADI. The ADI was blind to the results of the cognitive tests and to assessments carried out by the DRMC. All patients were assessed in areas of light and heavy traffic using a standard form (see Appendix 3.1). Although a set route was not used, patients were assessed over twenty-five specific test items. These items were road manoeuvres known to be difficult for people with neurological disabilities, such as turning right and merging with major traffic streams (Hunt et al., 1994), driving too close and positioning the car - known to be problematic for people with head injuries (Van Zomeren et al., 1988).

Each item was graded as 'correct', 'minor fault' or 'major fault'. On the basis of this, a decision was made about subjects' 'fitness to drive'. They were judged to be 'definitely' or 'probably safe' or 'definitely' or 'probably unsafe'. An indication about the likely benefit to be accrued by lessons was also made. This was graded 'of no benefit', where a subject's driving ability was poor, yet it was felt no improvement could be made; 'not needed' where the subject had driven well and lessons were considered unnecessary, or 'essential' where there was some question about the subject's ability which the ADI felt could be altered by lessons. If the instructor felt the subject was unsafe and likely to be a danger to themselves or others on the road, the test was terminated and the subject graded as having failed on all items of the test. The decision made by the driving instructor was considered to be the 'Gold Standard' of driving ability against which the

prediction made by the SDSA and the outcome of the additional cognitive tests were compared.

3.3.5 Data Analysis

The group was analysed as a whole and as four diagnostic subgroups. These were i) people with traumatic brain injury, ii) people with multiple sclerosis, iii) people with Parkinson's disease and iv) people with dementia.

Mann-Whitney 'U' tests were used to identify differences in cognitive test results between patients who had passed the public road assessment (PRA) and those who had failed. Differences between the groups on non cognitive test variables such as the Nottingham Extended ADL scores, age and sex differences, number of years driving experience, time since onset and the length of time since the patient last drove a car were examined using Chi-square tests for nominal data and Mann-Whitney-U tests for ordinal data.

Agreement between the prediction made by the SDSA and the overall decision made by the ADI was measured using the Kappa statistic (Cohen, 1960).

Direct (standard) discriminant function analysis (Tabachnick and Fidell, 1996) was used to find classification functions from the cognitive tests, to predict group membership ('Pass' or 'Fail' on the public road assessment). The cognitive tests that differed significantly between the Pass and Fail groups and which were considered to yield important information about group membership were used in the analyses.

Discriminant Function Analysis was chosen because its primary goal is to find dimension(s) along which groups differ. The dimensions or classification functions can predict group membership. The number of functions depends along how many dimensions the groups differ (either one fewer than the number of groups or equal to the number of predictor variables, whichever is less). The outcome of the analysis is one or more linear equations, which can easily be used to classify new cases into groups. Since the SDSA is mainly targeted for use by therapists and nurses, a simple 'Pass'/'Fail' classification was considered important. Discriminant analysis also generates information about the proportion of cases that are correctly classified, together with

information about misclassified cases. In direct discriminant analysis, predictor variables (cognitive tests) are entered into the equations together (without prior assumption about their predictive power by the researcher). This means important information about the relationships between the variables is incorporated in the analysis (Norušis, 1994).

A potential weakness of discriminant analysis with small sample sizes is 'over fitting' of results to the studied sample, hence poor generalisability. This is because classification is based on classification coefficients derived from the sample. Since some predictor variables were not expected to have a normal sampling distribution in the population being sampled, rigid screening and transformations were used to ensure fit with the assumptions of multivariate analysis prior to analysis.

Analysis was conducted using SPSS for Windows release 6.1 (Norušis, 1994) and Minitab 11 for Windows (Minitab, 1996). An independent assessor carried out random checking of 10% of the data set. Further independent checks of a random 10% of the head injured, multiple sclerosis and Parkinson's disease subgroup data were also carried out. The dementia subgroup (n = 10) was checked in it's entirety.

3.4 Results

3.4.1 Patient Characteristics

Of the 248 Patients referred to the Derby Regional Mobility Centre (DRMC) between 1st August 1995 and 1st April 1998, 52 were novice drivers (having never driven or with less than two years driving experience) and five lived too far away.

One hundred and ninety-one patients were considered for inclusion in the study. Of these: -

10 refused consent

10 cancelled their appointment at the centre (or stopped driving of their own volition)

Four were slotted into cancellations by the driving centre

Three were overlooked by the research team.

Three had no recent driving experience i.e. stopped driving more than four years previously but then wished to resume.

Two had taken part in the study in the previous year

Two had their licence returned in administrative error by the DVLA prior to DRMC assessment

Two had a history of stroke

One was licensed only to drive a three-wheel vehicle

One was not approached at the Consultant's request

One had legal complications (patient had re-applied for licence without medical consent)

One had an epileptic fit prior to assessment

One hundred and fifty one patients were recruited to the study and assessed on the cognitive assessments. Of these a further eight patients were excluded for the reasons listed below.

One had his licence returned in administrative error by the DVLA prior to the DRMC assessment and withdrew. One could not be assessed at the centre

because inadequate facilities were available to allow her to be assessed driving from her powered wheelchair. One did not attend for the DRMC assessment. One died prior to the public road assessment (PRA). One patient withdrew from the study. Three were recruited prior to the appointment of the ADI and were not assessed on the public road. Patients were excluded in order of the criteria specified in the method.

3.4.2 The whole group

One hundred and twenty nine patients completed all assessments (95 men, 34 women), mean age 48.8 years (SD 14.63, Range 21 - 89 years). Most of the patients had suffered a traumatic brain injury or suffered from multiple sclerosis (MS). Diagnostic groups are shown in Table 3.0.

Table 3.0: Classification of acquired neurological disabilities represented in the study sample

Traumatic Brain Injury	52
Multiple Sclerosis	34
Parkinson's disease	7
Dementia	10
Sub-arrachnoid haemorrhage	7
Tumour	5
Motor neurone disease	2
Huntingdon's disease	2
Anoxic brain damage	3
Other	7
TOTAL	**129**

The mean time since onset of the neurological disability (available in 128 cases) was 4.45 years (SD 6.47, range 0.09 - 33.9 years) and the mean number of years driving experience (available in 128 cases) was 25 (SD 13.62, range 2

- 72 years). The median time since last having driven a car was nine months (mean 16.91, SD 20.05, range 0 - 99, n = 128).

Although it was intended that all patients should progress to a public road evaluation, so that their 'fitness to drive' could be determined by the same independent ADI, in some cases it was found to be impractical (when suitable adaptive equipment was not available), unfair (to ask patients to be assessed on the PRA when failure was clearly evident) or illegal (due to eyesight failure) by the technician and/or medical consultant in the earlier assessments. Four patients were precluded from the public road assessment when their vision did not meet the legal requirements[1] for driving. Five were not assessed for physical reasons such as inadequate power in the limbs to control a vehicle or because of the delay in reaction times. One person was not seen on the road because suitable adaptive equipment was not available to allow her to drive a car. These patients were included in the analysis and deemed to have failed the public road assessment. Two patients were seen in their own vehicle, one because her own vehicle was adapted to suit her personal needs and one, resulting from confusion on the part of the ADI (a separate study taking place in Nottingham allowed patients with PD to be assessed in their own car). Three patients were seen by a technician on the public road when the driving instructor was not available due to illness. These three assessments were included in the analysis.

---

[1] " to read in good light...a registration mark fixed to a motor vehicle and containing letters and figures 79.4millimetres high at a distance of 20.5 metres.....a field of vision of at least 120^{0} on the horizontal measured by the Goldmann perimeter...In addition there should be no significant defect in the binocular field which encroaches within 20^{0} of fixation above or below the horizontal meridian." (At a Glance Guide to the Current Medical Standards of Fitness to Drive, DVLA, Swansea, 1998)

3.4.2.1 Comparison of patients passing and failing the public road assessment

The road test categories 'definitely safe' and 'probably safe' were grouped together to form the 'Pass' group and 'definitely unsafe' and 'probably unsafe' to form the 'Fail' group. Patients who did not progress to the public road assessment because their eyesight did not meet the legally required standard for driving (n = 4) or because they had inadequate power or speed of movement in the limbs to control a motor vehicle (n = 6) were categorised as 'Fail'.
Of the 129 patients with acquired neurological disabilities, 86 passed and 43 failed the PRA. The distribution of diagnostic groups according to road test performance is shown in Table 3.1.

Table 3.1: Distribution of PRA gradings according to Diagnosis.

Diagnostic Group	Pass	Fail
Traumatic Brain Injury	37	15
Multiple Sclerosis	21	13
Parkinson's disease	4	3
Dementia	1	9
Sub-arrachnoid Haemorrhage	7	0
Tumour	4	1
Motor Neurone Disease	2	0
Huntingdon's Disease	1	1
Anoxic Brain Damage	3	0
Other	6	1

This suggests that there is a relationship between diagnosis and performance on the PRA. The patients most likely to be found unsafe were those with dementia.

The Pass and Fail groups were compared using Mann-Whitney 'U' tests for non-parametric data and Chi squared tests for nominal data.

Comparison of demographic variables is shown in Table 3.2. There was a significant difference in age between patients passing and failing the PRA. Patients who failed were significantly older. There were no significant differences between the groups in the number of years driving experience, time since last having driven a car, or in years since the onset of their neurological disability. The median time between cognitive testing and the PRA was 18 days. There was no significant difference in time between cognitive and public road testing for the two groups (U = 1717.0, p= 0.51).

Table 3.2: Comparison of demographic variables between 'Pass' and 'Fail' groups.

	Pass n=86		**Fail n=43**		**U†**	**p - 2 tailed**	**95% CI**
sex	men wom[n]	68 18	men women	27 16	$\chi 2$ 3.91	0.06	
age	mean SD range med. IQR	44.5 13 21 - 75 46 34 - 53	mean SD range med. IQR	51.4 16.6 22-89 52 38-62	1383	0.02*	-13.0, -1.0
time since onset (yrs)	mean SD range med. IQR	4.0 5.7 .09 - 32.1 1.8 1.1 - 4.1	mean SD range med. IQR	5.4 7.8 0.3-33.9 2.1 1.2 - 5	1588	0.27	-1.0, 0.3
time since driven (Mths)	mean SD range med. IQR	15.6 18.9 0 - 84 10.5 0 - 23	mean SD range med. IQR	19.6 22.3 0-99 13 1.5-27.3	1589	0.26	-12.4, 3.8
exper-ience (yrs)	mean SD range med. IQR	23.6 12.6 2 - 53 24 12 - 31.5	mean SD range med. IQR	28.4 15.1 2 - 72 30 16 - 37	1468	0.07	-10.0, 1.0

† Mann -Whitney U test, $\chi 2$ Chi – Squared Test, *p<0.05, CI - confidence interval, med. = median, IQR = inter-quartile range

Comparison of the two groups on the EADL index showed significant differences on the Mobility and Leisure sub scales (see Table 3.3). Results for the EADL were missing in four cases.

Table: 3.3 Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Extended ADL Index.

Patients (n=125)

EADL	Pass n= 83		Fail n= 42		U†	p - 2 tailed	95% CI
MOB	med. IQR range	15 10.8 - 18 3 - 18	med. IQR range	12 7.8 - 15.3 2 - 18	1232	<0.01	0.0, 4.0
KIT	med. IQR range	15 11- 15 0 - 15	med. IQR range	13.5 10.8 - 15 5 - 15	1607	0.45	0.0, 1.0
DOM	med. IQR range	9.5 4 - 15 0 - 15	med. IQR range	9 5.8 - 11 0 - 15	1562	0.28	-1.0, 3.0
LEI	med. IQR range	13 9 - 15 2 - 18	med. IQR range	10 8 - 12.3 2 - 17	1235	<0. 01	0.0, 3.0
TOT	med. IQR range	49.5 38.8 - 58.3 11 - 66	med. IQR range	42.5 34 - 50 14 - 63	1282	0. 02*	1.0, 11.0

Key: '*' = p<0. 05, † Mann -Whitney U test, CI - confidence interval
MOB=mobility, KIT=kitchen, Dom=domestic, LEI= Leisure, TOT=Total score
med. = median, IQR = Inter-quartile range

Patients who failed the PRA were significantly less independently mobile and significantly less actively engaged in leisure pursuits than those who passed. The total EADL score (TOT) also differed significantly between the groups. Patients who passed the PRA were significantly more independent in extended activities of daily life.

3.4.2.2 Cognitive test results

The median, inter-quartile range and range for each of the cognitive test variables are shown separately for patients who passed (Pass) and patients who Failed (Fail) the Public Road Assessment (PRA). Mann Whitney 'U' tests

were used to identify differences in cognitive test scores between the two groups. The results for the entire group of 129 (unless stated otherwise) patients are given in Tables 3.4 to 3.8. It was hypothesised that those who failed the cognitive assessments would fail the public road assessment; therefore 1- tailed p values are given.

Results for the PASAT and most AMIPB sub tests were missing in two cases. One patient refused and one was unable to comprehend the instructions due to language problems. The AMIPB Information Processing sub tests were missing in three cases. Two for previously stated reasons and one because the researcher omitted them. Results for the Stroop were missing in the case of one colour-blind man.

Table 3.4: Comparison of the PRA pass group (Pass) and fail group (Fail) on the SDSA

SDSA	Pass n= 86		Fail n=43		U†	p – 1 tailed	95% CI
Dot Canc^n	med. IQR range	404 352 - 535 219 - 900	med. IQR range	556 420 - 703 318 - 900	1156	<0.01	-170.1, -42.2
Dot errors	med. IQR range	8 3 - 17.2 0 - 66	med. IQR range	11 5 - 25 1 - 138	1392	<0.05	-8.0, -1.0
Dot false +ve	med. IQR range	0 0 - 1 0 - 12	med. IQR range	1 0 - 4 0 - 110	1029	<0.001	-2.0, 0.0
Sq. matrix Direc^n	med. IQR range	32 21 - 32 0 - 32	med. IQR range	28 9 - 32 3 - 32	1349	<0.01	0.0, 5.0
Sq. matrix Ccards	med. IQR range	22 16.8 - 32 2 - 32	med. IQR range	14 9 - 24 2 - 32	1112	<0.001	4.0, 10.0
RSRT	med. IQR range	8 5 - 11 0 - 12	med. IQR range	6 2 - 7 0 - 10	930	<0.001	2.0, 5.0
Total score	med. IQR range	1.91 -0.58-4.73 -6.87-6.59	med. IQR range	-1.02 -3.1- 2.6 -6.9-14.5	1247	<0.01	0.9, 3.8

Key: † Mann -Whitney U test, CI - confidence interval, med. = median, IQR = Inter-quartile range

There were significant differences between the two groups on the SDSA Pass - Fail equation (Total Score). Patients failing the PRA scored significantly worse overall. Each SDSA subtest also differed significantly between the two groups. Patients who failed the PRA took significantly longer to complete and incurred significantly more errors and false positive errors on the Dot Cancellation test; scored significantly worse on both Square Matrices tests, Directions (Direc^{n}) and Compass Cards (Ccards) and on the Road Sign Recognition task (RSRT).

Mann-Whitney U tests revealed significant differences between those who passed and those who failed the PRA on the PASAT, Stroop and most AMIPB subtests. Comparisons are shown in Tables 3.5 to 3.8.

Table 3.5: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the PASAT.

Patients (n = 127)

PASAT	**Pass n= 86**		**Fail n= 41**		**U†**	**p - 1 tailed**	**95% CI**
Trial I	med. IQR range	48.5 33.7 - 55 0 - 60	med. IQR range	34 14 - 52.5 0 - 59	1263	0.01	1.0, 17.0
Trail II	med. IQR range	19.5 9 - 29 0 - 54	med. IQR range	11 1 - 22 0 - 39	1288	0.01	1.0, 12.0

Key: † Mann -Whitney U test, CI - confidence interval, med. = median, IQR = Inter-quartile range.

There were significant differences between the two groups on both Trials I and II of the PASAT. Failing patients scored significantly worse. Patients who failed the PRA also scored significantly worse on the Stroop test (Colour Word Score) (Table 3.6).

Table 3.6: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Stroop test.

Patients (n =128)

	Pass n= 86		Fail n= 42		U†	p - 1 tailed	95% CI
Colour Score	med. IQR range	111.5 110 - 112 51 - 112	med. IQR range	112 109 - 112 11 - 112	1705	0.58	0.0, 0.0
Colour Word Score	med. IQR range	86.5 66 - 106.3 4 - 112	med. IQR range	52 25 - 82.3 0 - 108	926	<0.001	0.0, 15.0

† Mann -Whitney U test, CI - confidence interval, med. = median, IQR = Inter-quartile range

Table 3.7: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Motor Impersistence test.

Patients (n =127)

	Pass n= 86		Fail n= 41		U†	p - 1 tailed	95% CI
MI	med. IQR range	422.5 406.8 - 440 299 - 440	med. IQR range	414 402.5 - 432.5 284 - 440	1429	0.08	-0.0, 15.0

† Mann -Whitney U test, CI - confidence interval, MI - Motor Impersistence, med. = median, IQR = Inter-quartile range

There was no significant difference between the two groups in scores for the test of Motor Impersistence.

Table 3.8: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the AMIPB.

Patients (n =127)

	Pass n= 86		Fail n= 41		U†	p - 1 tailed	95% CI
Story Recall Immd	med. IQR range	19 12 - 31.5 0 - 56	med. IQR range	18 5.5 - 27 0 - 42	1419	0.08	0.0, 9.0
Delay[d]	med. IQR range	16 9.8 - 30 0 - 49	med. IQR range	13 2 - 22.5 0 - 40	1361	0.04*	0.0, 10.0
% Retain[d]	med. IQR range	87.5 71.4 - 100 0 - 220	med. IQR range	82.6 41.4 - 98.1 0 - 175	1424	0.08	0.0, 19.6
Fig. Recall Copy	med. IQR range	76 75 - 76 64 - 76	med. IQR range	74 69.5 - 76 40 - 76	1089	<0.001	0.0, 3.0
Immd. recall	med. IQR range	58.5 43.3 - 68 3 - 76	med. IQR range	48 23.8 - 64 0 - 75	1340	0.02*	1.0, 16.0
Delay[d] recall	med. IQR range	52.5 28.5 - 65.3 0 - 99	med. IQR range	38 0 - 55.5 0 - 99	1325	0.01*	1.0, 21.0
List learn. Total	med. IQR range	42.5 34 - 50.3 11 - 63	med. IQR range	35 24 - 49 1 - 59	1320	0.02*	1.0, 12.0
Recall	med. IQR range	8 5 - 10 0 - 21	med. IQR range	5 2 - 10 0 - 13	1328	0.04*	0.0, 4.0
Inter-ference	med. IQR range	5.5 4 - 7 2 - 14	med. IQR range	4 3 - 6.8 0 - 10	1242	0.01*	0.0, 2.0
Intru-sion errors	med. IQR range	1 0 - 4 0 - 15	med. IQR range	3 1 - 5 0 - 14	1433	0.08	-2.0, 0.0
Design learn. Total	med. IQR range	32 24 - 39 13 - 45	med. IQR range	28.5 15.5 - 38 5 - 43	1397	0.04*	0.0, 9.0
Recall	med. IQR range	7 5 - 9 0 - 9	med. IQR range	6 2 - 8 0 - 9	1339	0.03*	0.0, 2.0
Inter-ference	med. IQR range	3 2 - 6 0 - 9	med. IQR range	3 2 - 5 0 - 7	1477	0.14	0.0, 1.0

Intru-sion errors	med. IQR range	10.5 4.8 - 21 0 - 52	med. IQR range	12 4.8 - 27.3 2 - 114	1582	0.26	-6.0, 1.0
Info. Pro. 'A' Total	med. IQR range	51.5 35.8 - 60.5 10 - 104	med. IQR range	39.5 31 - 46 7 - 72	1090	<0.01	5.0, 17.0
IPA Errors	med. IQR range	3.3 0 - 5.7 0 - 43	med. IQR range	5.8 2.4 - 12.5 0 - 83	1268	0.02*	-4.1, 0.0
IPA Speed	med. IQR range	42 31.8 - 48.3 12 - 68	med. IQR range	31.5 25.3 - 40 15 - 67	1136	<0.01	3.0, 12.0
IPA adjust[d] score	med. IQR range	57.4 39.7 - 69.8 11 - 119	med. IQR range	43.6 34.2 - 53.6 7 - 83	1126	<0.01	4.8, 18.5
Info. Pro. 'B' Total	med. IQR range	48.5 35 - 63.3 10 - 105	med. IQR range	32 22.3-36.8 5 - 69	803	<0.001	10.0, 25.0
IPA Errors	med. IQR range	0 0 - 3 0 - 73	med. IQR range	0 0 - 8.3 0 - 80	1681	0.82	0.0, 0.0
IPA Speed	med. IQR range	43 33 - 50.3 8 - 69	med. IQR range	32 27 - 41.8 15 - 57	1003	<0.001	4.0, 13.0
IPA adjust[d] score	med. IQR range	53.5 40.1 - 72.7 10.5 - 120.2	med. IQR range	35.3 23.9 - 42.9 5.1 - 80.8	823	<0.001	11.4, 28.7

Key: '*' P<0.05, † Mann -Whitney U test, CI = Confidence Interval, med. = median, IQR = Inter-quartile range

Mann -Whitney U tests revealed significant differences between those who passed and those who failed the PRA on the AMIPB Story Recall-delayed subtest, Figure Copy and immediate and delayed recall, Design Learning total and recall and all of the List Learning subtests except Instrusion errors. Both Information Processing tasks 'A' and 'B' scores also differed significantly between the two groups. Patients who failed the PRA scored significantly worse on all except six of the AMIPB sub test components. Scores for the

Design Learning interference list and intrusion errors, List Learning intrusions, Story Recall immediate and percentage retained and the Information Processing task 'B' errors did not differ significantly between the two groups.

3.4.2.3 Crosstabs

The PRA gradings were cross tabulated with the classification of scores on the SDSA (see Table 3.9)

Table 3.9: Comparison of SDSA and PRA outcome.

Outcome Public Road Assessment	No. of cases	SDSA Prediction	
		Pass	Fail
Pass	86	63	23
Fail	43	19	24

Sensitivity: 55.8%

Specificity: 73.3%

Accuracy: 67.4%

Sixty three of the 86 patients who passed on the public road were correctly classified by the SDSA (Specificity 73.3%) and 24 out of the 43 who failed were predicted to have failed (Sensitivity 55.8%). Of the misclassified cases, 23 patients who were predicted to fail actually passed the PRA and 19 of those predicted to pass, failed the PRA. The overall accuracy of prediction made by the SDSA was 67.4%.

This indicates that the SDSA correctly classified half of those who were unsafe to drive and two thirds of those who were safe. Agreement between the SDSA prediction and the ADI was measured using Cohen's Kappa (Cohen, 1960), $\kappa = 0.28$, approximate significance 0.01; agreement was 'Fair' (Altman, 1997).

Although each of the cognitive tests differed significantly between the two groups, the SDSA proved a poor predictor in a mixed diagnosis group. Therefore, its predictive validity was examined within four diagnostic groups.

3.4.3 Head injured group

Fifty-two patients completed all assessments (44 men and 8 women), mean age 39.1 years (SD 12.8, range 21 - 72). The mean time since onset was 27.7 months (SD 20.1, range 4.9 - 95, median 21.6 months). They had a mean average of 18.5 years driving experience (SD 12.38, range 2 - 50). The median time since last driving a car was 22 months. The mean time between cognitive testing and the public road assessment (PRA) was 47 days (SD 78.7, range 49 - 349, median 15.5 days). In all cases, except three, the time between cognitive and road testing was less than three months. In one case, the patient underwent an arm amputation between assessments, one patient did not turn up for the public road assessment and had to wait for a revised appointment and one was visited early by the researcher to link two visits in nearby geographical locations.

All except two patients were living in the community at the time of assessment. They were inpatients in head injury rehabilitation units. Most (39) of the patients were independently mobile, nine experienced some difficulty with walking, two required help and one person was unable to walk.

3.4.3.1 Comparison of Patients passing and failing the Public Road Assessment

Three patients who did not progress to the public road assessment because their eyesight did not meet the legally required standard for driving and one who had inadequate power or speed of movement in the limbs to control a motor vehicle were categorised as 'Fail'.

The median, inter-quartile range and range for each of the cognitive test variables are shown separately for patients who passed (Pass Group) and patients who Failed (Fail group) the PRA. Mann-Whitney U tests were used to identify differences in cognitive test scores between the two groups. Results are given in Tables 3.10 and 3.11.

There were no significant differences in age or sex between those who had passed and those who had failed the public road assessment. However, there was a significant difference between the two groups in time since last having driven a motor vehicle. Those who failed the public road assessment had had a significantly longer break from driving. Comparisons on the EADL showed significant differences for the Mobility and Leisure sub scales at the 5% level. Patients who failed the road test were significantly less mobile (5/14 had difficulty walking or required help and one was unable to walk). Differences in the total EADL scores also reached significance at the 5% level, with those who passed being significantly more independent (Tables 3.10 and 3.11).

Table 3.10: Comparison of demographic variables between 'Pass' and 'Fail' groups.

Head injured patients (n = 52)

	Pass n= 38		Fail n=14		Compa -rison	p- 2 tailed	95% CI
sex	men wom[n]	34 4	men wom[n]	10 4	$\chi 2$	.189 Fisher exact	
					U†		
age	mean SD range med.	39.5 12.6 21 - 72 37.5	mean SD range med.	37.9 13.6 22 - 62 34	245	0.66	-6.0, 10.0
months since onset	mean SD range med.	25.1 18.4 4.9 - 79.3 20.2	mean SD range med.	34.6 23.3 10.8 - 950 26.6	1870	0.10	-1.9, 18.7
months since driven	mean SD range med.	21.4 20.5 0 - 83 16.5	mean SD range med.	31.9 15.7 13 - 64 27	1460	0.03*	-252.0, -1.0
driving exper- ience (years)	mean SD range med.	19.2 12.5 2 - 50 18	mean SD range med.	16.3 12.2 1 - 37 11	229	0.52	-4.0, 13.0

Key: '*' = $p<0.05$, $\chi 2$ Chi – Squared Test, † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Table 3.11 **Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Nottingham Extended ADL Index.**

Head injured patients (n = 52)

EADL	Pass n= 38		Fail n=13		U†	p - 2 tailed	95% CI
MOB	med. IQR range	18 14 - 18 7 - 18	med. IQR range	12 9.5 - 18 2 - 18	153	0.03*	0.0, 6.0
KIT	med. IQR range	15 12 - 15 6 - 15	med. IQR range	14 11.8 - 15 9 - 15	214	0.42	0.0, 1.0
DOM	med. IQR range	12 5.8 - 15 1- 15	med. IQR range	9 5 - 11.5 1 - 15	191	0.22	-1.0, 5.0
LEI	med. IQR range	13 8.8 - 15 2 - 18	med. IQR range	10 7 - 12 6 - 15	156	0.05*	0.0, 5.0
TOT	med. IQR range	56 42 - 63 21 - 66	med. IQR range	45 38 - 52 20 - 63	158	0.05*	0.0, 16.0

Key: '*' = $p<0.05$, † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median, MOB=mobility, KIT=kitchen, Dom=domestic, LEI= Leisure, TOT=Total score

3.4.3.2 Cognitive test results

Tables 3.12 - 3.16 show the differences between the Pass and Fail groups for each of the cognitive tests using Mann-Whitney U tests. It was hypothesised that those who failed the cognitive assessments would fail the public road assessment, therefore 1 tailed p values are given.

Scores for the Colour Word task of the Stroop, both information processing tasks 'A' and 'B' and the Figure Copy and List Learning Intrusions from the Adult Memory and Information Processing Battery (AMIPB) differed significantly between the two groups of head injured patients. None of the other cognitive tests showed any significant differences between the two groups.

Table 3.12: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the SDSA

Head injured patients (n = 52)

SDSA	Pass n= 38		Fail n=14		U†	p - 1 tailed	95% CI
Dot Canc[n]	med. IQR range	384.5 342.4 - 491.9 219 - 900	med. IQR range	542.1 393.2 - 690 324 - 900	123	<0.01	-234.0, -40.0
Dot errors	med. IQR range	7 3.7 - 17 0 - 66	med. IQR range	15 4.5 - 56.5 1 - 77	197	0.08	-17.0, 0.99
Dot false +ve	med. IQR range	0 0 - 1 0 - 4	med. IQR range	1 0 - 4 0 - 61	136	<0.01	-2.0, 0.0
Sq. matrix Direc[n]	med. IQR range	32 21.8 - 32 0 - 32	med. IQR range	32 9.8 - 32 3 - 32	238	0.24	0.0, 2.0
Sq. matrix Ccards	med. IQR range	26 18 - 32 8 - 32	med. IQR range	17 13 - 27.2 2 - 32	178	0.03*	0.0, 12.0
RSRT	med. IQR range	9 7 - 11 2 - 12	med. IQR range	6 3.7 - 9 0 - 10	142	<0.01	1.0, 5.0
Total score	med. IQR range	3 1.2 - 5 -5.4 - 6.6	med. IQR range	1.4 -2.9 - 3.9 -6.9 - 6.3	186	0.10	-0.3, 4.1

Key: '*' = $p<0.05$, † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

There was a significant difference between the two groups in time taken to complete the dot cancellation task (Dot Canc[n]). Those who failed on the road took significantly longer to complete. Differences between the groups were also found at the 1% level for the number of dot cancellation false positive errors and the road sign recognition test (RSRT). Patients failing the PRA made more errors on both tests. There was also a significant difference in scores on the Square Matrices Compass Cards test (Ccards) with failing patients scoring worse.

Table 3.13: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Paced Auditory Serial Addition Task (PASAT).

Head injured patients (n = 52)

PASAT	Pass n= 38		Fail n=14		U†	p - 1 tailed	95% CI
Trial I	med. IQR range	48.5 35.8 - 54 0 - 60	med. IQR range	37 22 - 75 3 - 59	211	0.13	-4.0, 18.0
Trail II	med. IQR range	18 8.5 - 28 0 -51	med. IQR range	15.5 25 - 75 0 - 27	196	0.07	-1.0, 14.0

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Table 3.14: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the STROOP test.

Head injured patients (n = 52)

	Pass n= 38		**Fail n=14**		**U†**	**p - 1 tailed**	**95% CI**
Colour Score	med. IQR range	111 110 - 112 79 - 112	med. IQR range	111 105.3-112 24 - 112	238	0.53	-1.0, 1.99
Colour Word Score	med. IQR range	89.5 77.8 -108 4 - 112	med. IQR range	55.5 25.3 - 75.8 9 - 99	103	<0.001	13.0, 51.0

Key: † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Scores for the Stroop test differed significantly between head injured patients passing and failing the PRA. Those who passed performed significantly better.

Table 3.15: Comparison of PRA Ppss group (Pass) and PRA fail group (Fail) on the test of Motor Impersistence.

Head injured patients (n = 52)

	Pass n= 38		**Fail n=14**		**U†**	**p - 1 tailed**	**95% CI**
MI	med. IQR range	419 399.5-432.5 3510.0 - 440	med. IQR range	411.5 402.8-423.8 318 - 432	223	0.18	-6.0, 18.0

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

There was no significant difference between the two groups of head injured patients on the test of Motor Impersistence (MI).

Table 3.16: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the AMIPB.

Head injured patients (n = 52)

	Pass n= 38		**Fail n= 14**		**U†**	**p - 1 tailed**	**95% CI**
Story Recall Immd	med. IQR range	16.5 9.8 - 30.8 0 - 41	med. IQR range	19 6.5 - 28.5 4 - 33	241	0.33	-6.0, 9.0
Delay[d]	med. IQR range	13.5 7.8 - 30 0 - 39	med. IQR range	13 4 -21.8 0 -28	213	0.14	-4.0, 10.0
% retain[d]	med. IQR range	85.7 68.3 - 96.8 0 - 111	med. IQR range	65 40 - 93.3 0 - 100	211	0.18	-4.8, 31.2
Fig. Recall Copy	med. IQR range	76 75.8 - 76 72 - 76	med. IQR range	74.5 69 - 76 52 - 76	153	<0.01	0.0, 3.0
Immd. recall	med. IQR range	60 44.8 - 69.3 15 - 76	med. IQR range	50.5 28.3 - 67.5 17 - 75	213	0.14	-5.0, 21.0
Delay[d] recall	med. IQR range	56 36 - 66 0 - 99	med. IQR range	42.5 0 - 63.8 0 - 71	191	0.06	-1.0, 39.0
List learn. Total	med. IQR range	44 33.5 - 50 15 - 62	med. IQR range	33.5 25 - 48.5 18 - 56	215	0.15	-4.0, 14.0
Recall	med. IQR range	8 5 - 10 0 - 15	med. IQR range	3.5 2 - 11 1 - 12	215	0.15	-2.0, 5.0
Inter-ference	med. IQR range	5 4 - 7 3 - 13	med. IQR range	4 3.8 - 6.3 3 - 10	228	0.21	-1.0, 2.0
Intru-sion errors	med. IQR range	1.5 0.8 - 5.3 0 - 15	med. IQR range	5 3 - 6 1 - 9	152	<0.01	-4.0, -1.0
Design learn. Total	med. IQR range	34 27.8 - 40.3 17 - 45	med. IQR range	37.5 22.8 - 39.3 7 - 43	250	0.04*	-5.0, 7.0

Recall	med. IQR range	8 6 - 9 0 - 9	med. IQR range	7 2 - 9 0 - 9	229	0.21	-1.0, 3.0
Inter-ference	med. IQR range	4 2 - 5.5 0 - 9	med. IQR range	5 2 - 5.3 0 - 7	255	0.41	-1.0, 3.0
Intru-sion errors	med. IQR range	8 3.5 - 14 0 - 44	med. IQR range	7.5 4 - 12.8 3 - 114	263	0.47	-4.0, 4.0
Info. Pro. 'A' Total	med. IQR range	55 43.8 - 60.5 10 - 104	med. IQR range	38 29.5 - 42.3 13 - 55	98	<0.001	8.0, 24.0
IPA Errors	med. IQR range	3.3 0 - 48 0 - 15.6	med. IQR range	5.5 2.2 - 16.5 0 - 30.8	165	0.02*	-7.1, 0.0
IPA Speed	med. IQR range	44 36.5 - 50 14 - 68	med. IQR range	29 22.3 - 34 15 - 67	95	<0.001	8.0, 22.0
IPA adjust[d] score	med. IQR range	60.4 47.4 - 68.1 10.6 - 119.2	med. IQR range	43.0 32.9 - 50.9 13.5 - 64.2	110	<0.001	6.5, 26.1
Info. Pro. 'B' Total	med. IQR range	50 38.5 - 61.3 10 - 105	med. IQR range	31 23.5-35.3 5 - 62	90	<0.001	9.0, 30.0
IPA Errors	med. IQR range	0 0 - 3.1 0 - 10	med. IQR range	0 0 - 16.2 0 - 40	239	0.26	-9.1, 0.0
IPA Speed	med. IQR range	45 38.8 - 52.3 17 - 69	med. IQR range	29 24.5 - 34 15 - 41	63	<0.001	10.0, 23.0
IPA adjust[d] score	med. IQR range	54.67 41.3 - 68.9 10.5 - 120.3	med. IQR range	33.9 25.8 - 40.5 5.1 - 73.1	102	<0.001	9.0, 34.2

Key: '*' = P<0.05, † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

On the AMIPB subtests, patients who failed the PRA scored significantly worse on the Figure Recall-copy task. There was a significant difference in scores for the number of intrusion errors on the List Learning task with those who failed the PRA incurring significantly more. Comparisons on the two

information processing tasks showed that failing patients also scored significantly worse on both tasks 'A' and 'B' (adjusted) scores.

3.4.3.3 Crosstabs

The prediction made by the SDSA was cross tabulated with the overall outcome (pass or fail) of the PRA (see Table 3.17). Thirty two of the 38 patients who passed on the public road were correctly classified by the SDSA (Specificity 84.2%) but only five out of the 14 who failed were predicted to have failed (Sensitivity 35.7%). Of the misclassified cases, six patients who were predicted to fail actually passed the PRA and nine of those predicted to pass, failed the PRA. The overall accuracy of prediction made by the SDSA was 71.2% for head injured patients.

Table 3.17: Correlational analysis showing SDSA classification results for head injured patients.

Outcome Public Road Assessment	**No. of cases**	**SDSA Prediction**	
		Pass	**Fail**
Pass	38	32	6
Fail	14	9	5
Sensitivity: 35.7%			
Specificity: 84.2%			
Accuracy: 71.2%			

Agreement between the SDSA prediction and PRA outcome was 'fair' (Altman, 1997), $\kappa = 0.21$, approximate significance 0.12. In total 15 patients were misclassified by the SDSA prediction. Of those, two who were predicted to pass and one who was predicted to fail by the SDSA were not assessed on the public road because their eyesight did not meet the legally required standard

for driving. Of the six who were predicted to fail but passed, three previously worked in driving jobs (two were HGV drivers and one was a taxi driver) and one had resumed driving three months before taking part in the study. Two were misclassified for unknown reasons (one previously worked as a miner and one as a barman). One person who was predicted to pass by the SDSA, failed the PRA because their reaction times on the static rig were considered too slow to operate a motor vehicle. Of the remaining eight who were predicted to pass but failed, six had residual physical deficits as a result of their head injury.

3.4.3.4 Discriminant analysis

A direct discriminant functions analysis was performed using three cognitive tests (five cognitive test variables) as predictors of the overall decision (pass or fail) made by the driving instructor. They were tests, which differed significantly between patients who passed and failed on the road. i.e. the SDSA Dot Cancellation time (Dot. Canc^{n}) Compass Cards (Ccards) and Road Sign Recognition subtests (RSRT), the Stroop Colour Word Score (CWS) and the Information Processing task 'A' adjusted score (IPA).

Prior to analysis, individual cognitive test variables were examined through various SPSS programs for accuracy of data entry, missing values and fit between their distributions and the assumptions of Discriminant Function Analysis. The variables were examined separately for patients who passed and failed the public road assessment.

Of the original 52 cases, one was found to be a multivariate outlier and excluded from the analysis. This case was from the group who passed the PRA; a man with abnormally low cognitive test scores but with many years experience as an HGV driver. For the remaining 51 patients (37 who passed and 14 who failed the PRA), evaluation of assumptions of linearity and multicollinearity or singularity revealed no threat to multivariate analysis.

The SDSA Dot Cancellation False Positives, Figure Copy and Information Processing task 'B' adjusted score (IPB) also differed significantly between the two groups but examination of the assumptions of normality revealed Figure Copy to be significantly skewed in both the Pass (K-S Lilliefors 0.32, $p<0.001$) and Fail (K-S Lilliefors 0.26, $p<0.01$) groups due to a ceiling effect on the test. Dot Cancellation False Positives was also significantly skewed in both groups (Pass; K-S Lilliefors 0.40, $p<0.001$, Fail; K-S Lilliefors 0.41, $p<0.001$) due to a flooring effect on the test. Both tests were excluded from further analysis. IPB was excluded because of singularity, since both IPA and IPB are measures of information processing skills.

RSRT, Ccards and IPA were normally distributed for both the Pass and Fail groups. Dot. Canc^{n} was significantly skewed in the Pass group (K-S Lilliefors 0.18, $p< 0.01$). Removal of the one multivariate outlier and transformation using the square root, improved the distribution to fit with the assumptions of multivariate analysis (K-S Lilliefors 0.131, $p= 0.11$). CWS was also significantly skewed in the Pass group (K-S Lilliefors 0.15, $p= 0.02$). Transformation by squaring and removal of the multivariate outlier, improved the distribution to normal (K-S Lilliefors 0.12, $p= 0.18$). Although List Learning intrusion scores differed significantly between head injured patients passing and failing the PRA, it was not included in the analysis, since by itself, it was not considered to be an important cognitive measure.

Box's M was used to examine homogeneity of variance-covariance matrices and not found to be significant ($p= 0.24$) suggesting homogeneity.

During classification, unequal sample sizes were used to modify the probabilities with which cases are classified into groups. The means and standard deviations for the predictor variables are reported in Table 3.18.

Table 3.18. The means and standard deviations for the cognitive test scores (predictor variables).

	Pass group (n = 37)		Fail Group (n = 14)	
	Mean	SD	Mean	SD
CWS	8105.97	3580.97	3647.71	2992.52
IPA	60.29	18.08	41.60	13.23
Dot. Canc^n	20.03	2.43	23.72	3.89
Ccards	24.78	7.37	19.07	9.64
RSRT	8.68	2.73	5.93	3.20

Univariate F-tests for differences between the groups were significant for all SDSA sub tests; Dot.Canc^n; F = 16.52, p<0.001, Ccards; F = 5.13, p= 0.03, RSRT; F = 9.37, p=0.004 and for both the Stroop (CWS) F = 17.11, p<0.001, and the Information processing task 'A' score (IPA) F = 12.39, p<0.001. This supports the hypothesis that specific cognitive tests can be used to separate the two groups (i.e. those who pass from those who fail on the public road assessment). The discriminant analysis produced a linear function with the following standardised coefficients (see Table 3.19). This was found to be a significant predictor of group membership ($\chi^2 = 20.46$, df = 5, p< 0.01).

Table 3.19: Standardised canonical discriminant function coefficients

	Function 1
Dot.Canc^n	-0.13
CWS	0.63
IPA	0.38
Ccards	-0.45
RSRT	0.58

The Stroop Colour-Word Score (CWS), SDSA dot cancellation time (Dot.Canc^n) and the Information processing task 'A' score (IPA) were the variables most highly correlated with the discriminating function (see Table 3.20).

Table 3.20: **Pooled within groups' correlations between discriminating variables and canonical discriminant functions (variables ordered by size of correlation within function).**

	Function 1
CWS	0.79
Dot.Canc[n]	-0.78
IPA	0.68
RSRT	0.59
Ccards	0.44

The discriminating function successfully classified a total of 82.4% of the cases (see Table 3.21).

Table 3.21: Classification results

Actual group	No. of cases	Predicted Group membership	
		1 (Pass)	2 (Fail)
Pass	38	34 92%	3 8%
Fail	14	6 43%	8 57%

Overall 57% of those who failed and 92% of those who passed on the public road were correctly classified. Of the misclassified cases, three (8%) who passed the PRA were predicted to have failed and six (43%) who failed the PRA were predicted to have passed. Since one would expect 60.6% of cases to be correct by chance alone, the equation is substantially better than chance. Seven out of the 51 cases were misclassified (13.7%). Two of the misclassified cases performed well on the cognitive tests but failed the PRA due to eyesight or performance on the static rig. One performed poorly on the cognitive tests but had resumed driving for several months before having his licence revoked by the DVLA in confusion over the licensing laws. One who performed poorly

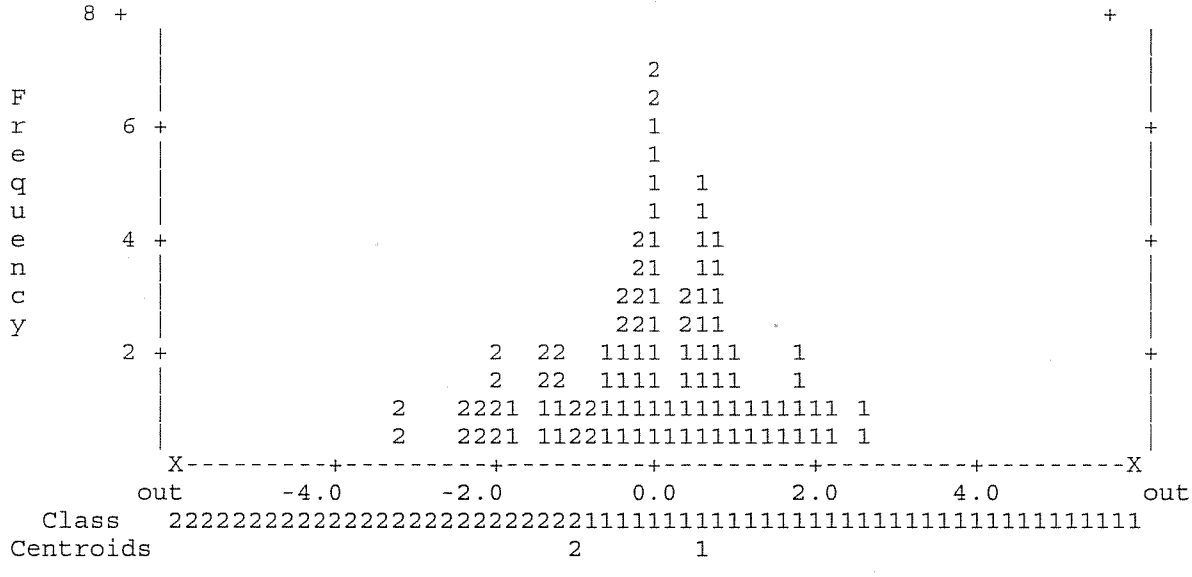
on the cognitive tests had worked as a taxi driver for many years and performed well on the PRA. Two who performed reasonably on some cognitive tests, yet poorly on others, failed the PRA, one of these had residual physical deficits. One person who performed poorly on tests of cognition, passed the PRA.

Table 3.22: Unstandardised canonical discriminant coefficients

	Function 1
Dot.Canc[n]	-0.04
CWS	0.00
IPA	0.02
Ccards	-0.06
RSRT	0.20
(constant)	-1.87

Figure 3.2 shows the combined groups plot of predicted group classification (1 = Pass, 2 = Fail) by the discriminant equation.

Fig. 3.2 Combined groups plot of Discriminant Classification.
All-groups Stacked Histogram
Canonical Discriminant Function 1



Key: 1 = Predicted Pass
2 = Predicted fail

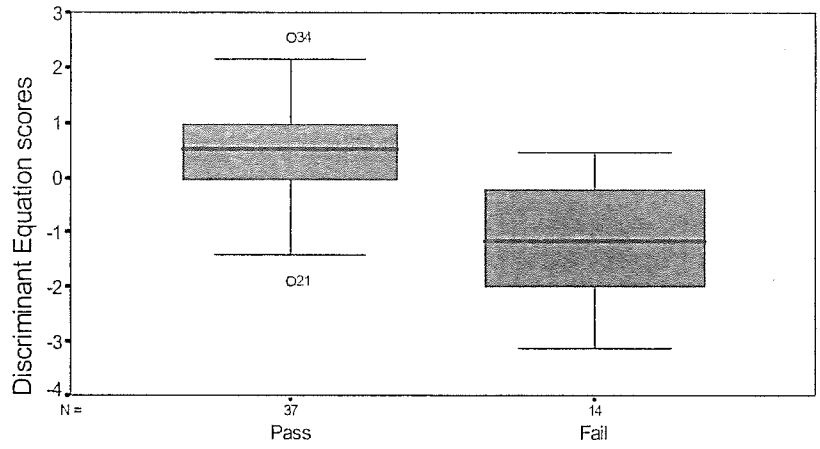
A discriminant equation (using the unstandardised canonical discriminant coefficients, see Table 3.22) was re-applied to the head injured subgroup (n = 51) to generate scoring norms. The distribution of scores was subdivided according to whether patients passed or failed the PRA. The mean, SD and range for the Pass and Fail groups are given in Table 3.23.

Table 3.23 Differences between scores for the pass and fail groups on the discriminant equation

Pass **n= 37**		**Fail** **n=14**	
mean	0.45	mean	-1.18
SD	0.98	SD	1.06
range	-1.90 - 2.56	range	-3.12 - 0.47

Scores for patients passing the PRA ranged from -1.90 to 2.56 and those failing ranged from -3.12 to 0.47 (see Fig. 3.2). Therefore, patients with a discriminant equation greater than 0.47 would be predicted to pass the PRA and those with a discriminant equation less than -1.9 would be predicted to fail the PRA (see Fig. 3.3). For patients scoring in the borderline range between -1.9 and 0.47, a PRA would be advised.

Fig. 3.3: Boxplots showing median, IQR and range of Discriminant Equation scores for head injured patients passing and failing the PRA.



3.4.3.5 Test order ANOVAs

Since the cognitive tests were administered neither in a set order nor truly randomly, Kruskall-Wallis one-way analysis of variance was carried out for each cognitive test to determine whether the stage of test administration had affected the test result. Complete information about the stage of administration (whether the tests were administered first, second, third, fourth or last) for all tests was available in 35 cases. Linear trends were anticipated owing to the overall time taken to administer the five tests. There were no significant differences in median test scores according to stage of administration, for any cognitive test. The results are given in Appendix 3.2.

3.4.4 Multiple Sclerosis (MS) group

Thirty-four patients completed all three assessments (17 men and 17 women). They had a mean age of 45.9 years (SD 10.4, range 24 - 69). The mean time since onset of the MS was 9.3 years (SD 9.82, range 0.09 – 33.9 years). They had a mean average of 23.8 years driving experience (SD 9.07, range 8 - 48). The median time since last having driven a car was 0 months (SD 15.03, range 0 – 72, mode 0).

No significant differences in age, time since onset of MS or number of years driving experience were found between those who had passed and those who had failed the PRA when tested using Mann-Whitney U tests (see Table 3.24). However, there was a sex difference between the groups ($\chi 2 = 4.48$, p=0.03). Significantly more women (n = 10) than men (n = 3) failed the PRA. The length of time since last having driven a car also differed significantly between the two groups (U = 77.5, p= 0.02). Patients who failed the PRA had longer mean duration time lapses since last having driven, than those who passed (see Table 3.24).

Table: 3.24 Comparison of demographic variables between 'Pass' and 'Fail' groups.

MS patients (n=34)

	Pass n= 21		**Fail n=13**		$\chi 2$	**p - 2 tailed**	**95% CI**
sex	men wom^{n}	14 7	men wom^{n}	3 10	6.10	0.03* Fe	
					U†		
age	mean SD range med. IQR	43.7 10.6 24 – 69 44 36 - 50	mean SD range med. IQR	49.5 8.6 36 – 65 48 42.5 - 57	88	0.09	-13.0, 1.0
time since onset (yrs)	mean SD range med. IQR	0.09– 32.1 3.9 1.4 - 11.4	mean SD range med. IQR	1.1 - 33.9 8.2 1.9 - 22.5	105	0.26	-122.3, 23.8
Mth's since drive^{n}	mean SD range med. mode IQR	5.1 9.5 0 – 33 0 0 0 - 9.5	mean SD range med. mode IQR	14.7 20.3 0 – 72 7 0 1 - 21	77.5	0.02*	-13.0, 0.0
years exper-ience	mean SD range med. IQR	22.3 10.4 8 – 48 23 14 - 27.5	mean SD range med. IQR	26.2 6.2 15 – 34 25 21.5 - 32	98	0.17	-11.0, 2.0

Key: '*' = p<0.05, † Mann -Whitney U test , Fe - Fishers exact, $\chi 2$ Chi Squared test, CI = Confidence Interval, SD = Standard Deviation, med. = median

All patients were living in the community at the time of assessment.

The mean time between cognitive testing and the PRA was 37.4 days, SD 38.75, range 1 - 213 days, median 32.5 days). Most (13) MS patients had difficulty walking, eight required some assistance with mobility, eight were independently mobile and five relied on a wheelchair. There were no significant differences in scores between the two groups for any EADL sub scale or the total score. Independence in mobility or other activities of daily life, as measured by the EADL index, did not discriminate between those who passed or failed the PRA. Results are shown in Table 3.25.

Table: 3.25 Comparison of PRA Pass group (Pass) and PRA fail group (Fail) on the Nottingham Extended ADL Index.

MS patients (n=34)

EADL	Pass n= 21		Fail n=13		U†	p - 2 tailed	95% CI
MOB	med. IQR range	8 6 – 13 4 - 17	med. IQR range	7 4.5 – 12 3 - 14	111	0.36	-2.0 - 4.0
KIT	med. IQR range	11 6 – 15 3 - 15	med. IQR range	12 8 – 14.5 5 - 15	134	0.91	-4.0 - 3.0
DOM	med. IQR range	9 3.5 – 12 2 - 15	med. IQR range	9 8 – 11 3 – 13	124	0.64	-5.0 - 2.0
LEI	med. IQR range	13 9 – 15 8 - 17	med. IQR range	10 8.5 – 12.5 6 - 15	97	0.15	-1.0 - 4.0
TOT	med. IQR range	40 27 – 51 21 - 59	med. IQR range	38 33.5 – 44 29 - 50	130	0.82	-8.0 - 11

† Mann -Whitney U test, MOB=mobility, KIT=kitchen, Dom=domestic, LEI= Leisure, TOT=Total score, , CI = Confidence Interval, SD = Standard Deviation, med. = median

3.4.4.1 Cognitive test results

The median , Inter-quartile range, and range for each of the cognitive test variables are shown separately for patients who passed and failed the public road assessment (see Tables 3.26 to 3.28). Mann Whitney 'U' tests were used to identify differences in cognitive test results between those who had passed and failed on the road.

Scores for the Dot Cancellation false positives (False +ve) and the Road Sign Recognition sub-tests (RSRT) of the SDSA differed significantly between the two groups. Patients who failed the PRA had significantly worse RSRT scores and significantly more False Positive errors. There were no significant differences between patients who passed and failed the PRA on the PASAT, the Stroop or the test of Motor Impersistence (Table 3.27). The Figure Copy, the Design Learning Interference score and the total and adjusted scores for both Information Processing sub tests of the AMIPB also differed significantly between the groups. None of the other cognitive tests differed significantly between the two groups.

Table: 3.26 **Comparison of PRA Pass group (Pass) and PRA fail group (Fail) on the Stroke Drivers Screening Assessment.**

Multiple sclerosis patients (n = 34)

SDSA	Pass n= 21		Fail n=13		U†	p – 1 tailed	95% CI
Dot Canc[n]	med. IQR range	487.7 374.6–693.5 278 – 900	med. IQR range	559.6 442.4–686.6 328.5 – 920	1090	0.16	-190.8, 73.0
Dot errors	med. IQR range	8 2 – 17 0 – 65	med. IQR range	10 3 – 22.5 1 – 52	114	0.21	-12.0, 4.0
Dot false +ve	med. IQR range	0 0 – 0 0 – 12	med. IQR range	1 0 – 5 0 – 40	77	<0.01	-3.0, -0.0
Sq. matrix Direc[n]	med. IQR range	32 27 – 32 10 – 32	med. IQR range	32 26 – 32 3 – 32	127	0.34	0.0, 4.0
Sq. matrix Ccards	med. IQR range	20 17 – 28 3 – 32	med. IQR range	20 9.5 – 24.5 2 – 28	106	0.14	-4.0, 10.0
RSRT	med. IQR range	9 5 – 12 2 – 12	med. IQR range	6 2.5 – 6.5 0 – 8	65	<0.01	1.0, 6.0
Total score	med. IQR range	1.6 -0.6 – 4.4 -6.9 – 6.1	med. IQR range	1.02 -3.2 – 2.7 -6.2 – 4.5	1060	0.14	-1.1, 4.0

Key: † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Table 3.27: Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the PASAT, STROOP and test of Motor Impersistence (MI).

Multiple sclerosis patients (n = 34)

	Pass n=21		Fail n=13		U†	p - 1 tailed	95% CI
PASAT Trial I	med. IQR range	48 29.5 – 56 7 – 60	med. IQR range	41 20 – 52.5 0 – 56	103	0.11	-2.0, 21.0
Trail II	med. IQR range	20 11.5–32.5 0 - 49	med. IQR range	13 4.5 – 31.5 0 - 39	111	0.18	-15.0, 7.0
STROOP Colour Score	med. IQR range	112 110 – 112 51 – 112	med. IQR range	112 110.5 – 112 11 – 112	133	0.44	0.0, 1.0
Colour - Word Score	med. IQR range	89 55 – 106.5 23 - 111	med. IQR range	74 43.5 – 93.5 27 - 105	104	0.13	-9.0, 33.0
MI	med. IQR range	420 404 – 440 299 - 440	med. IQR range	434 402 – 440 330 - 440	135	0.47	-20.0, 17.0

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Table: 3.28 Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the AMIPB.

Multiple sclerosis patients (n = 34)

AMIPB	**Pass n= 21**		**Fail n= 13**		U†	**p - 1 tailed**	**95% CI**
Story Recall Immd	med. IQR range	19 14.5 – 32 5 – 56	med. IQR range	23 15 – 29 3 - 37	135	0.48	-8.0, 11.0
Delay.	med. IQR range	19 13 – 28.5 4 – 49	med. IQR range	19 9.5 – 28.5 2 – 35	126	0.35	-8.0, 11.0
Figure Recall Copy	med. IQR range	76 75 – 76 74 - 76	med. IQR range	75 69 – 76 64 - 76	92	0.04*	0.0, 5.00
Immd	med. IQR range	62 48.5 – 66 27 – 76	med. IQR range	54 35 – 67 18 - 72	111	0.18	-6.0, 17.0
Delay	med. IQR range	53 40.5 – 64.5 0 – 76	med. IQR range	47 20.5 – 57 0 - 99	114	0.21	-8.0, 20.0

List learning Total	med. IQR range	46 36.5 – 55 11 – 63	med. IQR range	44 35.5 – 55 22 - 59	118	0.26	-7.0, 11.0
Recall	med. IQR range	9 6.5 – 11.5 2 – 14	med. IQR range	8 6 – 11.5 0 - 13	114	0.21	-2.0, 4.0
Inter-ference list	med. IQR range	6 3.5 – 7 3 – 14	med. IQR range	5 3.5 – 7 2 - 9	125	0.33	-1.0, 2.0
Intrusion errors	med. IQR range	2 0 – 4.5 0 – 9	med. IQR range	1 0 – 6.5 0 - 14	129	0.39	-3.0, 1.0
Design learning Total	med. IQR range	28 22 – 37 13 – 42	med. IQR range	33 23.5 – 38.5 13 - 42	115	0.22	-9.0, 5.0
Recall	med. IQR range	7 4 – 8.5 1 – 9	med. IQR range	7 4.5 – 7.5 2 - 9	124	0.32	-1.0, 2.0
Inter-ference list	med. IQR range	4 3 – 7 2 – 8	med. IQR range	3 1.5 – 5 0 - 6	85	0.03*	0.0, 3.0
Intrusion errors	med. IQR range	14 6.5- 27.5 3 – 40	med. IQR range	14 9 – 32 4 - 48	119	0.27	-1.0, 6.0
Info. Pro. 'A' Total score	med. IQR range	53 33 – 64 14 - 82	med. IQR range	36 31.3 – 45.6 30 – 71 (n = 12)	80	0.04*	-2.0, 25.0
Errors	med. IQR range	3.23 0 – 6.8 0 – 42.9	med. IQR range	2.76 0 – 9.9 0 – 24.3 (n = 12)	126	0.50	-3.9, 3.1
Speed	med. IQR range	39 28.5 – 49.5 12 – 57	med. IQR range	30.5 26 – 39.5 25 – 58 (n = 12)	94	0.12	-4.0, 14.0
Adjusted score	med. IQR range	60.3 39.7 – 76.3 11.5 – 101.1	med. IQR range	37.2 23.9 – 54.7 10.3 – 80.2 (n = 12)	70	0.02*	-1.4, 27.5
Info. Pro. 'B' Total score	med. IQR range	54 35 – 66 11 – 87	med. IQR range	33.5 22.3 – 49.3 10 – 66 (n = 12)	71	0.02*	1.01, 31.0
Errors	med. IQR range	0 0 – 2.7 0 – 72.7	med. IQR range	1 0 – 8.3 0 – 30 (n = 12)	109	0.25	-5.19, 0.50

Speed	med. IQR range	41 30 – 51 8 – 54	med. IQR range	29.5 27 - 45.3 24 – 57 (n = 12)	92	0.10	-5.0, 15.0
Adjusted score	med. IQR range	58.9 37.6 – 73.6 15 – 95	med. IQR range	39.4 33.9 – 52.6 32.6 – 79.1 (n = 12)	78	0.04*	0.4, 37.3

Key: '*' = $p<0.05$, † Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

The Figure Copy, Design Learning Interference score and the total and adjusted scores for both Information Processing sub-tests 'A' and 'B' of the AMIPB differed significantly between the two groups at the 5% level. Those who failed the PRA scored significantly worse on those sub tests.

3.4.4.2 Crosstabs

The prediction made by the SDSA was cross-tabulated with the outcome of the PRA to see whether the SDSA correctly classified patients according to the PRA gradings. Five patients did not progress to the public road assessment because their eyesight did not meet the legally required standard for driving (n = 1) or because they were considered by the DRMC technician to have inadequate power or speed of movement in the limbs to control a motor vehicle (n = 4). These patients were categorised as 'Fail'. One patient's drive was restricted to the grounds of the hospital, as she had not mastered driving with hand controls. She was considered unfit to drive on the public road and classified as 'Fail'. The classification results are given in Table 3.29.

Table: 3.29 Correlational analysis showing classification results of SDSA for patients with multiple sclerosis

Outcome Public Road Assessment	No. of cases	SDSA Prediction Pass	Fail
Pass	21	15	6
Fail	13	7	6

Sensitivity: 50%

Specificity: 68.2%

Accuracy: 61.8%

Of the 21 patients who passed on the public road, 15 were correctly classified by the SDSA (Specificity 68.2%) but only six out of the 13 who failed were predicted to have failed (Sensitivity 50%). Agreement between the SDSA prediction and the PRA outcome was measured using Kappa. Agreement was 'Poor' (Altman, 1997), $\kappa = 0.18$, approximate significance 0.30). Of the misclassified cases, six people who were predicted to fail actually passed the PRA and seven of those predicted to pass, failed the PRA. The overall accuracy of prediction made by the SDSA was 62%.

One of those predicted to fail the PRA was not assessed on the public road because his eyesight did not meet the legally required standard for driving. Patients who were not assessed on the PRA because their power and speed of movement in the limbs, as measured by the static rig, were considered insufficient to operate a motor vehicle all failed the SDSA.

3.4.4.3 Discriminant analysis

A direct discriminant functions analysis was conducted using those tests found to be significantly different between the PRA outcome (Pass or Fail), as predictor variables. These were the Dot Cancellation false positive score (False

+ve) and the Road Sign Recognition test (RSRT) from the SDSA, the Design Learning interference Score (DLI) and the information processing task 'B' adjusted score (IPB) from the AMIPB.

Prior to analysis, individual cognitive test variables were examined for accuracy of data entry, missing values and fit between their distributions and the assumptions of discriminant function analysis.

Although Figure Copy (FC) and information Processing task 'A' (IPA) also differed significantly between the two groups, examination of the assumptions of normality revealed FC was significantly skewed in both the Pass (K-S Lilliefors 0.26, $p < 0.001$) and Fail (K-S Lilliefors 0.24, $p < 0.05$) groups due to a ceiling effect on the test and it was subsequently excluded from the analysis. IPA was also excluded because of singularity, since both IPB and IPA are measures of information processing skills.

RSRT, IPB and DLI were normally distributed for both the Pass and Fail groups. False +ve was significantly skewed by outliers in both the Pass and Fail groups. Examination of outlying cases revealed these to be patients with motor control problems in the upper limb, who had incurred false positive errors by cancelling groups of three and five dots due to poor motor control (their pen didn't stop) when cancelling groups of four dots. The cases were re-scored and False +ve transformed using a square root transformation to improve fit with the assumptions of multivariate analysis. Although transformation improved the distribution, it remained significantly skewed (K-S Lilliefors 0.51, $p < 0.001$). However, because normality was violated by skewness rather than by outliers and one would expect skewness to occur in a wider population, the test was retained in the analysis. Values for IPB were missing in one case and replaced by the mean.

For the 34 patients (21 who passed and 13 who failed the PRA) in the analysis, evaluation of assumptions of linearity and multicollinearity revealed no threat

to multivariate analysis. Box's M was used to examine homogeneity of variance-covariance matrices and was not found to be significant (p= 0.06), suggesting homogeneity.

During classification, unequal sample sizes were used to modify the probabilities with which cases are classified into groups. The means and standard deviations for the predictor variables are reported in Table 3.30.

Table: 3.30 Means and standard deviations (SD) for MS patients in the 'Pass' and 'Fail' groups on the predictor variables (cognitive tests).

	Pass Group n=21		Fail Group n=13	
	Mean	**SD**	**Mean**	**SD**
IPB	57.63	24.21	39.80	21.09
DLI	4.81	2.02	3.23	2.01
False +ve	0.14	0.36	0.82	0.95
RSRT	8.33	3.57	4.69	2.78

Univariate F-tests for differences between the groups were found to be significant for the Road Sign Recognition (RSRT) and Dot Cancellation false positives (False +ve) and the Information Processing task 'B' score (IPB) from the AMIPB. DLI by itself did not differ significantly between the groups (see Table 3.31).

Table: 3.31 Univariate F tests for differences between Pass and Fail groups on cognitive test variables

	F	significance
IPB	4.53	0.04
DLI	3.43	0.07
RSRT	7.91	0.01
False +ve	3.99	0.01

The discriminant analysis produced a linear function with the following standardised coefficients (see Table 3.32). This was found to be a significant predictor of group membership ($\chi 2 = 13.166$, df = 4, p= 0.01).

Table: 3.32 Standardised canonical discriminant function coefficients

	Function 1
IPB	-0.10
DLI	0.23
RSRT	-0.81
False +ve	0.73

The Dot Cancellation false positives, Road Sign Recognition test and Information Processing task 'B' score were the variables most highly correlated with the discriminating function (see Table 3.33).

Table: 3.33 Pooled within groups correlations between discriminating variables and canonical discriminant functions (variables ordered by size of correlation within function).

	Function 1
False +ve	0.70
RSRT	-0.67
IPB	- 0.50
DLI	-0.44

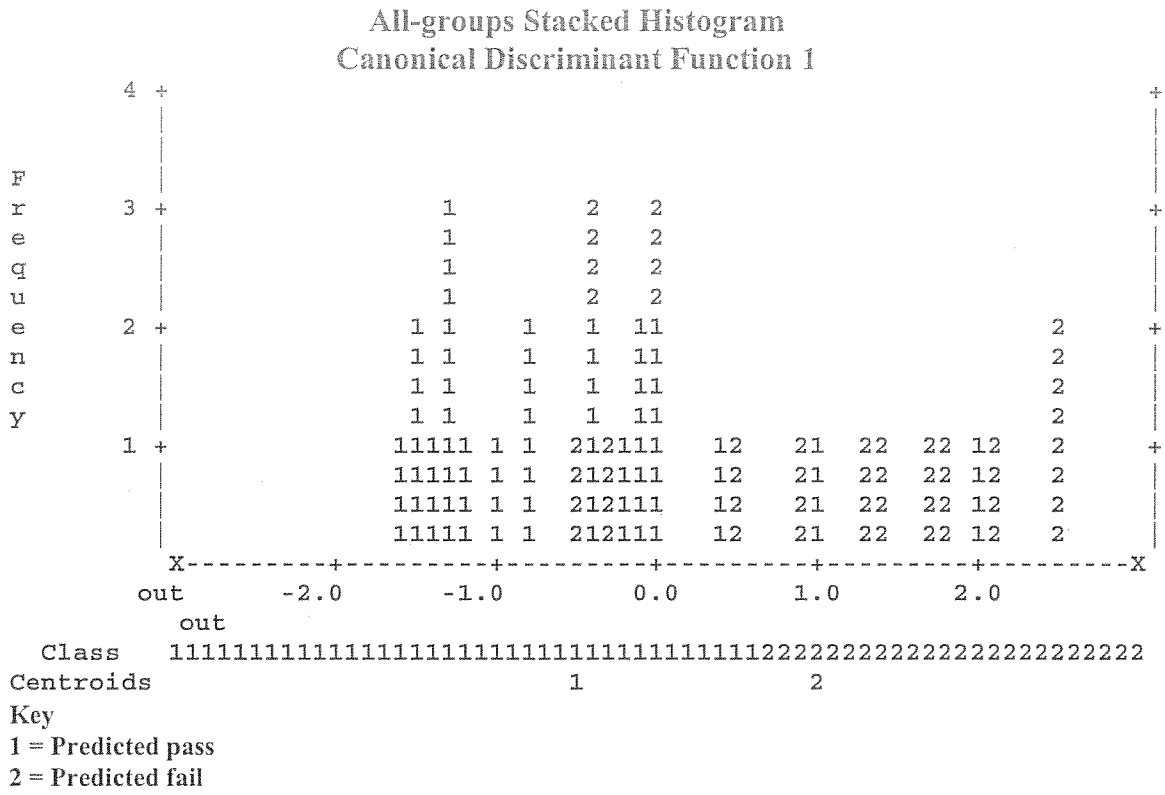
The discriminating function successfully classified a total of 79.4% of all the cases (see Table 3.34)

Table: 3.34 **Classification results of MS patients by discriminant equation**

	Cases	Predicted Group Membership	
Actual group		**Pass**	**Fail**
Pass	21	19 90.5 %	2 9.5%
Fail	13	5 38.5%	8 61.5%

Overall 61.5 % of those who failed on the public road were correctly classified and 90.5% of those who passed on the public road were correctly classified. Of the misclassified cases, two (9.5%) who passed the PRA were predicted to have failed and five (38.5%) who failed the PRA were predicted to have passed. Since one would expect 52.8% of cases to be correct by chance alone, the equation is substantially better than chance. Seven (20.6%) of the 34 patients were misclassified. Of the five who performed well on the cognitive tests, yet failed the PRA, all had deteriorated physically (four progressively, one had relapsed) resulting in the need for assessment, two of them had stopped driving whilst awaiting assessment. Four required adaptations to the vehicle to enable them to drive or continue driving. On the basis of their former occupations as chemist, pharmacist, university lecturer, teacher and personal secretary, all five could have been considered to have an above average IQ. One of those who performed poorly on the cognitive assessments, yet passed the PRA, had had his licence revoked pending re-assessment of his medical fitness to drive after involvement in a collision. This patient is also reflected as an outlier on the discriminant pass equation boxplot (see Fig. 3.5). The other was a current driver but without distinguishing features.

Fig. 3.4 **Combined groups plot showing classification to group by discriminant equation**



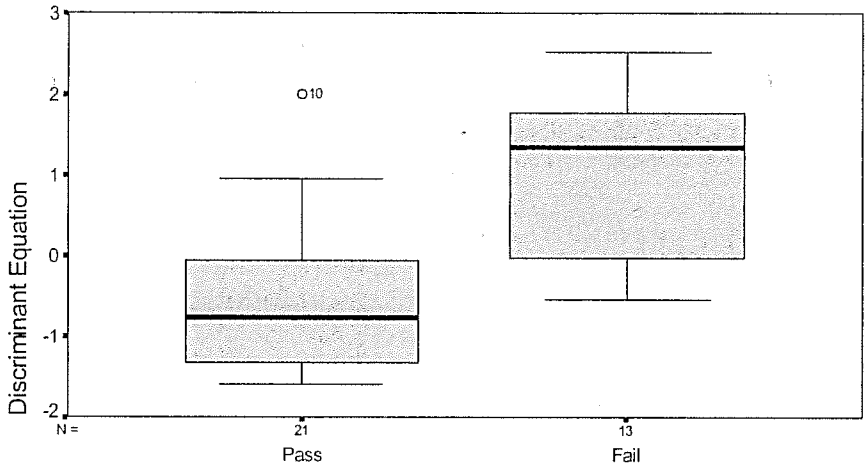
The discriminant equation (using the unstandardised canonical discriminant coefficients) was re-applied to the MS subgroup (n = 34) to determine whether cases were correctly classified and to generate a set of scoring norms. The distribution of scores was subdivided according to whether patients passed or failed. The median, Inter-quartile range and range for the Pass and Fail groups are given in Table 3.35.

Table 3.35 Differences between scores for the Pass and Fail groups on the discriminant equation

Pass n= 21		**Fail n=13**	
med. IQR range	-0.78 -1.33 - -0.04 -1.59 - 2.01	med. IQR range	1.35 -0.19 - 1.95 -0.54 - 2.52

Scores for patients passing the PRA ranged from -1.59 to 2.01and those failing the PRA, ranged from -0.54 to 2.52 (see Fig.3.4). Therefore, patients with a discriminant equation of less than -0.54 would be predicted to pass the PRA and those with a discriminant equation greater than 2.01 would be predicted to fail the PRA (see Fig. 3.2). For patients scoring in the borderline range between -0.54 and 2.01, a PRA would be advised.

Fig 3.5 Boxplot showing, median, IQR and range of Discriminant Equation scores for MS patients passing and failing the PRA



3.4.4.4 Test Order ANOVAs

As with the head injured group Kruskall Wallis one way analysis of variance was used to determine whether the stage of cognitive test administration had affected the test result. Complete information about the stage of administration for all tests was available in 21 cases. Among MS patients, there was a significant difference between groups for the Dot Cancellation errors of the SDSA. However there was no trend in the median scores for the groups, therefore this was assumed to be a chance finding. Median Dot cancellation error scores for each group are shown in Table 3.36. There were no significant differences in test scores according to stage of administration for any of the other cognitive tests.

Table 3.36: **Dot Cancellation median scores, grouped according to stage of test administration.**

Order	Count	Median	IQR	Range
First	6	14.5	8.8 - 29.5	5 - 52
Second	2	2.5		2 - 3
Third	1	1		1 - 1
Fourth	6	9.5	2.3 - 33.5	0 - 65
Fifth	6	3.5	2 - 5.5	2 - 7

3.4.5 Parkinson's disease group

Seven patients completed all three assessments (five men and two women). Their mean age was 67.7 years, (SD 6.42, range 56 -75). The mean time since diagnosis of Parkinson's disease was 6.4 years, (SD 7.4, range 1.2 - 22.2 years). Patients had an average of 40.6 (SD 7.6, range 30 - 53) years driving experience. The mean time since last having driven a car was 4 months (SD 7.3, range 0 -18). Most (4) of them were current drivers, one had not driven for six months and one for 18 months. This information was missing in one case. The mean time between cognitive testing and the PRA was 16.6 days, SD 9.25, range 4 -34, days. There were no significant differences in age, sex, time since onset of PD, number of years driving experience or in time since last having driven (see Table 3.37) between patients who passed or failed the public road test.

Table 3.37: Comparison of demographic variables between 'Pass and 'Fail' groups

PD group (n = 7)

	Pass n= 4		Fail n= 3		U†	p - 2 tailed	95% CI
sex	men womⁿ	3 1	men womⁿ	2 1	χ^2 0.1	1.0 (Fe)	
age	med. IQR range	68 57.8 - 74.5 56 - 75	med. IQR range	69 68 70 68 - 70	6.0	1.0	-14.0, 7.0
years since onset	med. IQR range	6.3 1.90 - 18.8 1.2 - 22.2	med. IQR range	2 1.9 - 4.6 1.9 - 4.6	3.5	0.37	-3.4, 20.3
Mth's since drivⁿ	med. IQR range	3 0 - 15 0 - 18	med. IQR range	0 0 - 0 0 - 0	2.0	0.27	
years exper -ience	med. IQR range	41.5 31.8 - 51.3 30 - 53	med. IQR range	40 35 - 43 35 - 43	5.0	0.72	-12.9, 18.0

† Mann -Whitney U test, Fe - Fishers exact, CI = Confidence Interval, SD = Standard Deviation, med. = median

All patients were living at home in the community at the time of assessment. Three were able to walk outside independently, one had difficulty walking and two required help. Differences in scores between patients who passed and patients who failed the PRA, on the EADL are given in Table 3.38. There were no significant differences in EADL sub scale or total scores between patients who passed and failed the PRA. EADL scores were missing in one case.

Table: 3.38 Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Nottingham Extended ADL Index.

PD subjects (n=7)

EADL	Pass n=4		Fail n= 3		U†	p - 2 tailed	95% CI
MOB	med. IQR range	14 3 - 14 3 - 14	med. IQR range	5 4 - 15 4 - 15	4.0	1.0	-12.0, 10.0
KIT	med. IQR range	11 3 - 13 3 - 13	med. IQR range	12 8 - 14 8 - 14	3.0	0.7	-11.0, 5.0
DOM	med. IQR range	9 0 - 11 0 - 11	med. IQR range	3 0 - 11 0 - 11	4.0	1.0	-11.0, 11.0
LEI	med. IQR range	15 5 - 16 5 - 16	med. IQR range	9 2 - 15 2 - 15	2.5	0.4	-10.0, 14.0
Total Score	med. IQR range	49 11 - 54 11 - 54	med. IQR range	29 14 - 55 14 - 55	4.0	1.0	-44.0, 40.0

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median, MOB=mobility, KIT=kitchen, Dom=domestic, LEI= Leisure, TOT=Total score

3.4.5.1 Cognitive test results

Tables 3.39 - 3.41 show differences between the Pass and fail groups for each of the cognitive tests using Mann-Whitney U tests. There were no significant differences in scores between PD patients who passed and those who failed the PRA for any of the cognitive tests.

Table 3.39 **Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the Stroke Drivers Screening assessment.**

PD patients (n = 7)

SDSA	Pass n= 4		Fail n= 3		U†	p– 1 tail[d]	95% CI
Dot Canc[n]	med. IQR range	487.5 384 - 808 381 - 883	med. IQR range	556 412 - 703 412 - 703	5.0	0.86	-321.9, 470.9
Dot errors	med. IQR range	14 8.8 - 18.5 7 - 20	med. IQR range	10 6 - 38 6 - 38	5.0	0.86	-31.0, 13.9
Dot false +ve	med. IQR range	1 0 - 7 0 - 5.5	med. IQR range	2 1 - 2 1 - 2	4.0	0.63	-2.0, 6.0
Sq. matrix Direc[n]	med. IQR range	26 19 - 32 19 - 32	med. IQR range	25 8 - 30 8 - 30	4.0	0.63	-11.0, 24.0
Sq. matrix Ccards	med. IQR range	11 3.5 - 20 2 - 22	med. IQR range	12 12 - 24 12 - 24	5.5	0.86	-12.0, 10.0
RSRT	med. IQR range	3.5 1.3 - 5.8 1 - 6	med. IQR range	7 2 - 7 2 - 7	2.5	0.23	-6.0, 4.0
Total score	med. IQR range	-3.03 -4.4 - 0.5 -4.8 - 1.5	med. IQR range	-1.2 -3.1 - -0.3 -3.1 - -0.3	4.0	0.63	-4.5, 4.6

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Table: 3.40 **Comparison of PRA pass and fail group on the PASAT, Stroop and Motor Impersistence.**

PD patients (n = 7)

PASAT	Pass n=4		Fail n=3		U†	p - 1 tailed	95% CI
Trial I	med. IQR range	46.5 33.8-57.8 33 - 58	med. IQR range	54 46 - 58 46 - 58	4.5	0.63	-25.0, 12.0
Trail II	med. IQR range	16 7.3 - 27.8 7 - 29	med. IQR range	18 11 - 26 11 - 26	5.0	0.86	-19.0, 18.0
Stroop Colour Score	med. IQR range	111 110.3-111.8 110 - 112	med. IQR range	112 107 - 112 107 - 112	5.0	0.86	-2.0, 5.0
Colour Word score	med. IQR range	78 59.3 - 98.3 54 - 104	med. IQR range	56 42 - 95 42 - 95	4.0	0.63	-41.0, 62.0
Motor Imper sistence	med. IQR range	425.5 413 - 438.8 412 - 440	med. IQR range	440 415 - 440 415 - 440	4.0	0.63	-28.0, 25.0

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

Comparisons between PD patients who passed and those who failed the PRA on the AMIPB sub tests revealed no significant differences between the two groups (Table 3.41).

Table 3.41 Comparison of PRA pass group (Pass) and PRA fail group (Fail) on the AMIPB.

PD patients (n = 7)

	Pass n= 4		**Fail n= 3**		**U†**	**p - 1 tail[d]**	**95% CI**
Story Recall Immd	med. IQR range	29.5 17.8 - 37.5 15 - 39	med. IQR range	23 20 - 40 20 - 40	6.0	1.0	-25.0, 19.0
Delay.	med. IQR range	30 16.3 - 33.5 13 - 36	med. IQR range	19 18 - 36 18 - 36	5.5	0.86	-23.0, 18.0

% retain	med. IQR range	96.2 88.1 - 102.3 86.7 - 103	med. IQR range	90 82.6 - 90 82.6 - 90	2.0	0.23	-3.3, 20.4
Fig. Recall Copy	med. IQR range	76 70.8 - 76 69 - 76	med. IQR range	73 72 - 76 72 - 76	4.5	0.63	-7.0, 4.0
Immd	med. IQR range	50 32 - 56.8 28 - 57	med. IQR range	57 26 - 63 26 - 63	4.5	0.63	-35.0, 31.0
Delay	med. IQR range	42.5 33 - 65 32 - 57	med. IQR range	37 18 - 68 18 - 68	6.0	1.0	-36.0, 39.0
List learn. Total	med. IQR range	38 29.8 - 38 28 - 52	med. IQR range	45 22 - 51 22 - 51	6.0	1.0	-23.0, 30.0
Recall	med. IQR range	7 4 - 10.8 4 - 11	med. IQR range	8 4 - 13 4 - 13	5.0	0.86	-9.0, 7.0
Inter-feren	med. IQR range	6.5 5.3 - 7.8 5 - 8	med. IQR range	3 0 - 10 0 - 10	4.0	0.63	-5.0, 8.0
Intru-sion errors	med. IQR range	1.5 0.3 - 3.5 0 - 4	med. IQR range	2 1 - 3 1 - 3	5.0	0.86	-3.0, 3.0
Des learn. Total	med. IQR range	31 19.5 - 41 17 - 43	med. IQR range	18 14 - 41 14 - 41	4.0	0.63	-24.0, 29.0
recall	med. IQR range	7 4.8 - 8.5 4 - 9	med. IQR range	4 3 - 7 3 - 7	2.5	0.23	-3.0, 6.0
Inter-feren list	med. IQR range	6 3.5 - 7 3 - 7	med. IQR range	3 2 - 4 2 - 4	1.5	0.11	-1.0, 5.0
Intru-sion errors	med. IQR range	17.5 5.8 - 45.8 5 - 52	med. IQR range	25 5 - 28 5 - 28	5.5	0.86	-23.0, 47.0
Info. Pro. 'A' Total	med. IQR range	45.5 28 - 60 27 - 60	med. IQR range	48 42 - 52 42 - 52	6.0	1.0	-25.0, 18.0
Errors	med. IQR range	3.3 0.8 - 6.4 0 - 7.4	med. IQR range	4.2 2.4 - 5.8 2.4 - 5.8	5.0	0.86	-5.8, 5.0
Speed	med. IQR range	35 31 - 38.3 30 - 39	med. IQR range	32 23 - 59 23 - 59	5.0	0.86	-29.0, 16.0

Adjust score	med. IQR range	51.2 30.2 - 69.5 29 - 70	med. IQR range	54.9 49.5 - 56.1 50 - 56	6.0	1.0	-26.9, 20.1
Info. Pro. 'B' Total	med. IQR range	50 34.8 - 63.8 34 - 64	med. IQR range	34 27 - 69 27 - 69	4.5	0.63	-35.0, 37.0
Errors	med. IQR range	1.6 0.4 - 2.6 0 - 3	med. IQR range	0 0 - 2.9 0 - 3	4.0	0.63	-2.9, 2.9
Speed	med. IQR range	31.5 30.3 - 36.5 30 - 38	med. IQR range	39 25 - 47 25 - 47	4.0	0.63	-17.0, 13.0
Adjust score	med. IQR range	57.8 38.4 - 75.1 37.4 - 75.4	med. IQR range	38.4 28.7 - 78.6 28.7 - 78.6	5.0	0.86	-41.2, 46.7

† Mann -Whitney U test, CI = Confidence Interval, SD = Standard Deviation, med. = median

3.4.5.2 Crosstabs

The prediction made by the SDSA was cross-tabulated with the overall outcome of the public road assessment (see Table 3.42).

Table 3.42 Correlational analysis showing classification results of SDSA for patients with Parkinson's Disease

Outcome Public Road Assessment	**No. of cases**	**SDSA Prediction**	
		Pass	**Fail**
Pass	4	1	3
Fail	3	0	3

Sensitivity: 100%

Specificity: 25%

Accuracy: 57.1%

One out of the four patients who passed the PRA was correctly classified by the SDSA (specificity 25%) and all three of those who failed were correctly

classified (Sensitivity 100%). The overall accuracy of prediction made by the SDSA was 57%. Of the misclassified cases, three who were predicted to fail actually passed the PRA. Agreement between the SDSA prediction and PRA outcome, measured by Kappa, was 'Fair', ($\kappa = 0.22$, approximate significance 0.35).

3.4.6 Dementia group

Out of eighteen patients referred to DRMC for an assessment of their fitness to drive, six were persuaded to stop driving or sold their car and withdrew from the study prior to assessment. One refused consent and one was seen by DRMC at the urgent request of the DVLA without the researcher's knowledge.

Ten patients were recruited and completed all assessments. Their mean age was 68.6 years, (SD 12.48, range 52 - 89 years) and (nine were men). Four patients were referred to the DRMC for assessment by the DVLA, five referred themselves or were encouraged by relatives, one was referred by his GP. Information about the nature of the dementia was taken from referral letters and medical reports submitted to the DRMC. Two patients had a diagnosis of Alzheimer's Disease, three had cerebral atrophy, one had cerebral ischaemia, one had multi-infarct dementia, two were referred because of confusion (according to police reports) and one 'other' dementia was recorded. Time since onset of dementia was recorded for nine patients. The mean time since onset was 27.3 months, (SD 45.41, range 3.6 - 145.7). Half of the patients were current drivers; half had not driven for some time (mean 7.7 months, SD 12.42, range 0 - 36 months). They had a mean average of 45 years driving experience (SD 13.75, range 25 - 72 years).

All except one of the patients were living at home at the time of assessment. One lived in a residential home for the elderly. Nine were independently mobile and one had difficulty walking. Scores for the Nottingham EADL are

given in Table 3.43. There were insufficient numbers of patients to make comparisons between those who had passed with those who had failed the PRA.

Table 3.43 Scores for dementia patients on the Nottingham Extended ADL Index

Dementia subgroup (n = 10)

EADL		
MOBILITY	median IQR range	15 14.3 - 18 8 - 18
KITCHEN	median IQR range	15 9 - 15 6 - 15
DOMESTIC	median IQR range	7 4.8 - 12.3 3 - 15
LEISURE	median IQR range	11 7.8 - 15.3 3 - 17
Total Score	median IQR range	43 38.5 - 59 33 - 62

IQR = inter-quartile range

3.4.6.1 Cognitive test results

Median, inter-quartile range and range for each of the cognitive test variables are given in Tables 3.44 to 3.45. Two patients did not complete all of the cognitive tests, one became distressed and one was unable to follow the instructions. One patient refused to continue with the AMIPB List Learning task. Only two of the patients who completed all of the cognitive tests did so in one sitting. Two visits were made to each of six patients. There were insufficient numbers of patients (only one passed the PRA) to compare cognitive test results for those who had passed with those who had failed.

Table 3.44 **Cognitive test scores for dementia patients on the Stroke Drivers Screening assessment.**

Dementia subgroup (n = 10)

SDSA	n = 10	
Dot cancellation time	med. IQR range	633.2 417.7 - 800 330 - 900
Dot cancellation errors score	med. IQR range	13 10.8 - 27.5 1 - 111
Dot cancellation false positives	med. IQR range	2 0 - 4.8 0 - 110
Square Matrices directions	med. IQR range	10.5 4.8 - 26.5 3 - 32
Square Matrices compass cards	med. IQR range	8.5 5.8 - 10.3 4 - 12
Road Sign Recognition test	med. IQR range	2 1 - 4.8 0 - 7
Total score	med. IQR range	-3.22 -4.28 - 1.23 -6.14 - 14.48

IQR = inter-quartile range

When scores for the SDSA sub tests were compared to stroke patients who failed the public road assessment in the development work, dementia patients performed slightly better on the Dot Cancellation test. They took less time to complete and scored fewer errors and false positive errors. This was anticipated, since Dot Cancellation predominantly measures visuo-spatial neglect, which is prevalent after stroke. However, demented patients performed much worse on both Square Matrix tests (Directions; Mean 15.2 , Compass Cards; Mean 8.1) than stroke patients (Directions; Mean 23.9 , Compass Cards; Mean 10.6) and comparatively poorly on the road sign recognition test, suggesting more extensive damage to the frontal lobes and more grossly impaired executive and attentional abilities among the dementia

group. These findings indicate that cognitive skills, which are important for safe driving in stroke patients are also detrimentally affected in patients with dementia, although the degree of impairment differs. The unique combination of impairments and the extent to which they affect driving ability in patients with dementia has yet to be established.

On the Stroop Colour Word test, all ten patients scored less than the designated 'cut off' score of 62, suggesting the presence of brain damage and 'moderate' dementia (Lezak, 1995). The one patient who passed the PRA, scored only 39/112 on the Colour Word test. The patient with the highest score (47) failed the PRA.

None of the patients who completed the test of Motor Impersistence achieved the full score of 440. This suggests motor impersistence was prevalent in varying degrees of severity amongst the dementia subgroup. The results reflect impaired self-control and distractibility as indicated by the inability to persevere in one or more of the tasks.

Table 3.45 **Cognitive test scores for dementia patients on the Stroop, Motor Impersistence and PASAT tests.**

Dementia subgroup (n =9)

STROOP	n = 9	
Colour Score	med. IQR range	110 108 - 112 88 - 112
Colour- Word Score	med. IQR range	19 0.50 - 32.5 0 - 47
Motor Impersistence	n = 8	
	med. IQR range	412.5 389 - 427.5 375 - 433
PASAT	n = 8	
Trial 1	med. IQR range	13.5 2.8 - 28.8 0 - 31
Trial 2	med. IQR range	4 0 - 14.8 0 - 22

med. = median, IQR = inter-quartile range

Scores for the PASAT showed marked impairment in information processing ability and an inability to divide attention.

Table 3.46: Cognitive test scores for dementia patients on the AMIPB.

Dementia subgroup (n=10)

Story Recall	Immediate recall	med. IQR range	4.5 2 - 10.3 0 - 21 (n = 8)
	Delayed recall	med. IQR range	0 0 - 12 0 - 15
Fig. Recall	Copy	med. IQR range	73 66 - 75.5 40 - 76 (n = 9)

	Immediate recall	med. IQR range	25 16.5 - 57 0 - 69
	Delayed recall	med. IQR range	16 0 - 47 0 - 63
List learning	Total	med. IQR range	22.5 13.8 - 24.8 1 - 29 (n = 8)
	Delayed recall	med. IQR range	1 1 - 5 0 - 5 (n = 7)
	Interference list	med. IQR range	4 1 - 5 1 - 5 (n = 7)
	Intrusion errors	med. IQR range	2 0.3 - 4 0 - 8 (n = 8)
Des learning	Total	med. IQR range	16 11 - 20.5 5 - 24 (n = 8)
	Recall	med. IQR range	3 2 - 5.8 0 - 7
	Interference list	med. IQR range	2 1 - 3 1 - 3
	Intrusion errors	med. IQR range	14 6 - 44.5 2 - 76
Info. Pro. 'A'	Total score	med. IQR range	42 32 - 47.5 30 - 51 (n = 8)
	Errors	med. IQR range	9.6 1 - 13.1 0 - 83.3
	Speed	med. IQR range	35 30.5 - 44.8 30 - 50
	Adjusted score	med. IQR range	46 34.9 - 53.6 31.8 - 56.5

Info. Pro. 'B'	Total score	med. IQR range	31 18.3 - 35 15 - 37 (n = 8)
	Errors	med. IQR range	0 0 - 4.3 0 - 60
	Speed	med. IQR range	34.5 31.3 - 44.3 30 - 51
	Adjusted score	med. IQR range	33.7 19.3 - 38.2 15.4 - 39.9

med. = median, IQR = inter-quartile range

Median scores for the AMIPB fell within the anticipated range for the age group on both information processing tasks, the Design Learning task and the Figure Recall task. Scores for the Story Recall task were below the 10th percentile and below the two standard deviation cut off for the immediate and delayed recall respectively. Scores for the List Learning task also fell below the two Standard Deviation cut off for both the total number of words recalled and words recalled after a delay, although scores for the interference list and number of intrusion errors fell between the 25 - 50 percentile. The results suggests that all 10 patients were severely impaired on verbal modality memory tests.

3.4.6.2 Crosstabs

The SDSA prediction was compared to patients' performance on the public road test. Results are shown in Table 3.47.

Table 3.47 **Comparison between SDSA classification and road test grading**

		PRA Outcome	
		Pass	**Fail**
	Pass	0	1
SDSA	**Fail**	1	8

The overall performance of the SDSA as a predictive assessment of being 'unsafe to drive' was: -

Sensitivity: 89%

Specificity: 0%

Accuracy: 80%

The SDSA was able to predict those who failed the PRA in 89% of cases. The overall prediction accuracy was 80%. Agreement, measured by Kappa, was 'poor', (κ = -0.11, approximate significance 0.73). Two patients were misclassified. One, who was predicted to Fail, passed the PRA and one, who was predicted to Pass by the SDSA, failed the PRA. The patient who was predicted to pass but failed the PRA, scored outside the anticipated range of scores for both the dot cancellation errors and false positives of the SDSA. Instead of cancelling out the groups of four dots as instructed, he joined together the dots in each group of three, four and five dots, resulting in abnormally high False positive and error scores, which fell outside the range of scores for stroke patients in the SDSA development.

3.4.7 Public Road Assessment

For all patients, driving faults were ranked separately for patients who passed and failed the public road assessment. Minor faults were scored 1, major faults 2 and where both major and minor faults were recorded for a road manoevre, a

score of 3 was allocated. The sum of scores for each road manoeuvre was used for ranking.

3.4.7.1 Head injured group

The cumulative driving faults made by the 48 head injured patients who completed the PRA are shown in Table 3.48. The faults most frequently observed in patients with a head injury were, positioning on the road, observations to rear and driving in traffic lanes. Other commonly recorded faults were cornering, use of signals and driving on roundabouts. The greatest number of major faults was observed in road positioning.

Table 3.48 Faults recorded on the PRA specific test points for head injured patients who completed the PRA.

	Minor Fault	Major Fault		Minor Fault	Major Fault
Starting precautions	4		Passing static vehicles	4	2
Moving off	3		Merging with traffic stream	2	5
Observations at side to junctions	5	2	Anticipation pedestrian behaviour	2	1
Observations to rear	11	3	Anticipation behav. of other road users	3	
Use of signals	8	3	Use of speed	8	3
Positioning on road	8	7	Obedience of road signs	2	
Cornering	6	4	Observation of speed limits	5	2
Braking	4	3	Courtesy		
Accelerating	5	3	Emergency Stop	4	2
Overtaking (inc. cyclists)	2		Reversing	7	3
Driving on roundabouts	8	3	Parking vehicle	4	2
Driving in traffic lanes	7	5	Turning right	3	
			Following too close	4	

Other additional documented mistakes included one minor and one major fault with steering and one major fault with the patient's 'attitude' towards driving. The driving situations, which presented most problems for head injured patients passing and failing the PRA were ranked according to frequency of occurrence and severity –(major faults afforded greater weight). Head injured patients who passed incurred more faults with Observations to the rear, Use of

signals and Driving in traffic lanes and those who failed with Road positioning, Use of speed and Merging with traffic streams (see Table 3.49).

Table 3.49 Driving faults incurred by HI patients passing and failing the PRA (ranked according to frequency of occurrence and seriousness).

'Pass'	'Fail'
1. Observations to the rear/Use of signals	1. Positioning on the road
3. Driving in traffic lanes	2. Use of speed
4. Positioning on the road/ Reversing	3. Merging with traffic streams, cornering, accelerating
6. Driving on roundabouts/ Observation of speed limits	6. Driving on roundabouts, Driving in traffic lanes, Observations to the rear.
8. Cornering/ Parking/ Use of speed/Emergency stop	

3.4.7.2 Multiple Sclerosis group

The cumulative driving faults made by the 30 MS patients completing the PRA are shown in Table 3.50.

Table 3.50 Faults recorded on the PRA specific test points for MS patients who completed the PRA (n = 30)

	Minor Fault	Major Fault		Minor Fault	Major Fault
Starting precautions			Passing static vehicles	1	
Moving off	2		Merging with traffic stream	2	3
Observations at side to junctions	2	3	Anticipation pedestrian behaviour		1
Observations to rear	6	3	Anticipation behav. of other road users	3	3
Use of signals	3	2	Use of speed	4	3
Positioning on road	6	3	Obedience of road signs	1	2
Cornering	3		Observation of speed limits	2	
Braking	5	2	Courtesy	2	
Accelerating	3	5	Emergency Stop	5	3
Overtaking (inc. cyclists)	2		Reversing	7	3
Driving on roundabouts	8	3	Parking vehicle	4	2
Driving in traffic lanes	7	5	Turning right	3	
			Following too close	4	

The faults most frequently observed in patients with MS passing and failing the PRA were:- in patients who passed the PRA; 'Emergency stop' 'Driving on roundabouts' and 'Reversing'; amongst those who failed, Acceleration control, Road positioning, Use of speed, Merging with traffic streams and Driving on roundabouts (Table 3.51).

Table 3.51 Driving faults incurred by MS patients passing and failing the PRA (ranked according to frequency of occurrence and seriousness).

'Pass'	'Fail'
1. Emergency stop	1. Accelerating
2. Driving on roundabouts	2. Positioning on the road
3. Reversing	1. Use of speed/ Merging with traffic streams/ Driving on roundabouts
4. Observations to the rear	6. Observation to the side at junctions/ Observations to the rear/ Anticipating the behaviour of other road users
5. Positioning on the road, Braking, Use of speed	
8. Use of signals, Parking, Anticipating the behaviour of other road users	

3.4.7.3 Parkinson's disease group

Driving faults recorded for the seven patients who completed the PRA are shown in Table 3.52. The most frequently recorded faults were positioning on the road, observations to the rear and driving on roundabouts.

Table: 3.52 **Faults recorded on the PRA specific test points for PD patients completing the PRA (n = 7)**

	Minor Fault	Major Fault		Minor Fault	Major Fault
Starting precautions			Passing static vehicles		
Moving off	3		Merging with traffic stream	2	
Observations at side to junctions	1	2	Anticipation pedestrian behaviour	1	
Observations to rear	5	1	Anticipation behav. of other road users	4	
Use of signals	2	1	Use of speed	3	2
Positioning on road	5	4	Obedience of road signs		
Cornering	2	1	Observation of speed limits	1	1
Braking	1	2	Courtesy	1	
Accelerating	2		Emergency Stop	1	
Overtaking (inc. cyclists)			Reversing	5	
Driving on roundabouts	2	4	Parking vehicle		
Driving in traffic lanes	2		Turning right		
			Following too close	2	

Table 3.53 Driving faults incurred by PD patients passing and failing the PRA (ranked according to frequency of occurrence and severity -[major faults afforded greater weight])

'Pass'	'Fail'
1. Positioning on the road	1. Positioning on the road
2. Reversing	1. Use of speed/ Driving on roundabouts
3. Driving on roundabouts	4. Observation to the side at junctions/ Observations to the rear/ Braking
4. Observations to the rear, Anticipating the behaviour of other road users	7. Moving off/ Use of signals/ Cornering

PD patients who passed the PRA made few driving faults. The highest-ranking fault, road positioning, had a total score of only six. Road Positioning was also the highest-ranking fault amongst PD drivers failing the PRA (see Table 3.53). None of the SDSA sub tests correlated with driving faults in the 'fail' group.

3.4.7.4 Dementia group

One patient did not progress to the PRA because he was unable to follow instructions. The technician terminated the assessment, when initially assessed in the hospital grounds. One PRA was cut short as it was felt the patient was unsafe to proceed.

Only one patient passed the PRA. Six were considered to be definitely unsafe and three probably unsafe. Of those considered definitely unsafe, lessons were not thought to be applicable in five cases and essential in one. Lessons were not considered necessary in the patient who passed.

The patient who passed had the shortest duration of time since onset of dementia (four months). The faults recorded for the nine patients assessed on the public road are shown in Table 3.54.

Table 3.54 Faults recorded on the PRA specific test points for patients with dementia who completed the PRA (n = 9)

	Minor Fault	Major Fault		Minor Fault	Major Fault
Starting precautions	1		Passing static vehicles	1	1
Moving off	1		Merging with traffic stream	1	3
Observations at side to junctions	3		Anticipation pedestrian behaviour		3
Observations to rear	3	4	Anticipation behav. of other road users	2	1
Use of signals	4	4	Use of speed	3	
Positioning on road	3	2	Obedience of road signs	1	1
Cornering	1	3	Observation of speed limits	2	1
Braking	1	3	Courtesy	1	
Accelerating	3	1	Emergency Stop	1	
Overtaking (inc. cyclists)			Reversing	2	2
Driving on roundabouts	3	4	Parking vehicle		
Driving in traffic lanes	1	3	Turning right		
			Following too close	1	

Other additional documented mistakes included one major fault with steering and two people who had major faults with using the handbrake. The one

dementia patient who passed the PRA, incurred only one minor driving fault with cornering, therefore driving faults were recorded for all patients together. The driving situations which presented most problems were - (ranked 1-8 according to frequency of occurrence and seriousness -[major faults afforded greater weight]).

1. Driving on roundabouts
2. Use of signals
3. Observations to rear, Road positioning, Braking, Merging with major traffic streams
7. Driving in traffic lanes, Anticipating behaviour of other road users and Reversing.

3.5 Discussion

The SDSA was not a good predictor of 'on-road' driving ability for a large mixed group of neurologically impaired drivers. The ability of the SDSA to predict the PRA outcome was accurate in only 65% of cases and the ability to detect failure at chance levels. Examination of the individual cognitive test scores revealed performance differences that were related to the patient's diagnosis. Therefore further analysis was restricted to four patient groups.

3.5.1 Head injured patients

On road test performance was accurately predicted by the SDSA in 71% of people with traumatic brain injury but the sensitivity for detecting failure was only 36%. Therefore the SDSA alone was not a good predictor of driving performance in TBI patients.

The inclusion of cognitive tests of executive and information processing abilities increased the overall prediction accuracy. Using discriminant analysis, an equation was generated that accurately predicted the PRA outcome in 85% of cases. Yet, it remained better at detecting who would pass (Specificity 92%) than who would fail (Sensitivity 57%).

A proportion of patients (13.7%) was misclassified by the discriminant equation. Three who were predicted to fail, passed the PRA and six who were predicted to pass, failed. Since it is preferable to identify those people who would be unfit to drive on the public road, then the misclassification errors are not in the desired direction. Of the six giving rise to concern, three had visual or physical deficits, not detected by the cognitive tests, which either precluded them from driving or could not be overcome. The findings suggest that physical disabilities arising from TBI are sometimes complex and difficult to compensate for by adapting the

vehicle. Whereas in stroke patients, physical disabilities such as hemiplegia are easier to compensate for. Visual deficits were also an important feature of this patient group and may preclude driving when cognition is otherwise intact. In the earlier stroke studies, these patients had already been excluded.

Of the other misclassified cases, one was a current driver and one formerly a taxi driver. As the literature suggests (Ranney, 1994; Van Zomeren et al., 1988) some patients have the ability to compensate for their driving abilities either with practice or by the over-learned nature of the driving task. For a minority of patients (one) misclassification was difficult to explain.

Examination of the individual cognitive test scores for misclassified patients indicated that some tests, which did not feature in the discriminant analysis, such as Figure Copy (not included because it was significantly negatively skewed) and Motor Impersistence (Gaze Fixation subtest), detected impairments such as perceptual and visual deficits, which could explain the road test outcome. Therefore, cognitive deficits that occur in some but not all head injured patients may be important for driving and may explain some of the recognised difficulty in predicting for large groups (Brooke et al., 1992; Brouwer and Withaar, 1997; Lambert and Engum 1992).

Some of the problem in predicting for groups of TBI patients could be attributed to difficulty in detecting patterns of disability associated with frontal lobe damage (i.e. attention, decision making, reasoning, mental flexibility and self-awareness) which lie alongside normal intellectual functioning (Taylor and O'Connell, 1995). Even when detected by cognitive tests, the on-road test may not always be demanding enough to test them (Fox et al., 1998). Some of these skills, which are essential for strategic level decisions (e.g. whether to drive in adverse weather

conditions) do not feature in existing assessment procedures (Van Zomeren et al., 1987) and as with accidents, situations that call upon the complex interplay of these cognitive abilities are infrequent and unlikely to occur in a one-off 'on-road' test. This reality exacerbates the problem of cognitive assessment in predicting driving ability. *I.e. the place of a screening device which indicates a person is unsafe*, who then goes go on to pass an on-road test at a specialist driving assessment centre. It is possible that TBI patients need to be assessed over a period of time, with a series of road tests and varying road situations, so that a more realistic impression of the actual driving ability is achieved (Brouwer and Withaar, 1997; Korteling and Kaptein, 1996).

The findings from this study, that tests of information processing ability are important predictors of road test performance among brain injured patients, support those of Gouvier et al., (1989) who found the Oral Digit Symbol Modalities test to be an important predictor of driving skill and Engum and Coworkers, (1988; 1989; 1990), Kumar et al., (1991) and Lundqvist et al., (1997) who all found the WAIS Digit Symbol to have predictive value for driving among brain damaged subjects. The findings also fit with research among normal drivers indicating that intact information processing abilities are important for driving (Lester, 1991).

Research to date indicates that groups of cognitive tests are better predictors of road test outcome among brain injured drivers than individual test scores (Engum et al., 1988; 1989; 1990; Fattal et al., 1995; Simms, 1994; Simms and O'Toole, 1994). These findings confirm this. However, some individual tests may detect problems, which are important determinants of fitness to drive for a minority of patients.

The overall findings suggest that cognitive factors are important in the prediction of fitness to drive for patients with traumatic brain injury.

3.5.1.1 Driving Faults

Head injured patients who passed the PRA were likely to incur faults, such as forgetting to use mirrors before signalling, road positioning, driving in traffic lanes and reversing. Mirror use and reversing might be considered operational level faults (i.e. technical car handling skills) (Michon, 1979; 1981).

Among head injured drivers who were considered unsafe, road-positioning faults were more serious and occurred more often than in those found safe to drive. Van Zomeren and colleagues (1988), also found that difficulty in maintaining position in the road (Lateral Position Control) was a feature of head injured drivers (who were considered to be safe) when tested on average six years post injury. Inspite of the global safety recommendation, lateral position control was observed in all head-injured patients but not in an age matched friends/family control group. Unsafe drivers in the present study also drove too fast and incurred the sorts of errors that may be attributed to poor judgement, such as difficulty merging with major traffic streams, misjudging corners (by either under or over-steering) and with acceleration (ranging from basic car handling skill deficits to more serious errors of judgement, such as pulling into traffic flows and failing to maintain speed). Judgement errors such as these are frequently documented among drivers brain damaged by stroke (Simms, 1985; Wilson and Smith, 1983) or dementia (Coyne et al., 1990; Kasniak, 1991; O'Neill, 1992) but few studies have reported on faults specific to head injured patients (Korteling and Kaptein, 1996; Van Zomeren et al., 1988). This raises the question of whether brain damaged drivers

considered to be 'unsafe', display similar driving faults, irrespective of diagnosis and whether fault patterns may have predictive validity for driving.

Detailed correlational analysis between faults and cognitive test scores may explain which cognitive abilities are important for specific driving manoeuvres. Unfortunately such analysis was beyond the scope of this study.

3.5.2 Drivers with multiple sclerosis

Few demographic differences were found between drivers with multiple sclerosis who passed or failed the PRA, except that those who failed had had a longer break from driving and tended to be women. These findings suggest that those who failed were probably more severely affected by their condition at the point of relapse or deterioration and had either taken longer to recover or needed car adaptations to enable them to resume driving. However, no comparisons were made on measures of MS severity. Another explanation may be that patients who had previously stopped driving, had subsequently found themselves isolated and regretted the decision to stop. This was the case for three rural dwelling, female patients in this study. However, the possibility that the decision to resume driving resulted from a loss of insight into their abilities cannot be ruled out. This would fit with literature suggesting patients with multiple sclerosis (MS) cannot realistically rate their own ability in daily life activities (Lincoln, 1981).

The predictive accuracy of the SDSA on its own was 62% but sensitivity was no better than chance (50 %). This suggests that cognitive deficits, which may be important features of MS, were not tested by the SDSA.

Analysis of the difference in cognitive test scores between drivers who passed and failed the PRA revealed tests of interference (Design Learning subtest from the AMIPB), perception (Figure Copy) and information processing ability to be

predictive of driving outcome. It is possible that interference (memory) deficits are attributable to deficits of attention (which contribute significantly to memory disorders (Litvan et al., 1988) and reduced processing speed, which affects the amount of information that can be attended to registered and processed at any time (Lezak, 1995). Including tests of information processing and interference substantially increased the SDSA prediction suggesting that these abilities, which were not important features of stroke patients, are important for safe driving among people with MS.

Physical factors that do not feature in the cognitive assessments but which are difficult to compensate for in the driving situation can explain the poorer prediction for failure among patients with multiple sclerosis. Unlike other physical deficits, such as hemiplegia, which may be easily overcome with vehicle adaptations, the physical deficits found among MS patients (such as bi-lateral weakness, poor co-ordination and tremor) may require more complex solutions (such as driving from a wheelchair) or may not be overcome at all. Physical deficits may be the main reason people with MS stop driving. All five of those who were predicted to pass but who failed the PRA had deteriorated physically since last having driven and four needed adaptations to enable them to resume driving.

The findings indicate that patterns of physical deterioration in MS are not consistent with cognitive decline. Of those predicted to fail but who passed the PRA, one was currently driving and one had had his licence revoked following a collision. These findings support those of Shanke et al., (1995) who found cognitive deficits to be more important than illness duration or severity in patients' fitness to drive.

3.5.2.1 Driving faults

The most important driving faults (in terms of frequency of occurrence and severity) among patients who passed the PRA were the emergency stop procedure and problems driving on roundabouts and with reversing. Since emergency stops are not often practised in daily driving, it is possible that the driving instructor was drawing attention to task sloppiness (for example drivers who press the clutch before the brake). Another explanation is that general psychomotor slowing associated with brain damage (Van Zomeren and Van den Berg, 1985) shows up in this task when other driving manoeuvres (which allow more time for compensatory strategies) fail to detect it. However, the emergency stop may be slower or less accurate when using hand controls or may reflect accustomisation to newly acquired controls. Of the 21 patients who passed the PRA, six, (29%) encountered problems with the emergency stop procedure, three of these drove with hand controls (in one case newly acquired) and one with a foot pedal conversion. For one other patient there was a question over whether he should convert to controls.

Among MS drivers who failed the PRA, faults indicated errors of judgement, e.g. use of speed, merging with traffic streams and driving on roundabouts and control skills, such as road positioning and acceleration control. In addition, a general failure to observe was noted. Simms and O'Toole (1994) found similar faults with mirror use, scanning the road and road positioning but no problems with car control skills and a tendency to perform well overall. The fact that the emergency stop did not feature among faults identified in multiple sclerosis patients who failed the PRA, or in other diagnostic groups, suggests it is only important among

MS subjects who otherwise drive well or that it occurs but it is not so bad as to make patients unsafe overall.

3.5.3 Patients with Parkinson's disease (PD)

Over half of the PD patients were found safe to drive. While this fits with research suggesting people with PD are conscientious drivers (Ritter and Steinberg, 1979), as so few people with Parkinson's disease were referred to the DRMC during the recruitment period (seven in three years), it is not possible to extrapolate from these findings. Drivers referred to the DRMC were either very conscientious (self-referring for assessment nearing the end of each periodic licence review period) or referred by their GP or families in an attempt to persuade them to stop. Although no significant differences were found in age or mobility between safe and unsafe drivers with PD, trends indicated failing drivers were older and more disabled. These findings reflect those of Lings and Dupont (1992) and Madeley and colleagues (1990) who found measures of PD severity were useful predictors of driving skill.

The SDSA accurately classified half (4/7) of the patients with Parkinson's disease and all three patients who failed were correctly classified. Three people, who were predicted to fail by the SDSA, passed the public road assessment. Two of them were driving at the point of participation. The three patients who failed the on road test had marked physical symptoms of their disease.

None of the additional cognitive test scores differed significantly between those who passed and failed on the road. Albeit tentatively, these findings suggest that cognitive problems are not as important in Parkinson's disease as physical problems. Therefore cognitive tests are not as predictive of road performance as physical ones.

3.5.3.1 Driving faults

The driving test faults indicated patients with PD tended to drive well and incurred few errors. The most common faults were road positioning (a tendency to drive towards the centre of the road), straight lining roundabouts and forgetting to use rear view mirrors. They also tended to drive too fast. Faults which, apart from road positioning, one might expect to see among any experienced driver. This suggests that PD drivers drove well and did not exhibit patterns of minor faults that other neurologically impaired drivers, who are also considered 'safe', did.

3.5.3.2 Cognitive tests

Examination of the individual test scores revealed that all patients performed poorly on the PASAT and were slow on the colour-naming task of the Stroop. Scores for the immediate and delayed story recall task fell below the 25th percentile when compared to a normative sample of the same age, indicating 'below average' performance. There was no evidence of perceptual impairment. Performance on all other tasks of verbal and visual retention indicated performance that was 'below average' but not significantly impaired.

Scores for the information processing subtasks were average for the age group and not indicative of brain damage. The test of Motor Impersistence indicated that distractibility was not a feature of the PD patients.

Patients performed well on the SDSA Dot Cancellation task but poorly on the Square Matrices Compass Cards task (median score 11/32 in the pass group and 12/32 in the fail group) and the Road Sign Recognition task (median score pass group 3.5/12; fail group 7/12) indicating deficits in executive abilities. This is consistent with research suggesting that executive dysfunction is a feature of

Parkinson patients and is often attributed to difficulties in formulating a strategy (Saint-Cyr and Taylor, 1992).

Although scores for the test of attention indicated impairment, measures of executive abilities and information processing were only 'below average' and not at a level likely to affect the ability to drive safely. This may be because people with PD drive cautiously and slowly, allowing themselves time to compensate for their failing cognitive abilities. It is also possible that this pattern of deficit is no more a feature of PD than normal age related decline and that older people with PD are as safe, if not safer, than older drivers of a similar age without the disease. However, a larger study recruiting sufficient numbers of safe and unsafe drivers should clarify this and help to identify which combination of physical and cognitive abilities need to be considered when assessing people with PD for their fitness to drive (Lincoln and Radford, 1999). Heikilla and colleagues (1998) found that performance on cognitive tests of visual memory, choice reaction time and information processing speed were related to driving ability. In a larger study their findings may be replicated but in this small study cognitive test scores failed to indicate impairment in these abilities. What is unclear from this study is whether cognitive changes occurring in younger people with PD differ from those occurring in older patients and whether these changes are important determinants of fitness to drive a car.

What is surprising is that so few people with PD consult specialist driving assessment centres for advice. It is thought that unless vehicle adaptations are needed, assessment costs, distance from centres and long waiting lists act as a deterrent. Where the question concerns whether a person is fit to continue driving rather than fit to resume, concerns about losing the drivers licence, particularly

where mobility is already compromised, mean people do not seek specialist advice. It is also possible that in progressively deteriorating conditions, while insight is retained, the question of giving up driving at some point is one they have addressed and that a conscientious decision to stop is often made well before the driver's safety or that of other road users is compromised.

One important aspect of PD drivers not addressed by this study was medication side effects, such as on-off periods and abnormal movements. It was assumed that drivers fitting the medical criteria for fitness to drive would have these symptoms under control at the point of assessment and those who did not would have been screened out during the medical assessment at the DRMC.

As with earlier studies of PD drivers (Dubinsky et al., 1991), this research has failed to confirm the relationship between cognitive abilities as assessed by formal cognitive tests and patients' performance on the road. It would appear from the results that those who fail the PRA have either physical deficits or a combination of cognitive and physical deficits, which make them unfit to drive.

3.5.4 Patients with Dementia

Results for the ten patients with dementia suggest that they are often unsafe on the road. Two were referred by the police for assessments following accidents. Half of the patients were current drivers when they took part in the study. The mean time since last having driven a car (7.7 months) was approximately the same as the length of the DRMC waiting list, suggesting that most were driving at the point of referral. One patient, who had not driven for three years, had been persuaded to wait until he was 'fully fit' by his GP, following knee replacement surgery!

Time since onset of dementia ranged from 3.6 months to 12 years, with the patient who passed the PRA, being the most recently diagnosed. This fits with work suggesting a sharp rise in accident rates and decrease in driving skill occurs at around three years post onset (Drachman and Swearer, 1993). No patient more than four months post onset passed the PRA.

The SDSA correctly identified all except one of the patients who failed on the road. The one patient who was assessed as fit on the SDSA but failed on the road had a very atypical pattern of test results. He performed poorly on all SDSA subtests but the overall equation was positive indicating fitness to drive. This patient's score on dot cancellation showed very high numbers of errors and false positive scores (he failed to follow instructions and joined all of the dots together). Since this did not occur in stroke patients on whom the test was developed, his scores fell outside the anticipated range for the fail equation. The one patient who passed on the road was the most recently diagnosed, a retired statistician, who inspite of gross CT changes, remained relatively independent in daily life (EADL score 58). This is consistent with literature suggesting that independence in daily life activities has predictive value for driving in patients with dementia (O'Neill, 1992) and longitudinal studies indicating that the greater the pre-morbid IQ, the slower the rate of cognitive decline (Deeg et al., 1990; Snowdon et al., 1996). On the basis of so few patients (only one patient passed the PRA) the overall predictive validity of the SDSA cannot be determined.

The high fail rate among demented drivers is probably due to the recruitment method used in this study. Of the original 18 patients referred for assessment at the DRMC, only 10 were seen and assessed. Eight patients either stopped driving of their own volition or were persuaded to stop and sell their car before being

seen. Seemingly only those patients suspected of being unsafe by the GP or who have lost insight and cannot be persuaded to stop are referred for specialist assessment.

An alternative approach would be to recruit patients from geriatric clinics but this would introduce a volunteer bias. Patients at risk of performing badly are unlikely to volunteer. Those who do and are found to be unsafe then present a dilemma for what action should be taken if advice is ignored. This is not a problem in conditions with sudden onset such as stroke or TBI, since the question concerns whether they are fit to resume driving rather than whether they are fit to continue. Examination of the individual test scores indicated severe impairment in frontal lobe function and verbal memory. However, patients performed within the age norms on tasks of visual memory and information processing ability. The test of Motor Impersistence indicated that distractibility was a feature of the demented patients in this study but of no other subgroup. Scores for the PASAT indicated severe problems with divided attention. No patient scored greater than 22/60 (median 4). The results suggest that intact cognitive skills of divided attention, executive abilities and perseverance may be important skills for car driving. The role of memory in driving is unclear (McKenna, 1998) but these results suggest that demented patients who have severely impaired verbal memory recall may be unfit to drive. However, further research on a much larger group of patients, incorporating both safe and unsafe drivers is needed to confirm these findings and indicate at what point in their cognitive decline, demented patients become unfit to drive.

3.5.5 General Points

The SDSA alone is not a good enough predictor of driving fitness for patients with acquired neurological disabilities other than stroke. In particular, the predictive validity for TBI patients and those with multiple sclerosis was poor. Among those with Parkinson's disease and dementia, in whom it shows promise, there were too few patients to draw firm conclusions. There may be two possible explanations for the poor predictive validity in patients with TBI and multiple sclerosis. Firstly, the SDSA was developed for use with stroke patients and it is possible that cognitive deficits that are features of TBI and MS patients, (such as processing speed, attention and reasoning problems) are not adequately assessed by the SDSA. However, pilot work on a group of 20 TBI patients (Hawkins, 1998) testing the construct validity of the SDSA has suggested that the three subtests are sensitive to impairments of frontal lobe function and attention. Secondly the combination of test scores and the relative weight of each subtest inherent in the predictive equation for stroke patients is inappropriate for other diagnostic groups. The improved classification when additional cognitive test are included suggests this may be the case.

On the SDSA, those test scores which differed significantly between passing and failing TBI drivers were the same as those for stroke patients in the test's development (Dot cancellation time and false positive scores, Compass Cards and Road Sign Recognition)(Nouri et al., 1987; Nouri and Lincoln, 1992), whereas among drivers with multiple sclerosis, only Dot Cancellation false positive score and Road Sign Recognition differed significantly between the two groups.

The failure of the SDSA predictive equations to apply to other groups is also perhaps an explanation of the predicted failure among an elderly control group in

the Mitchell et al., study (1995). However, since these people were not road tested it cannot be assumed that they were fit to drive on the road or that the SDSA prediction was inaccurate.

As in the original studies with stroke patients, the Road Sign Recognition test (RSRT), which was developed as a test of the ability to recognise road signs and road hazards and to add face validity to the SDSA, has emerged as an important predictor of driving fitness among patients with TBI and multiple sclerosis. This finding is supported by Carr et al., (1998) who also found traffic sign recognition to be related to on-road performance among older cognitively impaired drivers. This suggests these tests may tap domains that are relevant to driving (Odenheimer, 1993). The results of Chapter 2 indicate this test measures executive abilities and attention in addition to knowledge of road signs among stroke patients. Similarly, in a pilot study of TBI patients, performance on all three subtests was related to performance on the Stroop and Test of Everyday Attention - Telephone Search task (Robertson et al., 1994), suggesting they draw on complex attentional abilities and high level (executive) cognitive functions associated with the frontal lobes (Hawkins, 1998).

3.5.5.1 Other predictors

Unlike earlier findings among demented patients (O'Neill, 1992) indicating that independence in activities of daily (ADL) living is a useful indicator of driving fitness, among patients with PD and multiple sclerosis in this study, no significant differences in EADL scores were found between those who passed or failed the PRA. This finding contests the suggestion that ADL might be used as a yardstick of cognitive competence (DVLA, 1999). Although no comparison between ADL and road performance could be made for patients with dementia, EADL scores

ranged from 33 – 62 (IQR 38.5 - 59), indicating relative independence in most activities. The patient who passed the PRA did not achieve the highest EADL score.

3.5.5.2 Safety criterion

Research into the driving safety of neurologically impaired drivers in some other countries suggests more stringent criteria for what is accepted as 'adequate performance', since the proportion of patients considered unfit to drive tends to be higher (Heikilla, 1998; Lundqvist, 1997; Shanke et al., 1995). In a study of drivers with multiple sclerosis, (Shanke et al, 1995), 14 out of 33 patients were found to be unsafe. However, nine were considered unfit on the basis of medical and neuropsychological assessment alone and did not progress to an on-road test. It is possible that a proportion of these drivers would have been found safe if tested in a car on the public road. Providing they meet the minimum medical standards for fitness to drive, some drivers with moderate to severe cognitive impairment, still drive well and are thus misclassified by off-road evaluations (Simms, 1985; Simms and O'Toole, 1994). Some driver evaluation facilities in the states (Galski et al., 1996; Jones et al., 1993) and assessment centres in Britain also preclude some drivers on this basis. The fact that many neurologically impaired drivers do employ compensatory strategies for driving (for example strategic level decisions to avoid driving at certain times of the day, in certain conditions e.g. poor lighting, rush–hour or to avoid certain situations, such as busy roundabouts or motorways) to overcome their decreased ability to judge the speed of oncoming traffic, judge gaps in traffic, make fast decisions and turn right (Rabbit et al., 1996; Van Wolffelaar et al., 1990), suggests that they should not be precluded on the basis of off-road evaluations and that on-road testing, although

not ideal, should form part of driver evaluation techniques and be used as the gold standard of driving in research (Fox et al., 1998; Odenheimer, 1994).

It remains unknown exactly how much of driving is automatic (McKenna, 1996). Cognitively impaired people may appear safe in most driving situations. It is only in new or very demanding situations (such as unfamiliar towns or cities and major road networks with complex junctions and large roundabouts) that problems arise (Hiekilla et al., 1998). It is thought that most often, a one-off, time limited test may not be sufficient to test the cognitive abilities that become important in these unusual situations and may explain the proportion of patients in this study who are predicted to fail the PRA but drive well when tested on the road. Because driving situations do change and those situations associated with accidents differ, it would seem reasonable to check people's safety in new and demanding driving environments. For example, Heikilla et al., (1998) found PD drivers had difficulty driving in heavy traffic and in an unfamiliar city – a task thought to be more demanding than most PD drivers would attempt. Agreement between the psychologist and the driving instructor's ratings indicated that cognitive deficits (as measured by formal testing) were related to on-road performance when tested in a sufficiently demanding environment. Since even moderately brain damaged drivers can compensate for their diminishing driving skills by planning in advance to avoid situations they find too demanding (Ranney, 1994), it is unlikely that deficits in driving skill will be detected unless drivers are placed in sufficiently testing situations.

Driving is a complex skill requiring the interplay of several factors including physical, cognitive, personality, attitudes and behaviours. This suggests that a comprehensive approach is needed to discriminate safe from unsafe drivers

(Lundqvist et al., 1997). The number of neurologically impaired people intending to resume or continue driving and the shortage of specialist driving assessment centres indicate a need for two types of cognitive assessment procedure. Firstly a screening device that can identify those with little or no cognitive impairment, determine safe from unsafe drivers and direct those in whom uncertainty lies for more specialised assessment (Lincoln and Radford, 1999). Secondly, cognitive assessment should form part of more comprehensive evaluations at a Regional Mobility Centre (Lincoln and Radford, 1999). Although intended as a screening device, the lack of standardised procedures at many specialist driving assessment centres (Frye, 1995) and the poverty of research indicating which commonly used psychometric tests have predictive validity for on-road driving, suggest the SDSA may also have a place in specialised assessment facilities, to introduce some form of cognitive assessment where currently non takes place.

3.5.5.3 Choice of assessments

The choice of assessments in this study was restricted by the research situation. Since the cognitive assessments were carried out in the patient's home, tests were selected that were easily transportable, could be administered quickly and required no formal training. Since the study began additional measures are available, some of which could have replaced those used in this study. However, previous research (Galski et al., 1992; Nouri et al., 1987; Nouri and Lincoln, 1992; Sivak et al, 1991; Van Zomeren et al, 1987) and expert clinical opinion, governed the choice of measures to assess those cognitive abilities thought to be essential for driving. Until more is known about the exact neuropsychological functions that

underpin the ability to drive safely and the level of cognitive impairment which makes someone unsafe, then the basis for this selection remains sound.

Examination of the individual cognitive test scores for each diagnostic subgroup revealed no significant differences in scores for the PASAT between drivers who passed or failed the PRA. This may be attributed to the test's high sensitivity for detecting even mild attentional deficits. Very few patients performed well on the test, indicating impairment in almost all patients. This suggests that brain damaged drivers who are considered to be safe cope with varying degrees of attentional deficit. The significant difference between passing and failing patients when the group was considered as a whole, may be attributable to the fact that patients with dementia performed so badly on the test and most of them failed the PRA. However, because multiple comparisons were made and scores for all cognitive assessments differed significantly between passing and failing drivers in the whole group, this finding could be attributed to chance.

It is also possible that the version of the PASAT used in this study (NTBIS, 1998), differed from more widely accepted standardised versions recognised elsewhere (Gronwall and Sampson, 1974). In this version the numbers are presented at two and four-second intervals whereas the more widely recognised intervals are 2.4, 2.0, 1.6 and 1.2 seconds, which suggests that this test may not be as sensitive to variations in attentional deficit as other versions. This may explain the lack of distinction between safe and unsafe drivers in each diagnostic subgroup.

As with the other additional cognitive tests, scores for the AMIPB differed according to diagnostic group. Among head injured patients, tests of perception (Figure Copy), Verbal Memory and Information Processing ability differed significantly between the two groups. Among patients with multiple sclerosis

Figure Copy, interference (Design Learning) and Information Processing ability were important, suggesting that perceptual deficits and processing speed were important predictors in this group.

Motor Impersistence was not an important predictor of fitness to drive in any subgroup. The Stroop test was an important predictor for patients with TBI but not among drivers with multiple sclerosis. These findings fit with disease characteristics, suggesting that executive dysfunction is common among head injured patients (Lezak, 1995) but that patients with multiple sclerosis perform at normal levels on frontal tasks (Lezak, 1995).

3.5.5.3.1 Conclusion

Overall these findings suggest that those cognitive skills which are predictive of safety to drive differ according to the diagnostic group of the patient. Diagnostic groups of patients also display different patterns of faults when their driving abilities are tested on the public road. Therefore, patients with brain damage due to different causes should not be treated as one homogenous group in driving research.

The results of this study suggest that cognitive tests could be used to differentiate between brain damaged drivers who would or would not be safe to drive on the public road. However, since tests are better at predicting safe drivers than those who are unsafe, those who fail or score in the borderline range should also be road-tested. These findings fit with those of Lundqvist and colleagues (1997) who suggest that in addition to cognitive skills, experience, personality and attitudes to driving such as risk taking behaviour are important factors in driving. For this reason it is possible that neither neuropsychological tests, practical on road driving evaluations nor simulated driving alone can fully assess all of these important

aspects (Lundqvist et al., 1997). This would explain why a proportion of cognitively impaired patients are always misclassified by cognitive tests in driving research (Lambert and Engum, 1992; Nouri et al., 1987; Nouri and Lincoln, 1992; Simms, 1985; Simms and O'Toole, 1994).

3.5.5.4 Driving faults

Deficits in road positioning featured among all groups of neurologically impaired drivers and more critically among those found 'unsafe'. This finding is consistent with those of Van Zomeren et al., (1988) and is also observed to critical levels in normal drivers who are drunk or totally deprived of sleep and to a lesser extent in those only partially deprived of sleep (Fairclough and Graham, 1999). This would suggest that cognitive abilities whether temporarily or permanently impaired have an impact on this aspect of driving performance to a greater or lesser extent.

3.5.5.5 Limitations of the analytical methods

Given that there are fewer than 20 cases for each predictor variable (Stevens 1992), it could be argued that the results of the discriminant analyses capitalise on random characteristics of the data set (Brouwer and Withaar, 1997). However, efforts were made to ensure that the data fit strictly with the assumptions of linear discriminant analyses and the prior probabilities of pass/fail group sizes were accounted for in the predictive equation. Although small, the groups are important and remain the largest studies attempting to predict driving in traumatic brain injured and patients with multiple sclerosis in Europe. Since classification based on the same sample from which the equation is generated tends to be over optimistic, further validation on a separate group of patients is required.

It could be argued that a more lenient approach to this analysis (including all SDSA subtests, all patients and without transformation of scores), which violates

some of the assumptions of discriminant analysis, would be more appropriate for use in clinical practice, since all parts of the SDSA would need to be completed in clinical testing. In addition, scores for patients who perform very badly on all tests included in the discriminant equation (multivariate outliers) should be included in the analysis, since they do not occur from sampling error. Equations generated from this approach to analysis yield a more accurate classification prediction, with improved sensitivity (see appendices 3.4 and 3.5) for both TBI patients and those with multiple sclerosis (60% and 83.3% respectively). However, while linear discriminant analysis is considered to be a robust technique, non-parametric classification should ideally be used if this approach is adopted. Therefore the conservative approach used in this study favours the small sample numbers and offers a more robust prediction.

3.6 Summary

Overall, the prediction was not supported that those who failed the SDSA would be unsafe to drive. It is a better predictor of who is safe than who is unsafe. However, group differences suggest it may be more predictive in some groups of patients than others.

The conflicting results for different groups of patients suggest the relative importance of different factors influencing the ability to drive will differ according to the diagnosis of the patient and in future, research should be diagnosis specific; all brain damaged patients should not be treated as one homogenous group. The results suggest that cognitive skills differ in degrees of importance for different diagnostic groups of patients and this is also reflected by different patterns in

driving faults. Further research is needed to establish which cognitive skills are important for specific road manoeuvres.

The SDSA is a better predictor when combined with additional tests, specific to the patient's diagnostic group. This is probably because attention, memory and reasoning problems that commonly occur following head injury and multiple sclerosis are not adequately assessed by the SDSA.

A proportion of patients was misclassified by cognitive tests. In both multiple sclerosis and head injured patients, a small proportion of drivers considered unfit on cognitive tests, performed well when tested on the road. Reasons for these misclassifications are not always clear. It is possible that some drivers have the ability to compensate for their cognitive impairments by adapting their driving behaviour or their deficits are possibly masked by the automatic, over-learned nature of the driving task (McKenna, 1998). However, the possibility exists that the on-road test is not sufficiently demanding to test cognitive deficits, which only become important in unusual situations. It is reasonable to assume that the 'gold standard' of driving ability (on which the cognitive test results are based) is not 100% accurate and further work should address the validity and reliability of on-road testing.

Physical and visual deficits can often explain the misclassification of patients predicted to pass by cognitive tests, who then fail on the road. Since the conservative approach to safety adopted suggests it is they who pose a greater problem, then concern for the small numbers of patients misclassified is not great. Furthermore, where cognitive testing takes place as part of a more comprehensive assessment at a specialist driving centre, these deficits would be detected by other members of the team.

Although decisions made solely on the basis of cognitive tests would permit a proportion of unsafe drivers to resume, standard procedures also allow some unsafe drivers on the road (Nouri and Lincoln, 1993) but exactly what proportion is unknown. Since this is a pre-requisite to establishing the true value of the cognitive tests, it remains an important issue to be addressed by further research. The suggestion made by the DVLA (1998) that ADL measures may be used as a yardstick of cognitive competence is not supported for patients with TBI, or multiple sclerosis. Too few patients with dementia or Parkinson's disease were recruited to comment on the use of ADL measures for these groups.

On road tests are an essential component of specialised driving assessment and should be used in addition to other forms of driving evaluation, since it is unlikely that off road tests are predictive of driving in real traffic (Fox et al., 1998; Odenheimer et al., 1994). A small proportion of patients clearly identified as unsafe on the basis of cognitive tests may still need to be tested on the public road, since failing in a live driving situation may provide a more credible outcome and increase compliance with advice.

Chapter 4

CONSTRUCT VALIDITY OF THE 'GOLD STANDARD' OF DRIVING ABILITY

4.1 Aim

The aim of the study was to check the inter-rater reliability of the 'Gold Standard' of driving ability used in the study to validate the Stroke Drivers Screening Assessment (SDSA) for people with acquired neurological disabilities.

4.2 Introduction

In the study to validate the SDSA for people with acquired neurological disabilities (Chapter 3) subjects were assessed on the SDSA and other tests of cognitive abilities. They then underwent an hour-long assessment on the public road (PRA) by a Department of Transport approved driving instructor (ADI), experienced in the assessment of people with neurological disabilities. The ADI was asked to grade the subjects' performance as correct, minor fault or major fault over a series of 25 road manoeuvres and to make an overall impression (global rating) of the subjects' 'fitness to drive', graded as definitely safe, probably safe, probably unsafe or definitely unsafe. The PRA was considered to be the 'Gold Standard' of driving ability against which the outcome of the SDSA and the results of the additional cognitive tests were compared.

Comparing the ratings of two or more driving instructors whilst assessing brain damaged drivers has been done before (Wilson and Smith, 1983; Fox et al., 1992; Hunt et al., 1993). Nouri (1991); Nouri and Lincoln (1992) compared the ratings of a BSM driving instructor to those of an Occupational Therapist in the

assessment of 39 stroke patients assessed over a set route in a dual controlled car. They found 'considerable agreement' between raters, suggesting that assessors from different backgrounds and with different levels of expertise and medical knowledge can compare favourably and that these factors do not adversely affect agreement. However, global ratings of driving performance have been criticised for lacking specific information about driving performance (Odenheimer, 1994) and differences between global ratings and observed manoeuvres of driving skill have been found (Brooke et al., 1992; Odenheimer et al., 1994; Van Zomeren et al., 1988).

In a pilot project Brown (2000) compared the SDSA prediction to the outcome of a PRA over a set route, using a different procedure to that used by the Derby Regional Mobility Centre. Her findings were consistent with those of Nouri et al., (1987) in the SDSA development, suggesting that different instructors and different methods of road testing are comparable.

Since the validation of the SDSA in a study of patients with acquired neurological disabilities depended on the decision made by the driving instructor, it seemed important to check the reliability of this decision, to ensure that the judgement made by the instructor used in that study was no more strict or lenient than that of ADIs from other Regional Mobility Centres.

4.3 Method

4.3.1 Subjects

Three qualified driving instructors, experienced in the assessment of drivers with neurological disabilities took part in the study. The driving instructors were employed by three Regional Mobility Centres: Derby Regional Mobility Centre

(DRMC), Banstead Mobility Centre, Surrey and the Mobility Advice and Information Centre (MAVIS), Berkshire. All three centres were well established and accredited both by Motability (a charitable organisation that operates a vehicle lease hire service to people receiving the mobility component of disability living allowance) and by the Forum of Regional Mobility Centres, which aims to set minimum standards for the assessment of disabled drivers.

Two of the instructors (VR and SV) were Department of Transport Approved Driving Instructors (ADIs) currently registered to teach driving. One (BE) was a former ADI, currently employed solely to assess disabled drivers. VR was the instructor used in the study to validate the SDSA for patients with acquired neurological disabilities (Chapter 3). SV and BE had been involved in similar studies in other centres and were selected for their expertise and experience in assessing disabled drivers and for their known interest in research. All three instructors were from different backgrounds. VR was a driving instructor who also taught novices to drive; SV was an Occupational Therapist and BE came from an engineering background. The instructors were paid a nominal fee for the assessments they carried out as part of this study.

4.3.2 Procedure

Prior to the assessment, the visiting instructors were sent a detailed study protocol (Appendix 4.0) and maps of the local area, indicating possible routes, which could be taken. These were suggested by the researcher and the DRMC's driving instructor who were both familiar with the area. The intention was to inform the visiting instructors (who were unfamiliar with Derby) of possible areas over which assessment could take place, rather than to promote a particular route. On the day

of the study, the visiting instructors were taken for a drive with the researcher and the DRMC driving instructor (VR) to familiarise them with the local area.

Eight patients who had already agreed to take part in the study to test the predictive validity of the SDSA for people with acquired neurological disabilities (Chapter 3), were selected consecutively from the DRMC waiting list by the DRMC. They were contacted by letter (Appendix 4.1) and asked to take part in an additional study to check the accuracy of decisions made by the DRMC driving instructor, when assessing subjects' 'fitness to drive' on the public road. Patients who had consented verbally were visited at home and written consent was obtained.

Four patients visited the DRMC for advice and assessment of their 'fitness to drive' on each of two separate days. On day one, two patients with multiple sclerosis (both of whom were wheelchair dependent) and two who had been treated for brain tumours (one by surgical removal and the other with a combination of radiotherapy and chemotherapy) were assessed. On day two, two patients who had suffered a traumatic brain injury, one patient with Parkinson's disease and one suffering from alcohol related cognitive decline were assessed. Patients underwent routine assessment at the DRMC. This included a medical examination; visual and static rig assessments, an off-road evaluation and assessment in areas of light traffic (a more detailed description of the DRMC assessment can be found in Chapter 3, section 3.3.4).

The allocation of patients to instructors was determined in advance using random number tables and concealed in opaque envelopes that were opened on the day of the study.

4.3.3 Driving assessment

Patients were then assessed for an hour on the public road (PRA) by two independent driving instructors. One instructor sat in the passenger seat and one sat in the back of the car during each assessment. Both instructors made an independent rating of the patients 'fitness to drive', using the same standard form (Appendix 3.1) as used in previous studies. No information from assessments conducted by DRMC prior to the PRA was communicated to the ADI's.

Patients were not assessed over a set route, but rather they were rated on 25 specific test items. These included road manoeuvres known to be difficult for people with acquired neurological disabilities. A decision not to assess patients over a set route was made since it was considered more important to record patients' driving abilities over the 25 test items. This gave instructors the freedom to request repeat manoeuvres, when doubt existed about a patient's ability to perform a manoeuvre. This was the method used in the study described in Chapter 3. It was considered important to make comparisons between the instructors using the same method as used in the previous study.

All patients were given the choice to be assessed in either an automatic or manual vehicle. (A detailed description of the cars used is given in Chapter 3, section 3.3.4). All vehicles were dual controlled and could be adapted to suit most disabilities.

Each instructor assessed two patients from the passenger seat and two patients from the back seat of the car. The instructor seated in the front passenger seat of the vehicle led the assessment i.e. he/she instructed the patient on the route to be taken and directed road manoeuvres (such as when to turn right, merge with major streams of traffic or perform an emergency stop) as specified by the form. Strict

instructions were given to the ADIs not to discuss the patient at any time, before, during or after the assessment, until completed assessment forms had been collected by the researcher. An overall (global) rating (definitely or probably safe or definitely or probably unsafe) of the patient's ability was then made together with a decision about the likely benefit to be accrued by driving lessons. The purpose of the distinctions within categories was to allow the instructors to feel more comfortable with the decision they were asked to make.

The study was repeated on a separate day with the second visiting independent driving instructor who was also experienced in the assessment of disabled and elderly motorists.

The independent ratings of the two visiting ADI's were compared to the ratings made by the instructor used in previous studies (VR). Unfortunately, practical constraints on the number of assessments that could be carried out by DRMC in one day meant that only four patients were seen each day. Therefore it was not possible to compare the two visiting instructors with each other.

Study Plan

Patients recruited, written consent obtained

⇩

Consenting ADI's sent detailed protocol and maps

⇩

Consenting ADI's taken for test drive of local area

⇩

DAY 1	DAY 2
Full DRMC assessment ⇩ Public Road Assessment	Full DRMC assessment ⇩ Public Road Assessment
Pat 1 BE in front passenger seat VR in back seat	Pat 5 VR in front passenger seat SV in back seat
Pat 2 BE in front passenger seat VR in back seat	Pat 6 SV in front passenger seat VR in back seat
Pat 3 VR in front passenger seat BE in back seat	Pat 7 SV in front passenger seat VR in back seat
Pat 4 VR in front passenger seat BE in back seat	Pat 8 VR in front passenger seat SV in back seat

Key:

SV = Visiting instructor from Banstead Mobility Centre

BE = Visiting instructor from MAVIS

VR = Instructor from DRMC, used in previous study.

Pat = patient

Figure 4.0: Detailed plan of the study, showing random allocation of patients to instructors

4.3.4 Data Analysis

Data were treated as non-parametric. Agreement between the instructors' observations i.e. the number of recorded faults (major or minor) and whether a manoeuvre was recorded as having been observed, (correct or not assessed) is shown as percentage concordance. Wilcoxon matched pairs signed ranks tests were used to test the mean difference in the overall number of faults (major and minor) recorded across the 25 road manoeuvres between the two driving instructors for each patient. Differences in the overall (global) ratings of driving performance (definitely or probably safe or definitely or probably unsafe) are described.

Insufficient numbers of patients were available to test statistically agreement between the independent ratings of the driving instructors on the overall driving outcome (definitely safe, probably safe, probably unsafe or definitely unsafe) (Cohen, 1960).

The data were checked in its entirety by an independent assessor.

Analysis was carried out using SPSS version 6.3.1. for Windows (Norušis, 1994).

4.3 Results

Of the eight patients who participated in the study, one was not assessed on the public road, since she was considered by both instructors to be unfit to drive any of the vehicles available for assessment at the Derby Regional Mobility Centre. This patient was rated by one instructor as 'definitely unsafe' to drive, whereas the other instructor withheld comment pending the possibility of further evaluation in a vehicle more suited to her needs. Therefore seven pairs of driving reports were available for analysis. Percentage concordance between the two instructors was

recorded across all 25 manoeuvres for each patient and overall (across all patients). Instructors were considered to agree if manoeuvres were rated by both to be 'correct' or at 'fault' (irrespective of fault severity i.e. major or minor) and if they were observed by both instructors. The total number of faults recorded for each patient by each instructor (0= 'correct', 1 = 'minor fault', 2 = 'major fault' or 3 = 'both') and the percentage concordance between the two visiting instructors and VR are shown in Tables 4.0 and 4.1. Instructors were considered to agree globally if they both indicated that the patient was safe to drive or unsafe to drive, irrespective of whether the rating was 'definitely' or 'probably'. The terms concordance and agreement are used for clarity, to distinguish between fault ratings and global ratings and do not infer different procedures.

Table: 4.0 Concordance between BE and VR in recorded faults and overall global ratings of driving performance for the four patients

Day 1.

Patient	BE		VR		Concord -ance (%)	Global Rating Agreement
	Faults	Global Rating	Faults	Global Rating		
1	0	Def safe	4	Def safe	88%	75%
2	0	Prob safe	6	Def safe	76%	
3	19	Def unsafe	15	Prob safe	44%	
4	0	Declined to rate	0	Def unsafe	100%	
Overall	19		35		77%	

Key: Def = definitely, Prob = probably

Table: 4.1 Concordance between SV and VR in recorded faults and overall global ratings of driving performance for the four patients

Day 2.

Patient	SV		VR		Concordance (%)	Global Rating Agreement
	Faults	Global Rating	Faults	Global Rating		
5	9	Prob safe	9	Prob safe	48%	100%
6	14	Def unsafe	13	Def unsafe	60%	
7	10	Prob safe	10	Prob safe	44%	
8	21	Def unsafe	13	Prob unsafe	52%	
Overall	**54**		**45**		**51%**	

Key: Def = definitely, Prob = probably

Wilcoxon matched pairs signed ranks tests were used to test the mean difference in the overall number of faults (major and minor) recorded across the 25 road manoeuvres between the two driving instructors for each patient. There were no significant differences in the number of faults recorded between VR and SV ($Z = -1.34$, p (2-tailed) = 0.18) nor between VR and BE ($Z= -0.816$, p (2-tailed)= 0.41).

4.4 Discussion

The outcome of 'on-road' testing is often used as the gold standard of driving ability against which cognitive tests are validated, but the validity of this gold standard is seldom questioned (Fox et al., 1998; Odenheimer et al., 1994; Simms 1994). In both the development of the SDSA (Nouri et al., 1987; Nouri and Lincoln, 1992; Nouri and Lincoln, 1993) and studies to validate it for patients with acquired neurological disabilities other than stroke (Chapter 3) (Radford et al., 1999), the public road assessment (PRA) was used as the 'gold standard' of

driving ability. Similarly, in studies by Lundqvist et al., (1997, 2000); Sivak et al., (1981); Engum et al., (1989); Brooke et al., (1992); Odenheimer et al., (1994) and Fox et al., (1992), driving in real traffic was the criterion for validating and evaluating the predictive value of neuropsychological tests. For this reason, the often-overlooked question of whether the driving instructor's overall decision is reliable is important.

Although no principal differences in fault ratings were found between the instructors in this study, slight differences in global ratings did exist. Between BE and VR, global agreement occurred for three out of the four patients assessed (75%) and concordance based on fault ratings was similarly high (77%). Global rating categories differed by three categories in one case and by one category in two cases. Between SV and VR, concordance reached only 51%, whereas the global agreement was much higher (100%). These instructors agreed fully on three out of the four patients assessed, and differed by only one category (one 'definitely unsafe' and the other 'probably unsafe') on the fourth. In terms of concordance in fault ratings, BE and VR were more similar, yet the global ratings of SV and VR were almost identical. Global rating differences amounted to a discrepancy in whether a person was safe or unsafe to drive only once. In the comparison between VR and BE, patient three was considered 'definitely unsafe' by one instructor and 'probably safe' by the other.

There was a relationship between the number of recorded faults and global outcome: patients incurring high fault ratings were more likely to be found unsafe to drive. However the differences between fault ratings and global outcome suggest the basis for this final judgement is unclear and not necessarily based on faults observed during the actual on-road test.

There may be several explanations for these findings. Recorded faults are based on observed manoeuvres; whereas 'global decisions' about driving safety may encompass other factors such as impressions of the patient's attitude or behaviour or 'gut feelings'. These factors may influence the instructor's decision about whether the patient is 'definitely safe', 'probably safe', 'probably unsafe' or 'definitely unsafe' to drive or persuade the instructor who has observed a faultless performance to decide a patient is only 'probably' rather than 'definitely safe'. BE's refusal to make a global outcome rating in the case of patient 4 suggests agreement with VR, since instructors were asked to make a decision based on whether patients were considered to be safe to drive at the time they were assessed i.e. is this person safe to drive this car on this day?

Although detailed protocols and copies of the driving test form were sent to the visiting instructors in advance of the study, they were less familiar than VR with this form and the on–road testing procedure used by the Derby Regional Mobility Centre. A period of familiarisation and training in the method of test administration may have resolved discrepancies.

The driving test evaluation form used in this study (Appendix 3.1) was the same as that used in the SDSA validation study (Chapter 3). It was adapted from the one used in the development of the SDSA (Nouri, 1991), to include the types of faults anticipated in the neurologically impaired driver, and is based on the Driving Standards Agency's, (DSA) Driving Test (Appendix 4.2). Although the scoring differs, similarities between the form used in this study and that of the DSA might have prompted ADIs (who are trained in DSA Test Administration) towards an overall outcome decision (e.g. any major fault indicates failure). This might explain the closer global agreement between SV and VR who are both

currently approved DSA driving instructors and the difference between VR and BE, whose accreditation had lapsed. However, in such a small study where comparison between BE and SV was impossible, no firm conclusions can be drawn.

Poor concordance between SV and VR can be explained in part by SV's tendency to rate faults more seriously than VR, which SV attributed to the potential for danger arising from them.

Global rating discrepancies are harder to explain than fault ratings. For example in the comparison between BE and VR, patient 3 was noted to incur several major faults by VR but still rated overall 'probably safe'. Factors such as medical knowledge, experience, disability awareness and technical knowledge may have affected the global outcome decision. For example, an instructor with little or no medical knowledge may make misguided assumptions about the cognitively impaired patient who presents as a little out of practice but whose difficulties are unlikely to be overcome with tuition. It is also possible that medication side effects may be misinterpreted. Disability awareness and technical knowledge assist the instructor in knowing which adaptations are available and which may suit the disabled driver and for how long. For example, the global discrepancy between VR and BE in which VR rated patient 4 as definitely unsafe and BE declined to comment, might be attributable to the more technically knowledgeable BE's awareness of what might be available as a solution to the presenting disabilities. However this may also be a reflection of discrepancies in funding and facilities between Forum centres, which dictate the types of assessment that can be conducted.

Lack of familiarity with the routes may have affected the outcome. Visiting instructors may have missed things when assessing their first patient in an unfamiliar city. Although efforts were made to familiarise both visiting instructors with routes surrounding the DRMC (road test starting point), it is possible that their initial observations were more inaccurate.

It could be argued that the failure to standardise the route meant that clients did not experience the same opportunities for making errors, possibly reducing the inter-rater reliability. However, since the non-set route was a feature of the validation study (Chapter 3) and thought to allow freedom for manoeuvres giving rise to concern to be re-tested, it seemed important to retain the same features when testing the reliability of this method of on-road testing. Although not set, the route was not totally un-standardised. All routes incorporated the same important features, i.e. quiet side streets; busy built up areas, areas of dual carriageway, multi-lane roads and major junctions, which allowed all 25 road manoeuvres to be tested. The test was designed specifically to include manoeuvres thought to measure the tactical levels of driving (Michon, 1979) (such as the driver's ability to pick out and follow road signs for a specified route or make judgements) and it is for this reason that a more flexible approach was used. Rigid standardisation may have altered the test's potential to examine these tactical skills or failed to allow for the anticipated variation in performance of brain damaged drivers that one might expect in 'normal' drivers. Whilst the argument for scientific rigor (more easily upheld by rigidly standardised tests) is strongly supported, literary emphasis on the need to move away from on-road tests that are based on technical skill (driving on the operational level) among brain damaged drivers (Brouwer and Withaar, 1997) supports this approach.

Another criticism which could be levelled at the on-road test is that decisions and judgements made by instructors familiar with assessing learner drivers (driver educators) may differ from those familiar with assessing experienced brain damaged drivers. It is possible that driver educators provide too much tuition during the course of the evaluation, allowing little opportunity for the patients' own judgement and reasoning abilities to be tested. This may explain the slight difference in global ratings between BE and VR (who was more familiar with learners). Although agreement between observed driving manoeuvres (measures of driving skill) was good, something other than observable phenomenon was responsible for the global outcome difference.

Efforts to eliminate bias by randomly allocating patients to assessors dictated where the instructors sat. It is possible that faults were less easily observed by the instructor seated in the rear of the vehicle during assessment and may explain worse concordance between VR and SV when VR is seated in the back. On twelve occasions, manoeuvres that were observed and rated by SV were not recorded by VR. However, it has been argued that some manoeuvres e.g. visual scanning can be better observed by the rear seat rater who is freed from the tasks of vehicle safety and giving directions (Jones, 1978). Nevertheless the lack of systematic difference between recorded faults between the instructors suggest this is not an important factor.

In the SDSA development and subsequent validation studies (Nouri et al., 1987; Nouri and Lincoln, 1992), as in work by Brooke et al., (1992); Galski et al., (1993); Hartje et al., (1991) and Odenheimer et al., (1994), it is the overall impression of safety (global rating), rather than scores derived from the number of faults that was used as the criterion measure for validating cognitive tests. The

lack of difference in global ratings of driving performance between instructors in this study, suggests global agreements are reliable and supports their use as a criterion measure.

Odenheimer and colleagues (1994) and Fitten and co-workers (1995) both found high inter-rater agreement using standardised driving routes and scoring procedures. However, no matter how conscientious the efforts to standardise the on road test, different instructor ratings may prevail. In the development of the SDSA, the global test results of stroke patients varied when a different instructor was introduced to carry out assessments in a validation study. In the initial study (Nouri et al., 1987) most subjects passed on the road, whereas in the validation study (Nouri and Lincoln, 1992) most patients failed. Although the results might be explained by a change in route complexity, the possibility that the instructors had different criteria for adequate performance cannot be ruled out (Fox et al, 1998). Fox uses this example to support the argument for rigidly standardised routes. However, recently completed pilot work (Brown, 2000) comparing the SDSA prediction to the outcome of an on road assessment using very different procedures at a different centre found the same, if not improved, SDSA classification, confirming the predictive validity of the SDSA. This suggests that SDSA results should hold true for on-road assessments carried out elsewhere. It also indicates that identical routes, providing they incorporate the same features of assessment, may not be important (Brown, 2000).

4.5.1 Limitations of the study design

Had it been possible, patients of known driving ability would have been selected for this study. Unfortunately, drivers previously deemed unfit to drive could not have been assessed on the public road and ethical approval and consent may have been difficult to obtain. Ideally a group of drivers of questionable ability i.e. 'borderline' cases would have provided a better testing environment, where the instructors would be pushed harder to make decisions. The consecutive selection of patients for this study resulted in two very good and two very poor drivers for BE and VR and one poor and three questionable drivers for SV and VR. However, the lack of complete agreement suggests the patient mix still provided an appropriate testing ground.

Although attempts were made to withhold information about the patients from the instructors so that they were partially blinded to the diagnosis, the possibility that driving instructors were influenced by information elicited from patients themselves cannot be ruled out. The instructors may also have influenced each other, in terms of assessment technique; although with so few comparisons this influence was negligible.

4.5.2 Further work

Although small, this study is an important attempt to check the reliability of decisions made by the instructor used to validate the SDSA for people with acquired neurological disabilities, by comparing his ratings to those made by other instructors experienced in assessment of brain damaged drivers. The results suggest that standards of assessment between instructors employed in different Forum centres are similar when global ratings are used.

An alternative approach would have been to include a second independent rater on all assessments throughout the main study (Chapter 3) but financial constraints made this impractical. Moreover, the comparison of instructors from different centres adds a unique dimension. Potentially the inter-rater reliability is reduced by removing the influence of systematic training in one centres procedures. The fact that comparison between the instructors' global ratings remained good and there were no principal differences in error ratings suggests there were no real differences between VR (the instructor used in previous studies) and experienced instructors from two other Forum accredited driving centres. Had any principal differences been found, then the power of studies to validate the SDSA for patients with acquired neurological disability may have been questioned.

Although there were slight discrepancies in the global ratings between one of the visiting instructors and VR, it is encouraging that they only differed by one category for one patient. This was a young woman who had undergone repeated brain tumour excisions and had driven only intermittently in the preceding nine years.

Ideally a much larger study involving more patients and instructors from all Forum accredited centres would have been preferable. Such a study would have allowed the visiting ADIs to be compared to each other and yielded more information about the between-centre standards of assessment of neurologically impaired drivers.

One way of increasing inter-rater reliability would be to limit the observed manoeuvres in some way and restrict driving to a closed course. This is likely to result in high inter-rater agreement (Schweitzer et al., 1994; Wilson and Smith, 1983) but is unlikely to satisfy the requirements for assessing driving

performance, since it provides no opportunity to interact with real traffic (Odenheimer et al., 1994). Closed course driving therefore lacks validity as a criterion measure for driving on the public roads in real traffic. Closed course measures restrict driving to a level where little more than basic car handling skills, e.g. steering, position control, braking (driving on the operational level), can be assessed (Fox et al., 1998). However, they may shed light upon whether a patient has the fundamental car handling skills needed to progress to the public road.

5.6 Summary

Although not ideal, the on-road test is thought to be the closest approximation to daily driving and therefore the best criterion against which to measure driver safety (Anonymous 1990; Fox et al., 1998; Pentland et al., 1992). The purpose of this study was to check the reliability of the decision made by the driving instructor (VR) used in the study to validate the SDSA for patients with an acquired neurological disability other than stroke (Chapter 3). In the present study VR was compared to experienced instructors doing a similar job elsewhere. There were no significant differences in fault ratings between VR and experienced instructors from two other Forum accredited driving centres and there was agreement in the overall (global) ratings for seven out of the eight patients assessed. Where global rating differences occurred, they were only by one category, except on one occasion where there was a three category discrepancy - the difference between a pass and a fail.

The results suggest that minor differences may exist between individual assessors from different centres when global ratings are used as the outcome measure of on-road tests. However, the favourable comparison between the second instructor

and VR suggests these differences may not be generalisable, as they occur infrequently and may be attributed to the selection of instructors for this study.

In view of the differences in road test procedures between Forum centres, the fact that visiting instructors were unfamiliar with the Derby road network and the lack of set route in this study, the inter-rater agreement was considered to be good. Moreover, the lack of principal differences in error ratings suggests decisions made by VR are reliable and that the 'gold standard' of driving ability used in the SDSA validation study may be valid. However, in view of the sample size (eight patients), this study can only be considered exploratory and needs to be repeated on a much larger scale to confirm the findings.

CHAPTER 5: CONCLUSION

Driving is an area of concern to many people with acquired neurological disabilities. However, advice and assessment techniques are inconsistent, particularly in relation to the assessment of cognitive fitness to drive. Many techniques used have not been validated against actual on-road driving performance or lack clear cut-offs in the distinction between safe and unsafe drivers.

The Stroke Drivers Screening Assessment (SDSA), an established test of cognitive abilities, had predictive validity for driving in stroke patients but it was not known which cognitive abilities it assessed, nor whether it could be used to predict driving in patients with other acquired neurological disabilities.

STUDY 1:

This study set out to determine the nature of cognitive abilities tested by the SDSA. It has established that the SDSA predominantly measures executive abilities and attention and to a lesser extent visuospatial abilities and memory. The findings confirm that these cognitive skills are important for driving after stroke and support research relating these abilities to safe driving in brain damaged patients.

The SDSA could now be introduced more widely in the screening of stroke patients wishing to resume driving and the individual test scores interpreted more confidently in light of the abilities they are known to measure and their predictive validity for driving.

STUDY 2:

This study set out to determine whether the SDSA could be used to predict fitness to drive in patients with acquired neurological disabilities other than

stroke. The results suggest the SDSA alone is not sufficient for this purpose and that different cognitive abilities are important for different diagnostic groups of patients. When measures of these cognitive abilities were combined statistically for patients with head injury and multiple sclerosis, accurate predictions of driving performance could be made in 82.4% and 79.4 % of cases respectively. However, these procedures were better at predicting safe than unsafe drivers. Other factors, such as physical and visual deficits, which account for a proportion of patients misclassified by the cognitive tests, were also important.

The findings suggest that in future, research should be diagnosis specific and all brain damaged patients should not be treated as one homogenous group. Further work is needed to establish the predictive validity of the SDSA for patients with Parkinson's disease and dementia.

STUDY 3:

This exploratory study set out to determine the reliability of the public road assessment. A lack of principal differences in error ratings and only slight global outcome discrepancies between the driving instructor used in studies to validate the SDSA (VR) and two visiting instructors, suggest the decision made by VR may be reliable and that the 'gold standard' of driving ability used in the SDSA validation may be valid. However, in view of the study size (eight patients) a much larger study is needed to confirm these findings and to determine the reliability of on-road testing procedures used by Forum accredited driving centres.

REFERENCES

Adler G, Rottunda SJ, Dysken MW (1996) The driver with dementia. A review of the literature. American Journal of Geriatric Psychiatry, 4, 110-120.

Adler G, Rottunda S, Kuskowski M (1999) Dementia and driving: Perceptions and changing habits. Clinical Gerontologist, 20(2), 23-24.

Agid Y, Ruberg M, DuBois B, Pillon B (1987) Anatomoclinical and biomedical concepts of subcortical dementia. In Stahl SM, Iverson SD, Goodman EC (Eds) Cognitive Neurochemistry. Oxford University press, Oxford.

Aho K, Harmsen P, Hatano S, Marquardsen J, Smirnov VE, Strasser T (1980) Cerebrovascular disease in the community: Results of a WHO collaborative study. Bulletin of the World Health Organisation, 58, 113-130.

Allen CC and Ruff RM (1990) Self-rating versus neuropsychological performance of moderate versus severe head injured patients. Brain Injury, 4, 7-18.

Alm H (1989) Driver behaviour models and accident causation. Drive Project V1017 (Bertie).

Altman DG (1997) Practical Statistics for Medical Research, Chapman and Hall, London.

Alzheimer's Disease Society (2000) Statistics on dementia. Internet www page at: <http://www.alzheimers.org.uk/dementia2.htm> (Accessed 06.01.00, Updated 2000).

American Psychiatric Association (1987) Diagnostic and Statistical manual of Mental Disorders (3rd Edition, revised). American Psychiatric Association, Washington, DC.

Annoni JM, Beer S, Kesseling J (1992) Severe traumatic brain injury - epidemiology and outcome after three years. Disability and Rehabilitation, 14, 23-26.

Anonymous (1990) Driving and Parkinson's Disease, Lancet, 336,781.

Armitage SG (1946) An analysis of certain psychological tests used for the evaluation of brain injury. Psychology Monographs, 60 (Whole no. 277).

Avolio BJ, Kroeck KG, Panek PE (1985) Individual differences in information-processing ability as a predictor of motor vehicle accidents. Human Factors, 27, 577-587.

Baddeley, AD, Della Sala S, Colin G, Papagno C, Spinnler H (1997) Testing central executive functioning with a pencil and paper test. In Rabbitt P (Ed)

Methodology of Frontal and Executive Function (pp 61-80), Psychology press, Hove.

Ball K and Owsley C (1991) Identifying correlates of accident involvement for the older driver. Human Factors, 33, 583 - 595.

Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR (1993) Visual attention problems as a predictor of vehicle crashes among older drivers. Investigative Opthalmology and Visual Science, 34, 3110 - 3123.

Bamford J, Sandercock P, Dennis M, Warlow C, Jones L, McPherson K, Vessey M, Fowler G, Molyneux A, Hughes T, Burn J, Wade D, (1988) A Prospective study of acute cerebrovascular disease in the community: The Oxfordshire community stroke project 1981-1986. 1. Methodology, demography and incident cases of first ever stroke. Journal of Neurology, Neurosurgery and Psychiatry, 51, 1373-1380.

Bannister R (1992) Brain and Bannister's Clinical Neurology (7th Edition), Oxford University press, Oxford.

Bardach JL (1971) Psychological factors in the handicapped driver. Archives of Physical Medicine and Rehabilitation, 52, 328-332.

Barnes M, Eames P, Evans C, Iannotti F, Jessop E, McLellan L, Pentland B, Wilson B (1998) Rehabilitation after Traumatic Brain Injury: A working Party report of the British Society of Rehabilitation Medicine, BSRM, London.

Barnes MP and Hoyle EA (1995) Driving assessment - a case of need. Clinical Rehabilitation, 9,115-120.

Barnes MP (1997) Driving for disabled people. Critical Reviews in Physical and Rehabilitation Medicine, 9(1), 75-92.

Beatty WW (1992) Memory disturbances in Parkinson's disease. In Huber SJ and Cummings JL (Eds) Parkinson's Disease, Oxford University Press, New York.

Beatty WW (1993) Memory and frontal lobe dysfunction in multiple sclerosis. Journal of the Neurological Sciences, 115(Suppl.), 38-41.

Beatty WW and Monson N (1994) Picture and motor sequencing in multiple sclerosis. Journal of Clinical and Experimental Neuropsychology, 16, 165-172.

Beatty WW and Scott JG (1993) Issues and developments in the neuropsychological assessment of patients with multiple sclerosis. Journal of Neurologic Rehabilitation, 7, 87-97.

Beatty WW, Paul RH, Wilbanks SL, Hames KA, Blanco CR, Goodkin DE (1995) Identifying multiple sclerosis patients with mild or global cognitive

impairment using the Screening Examination for Cognitive Impairment (SE-FCI). Neurology, 45, 718-723.

Beatty WW, Wilbanks SL, Blanco CR, Hames KA, Tivis R, Paul RH (1996) Memory disturbance in multiple sclerosis: Reconsideration of patterns of performance on the selective reminding test. Journal of Clinical and Experimental Neuropsychology, 18, 56-62.

Beddoe-Rees J.A. (1970) The Use of the Rey-Osterrieth drawing test and the Wechler Logical Memory subtest as indices for lateralisation of temporal lobe lesions. M Phil Thesis, University of London, cited by Coughlan A.K., Hollows SE (1985) The Adult Memory and Information Processing Battery (AMIPB) Psychology Department, St James's University Hospital, Leeds, UK.

Benson DF (1993) Aphasia. In Heilman KM and Valenstein E (Eds.) Clinical Neuropsychology (3rd edition) Oxford University Press, New York.

Benton AL (1979) Visuoperceptive, visuospatial and visuoconstructive disorders. In Heilman KM and Valenstein E (Eds.) Clinical Neuropsychology (3rd Ed.) Oxford University Press, New York.

Benton AL and Hécaen H (1970) Stereoscopic vision in patients with unilateral cerebral disease. Neurology, 20, 1084-1088.

Benton AL and Hamsher R (1976) Multilingual Aphasia Examination. University of Iowa Press, Iowa City.

Bigler ED (1990) Neuropathology of traumatic brain injury. In Bigler ED (Ed.) Traumatic Brain Injury. Pro-ed, Austin, Texas.

Binet A and Simon TH (1908) Le Developement de l'intelligence chez les enfants. L'Anneé Psychologigue, 14, 1-94.

Boll TJ and Reitan RM (1973). Effect of age on performance of the Trail Making Test. Perceptual and Motor Skills, 36, 691-694.

Boller F, Mizutani T, Roessmann U, Gambetti P (1980) Parkinson's disease, dementia and Alzheimer's disease: Clinicopathological correlations. Annals of Neurology, 7, 329-335.

Bonita R and Anderson A (1983) Speech and language disorders after stroke: An epidemiological study. New Zealand Speech and Language Therapy Journal, 38, 2-9.

Bornstein RA (1985) Normative data on selected neuropsychological measures from a non-clinical sample. Journal of Clinical Psychology, 41, 651-659.

Brassington JC and Marsh NV (1998) Neuropsychological aspects of multiple sclerosis. Neuropsychology Review, 8(2) 43-77.

Brittain JL, La Marche JA, Reeder K Roth DL (1991). The effects of age and IQ on Paced Auditory Serial Addition Task (PASAT) performance. The Clinical Neuropsychologist, 5, 163-175.

Brooke MM, Questad KA, Patterson DR, Valois TA (1992) Driving Evaluation after traumatic brain injury. American Journal of Physical Medicine and Rehabilitation, 71, 177-182.

Brooks DN, Hosie J and Bond MR (1986) Cognitive sequelae of severe head injury in relation to the Glasgow Outcome Scale. Journal of Neurology, Neurosurgery and Psychiatry, 49, 549-553.

Brouwer WH and Withaar FK (1997) Fitness to drive after traumatic brain injury. Neuropsychological Rehabilitation, 7(3), 177-193.

Brouwer WH, Ponds RW, van Wolffelaar PC and van Zomeren AH (1989) Divided attention 5 to 10 years after severe closed head injury. Cortex, 25, 219-230.

Brower WH and Ponds RWHM (1994) Driving competence in older persons. Disability and Rehabilitation, 16(3), 149-161.

Brouwer WH, Van Zomeren AH, Van Wolffelaar PC (1990) Traffic behaviour after severe traumatic brain injury. In Deelman BG, Saan RJ and van Zomeren AH (Eds), Traumatic Brain Injury, Clinical, Social and Rehabilitational Aspects. pp 89-100. Swets and Zeitlinger, Lisse.

Brown Y (2000) Driving Assessment Following a Stroke. Unpublished Masters Thesis. Brunel University, UK.

Brown GG, Spicer KB, Robertson WM, Baird AD, Mali KG (1989) Neuropsychological signs of lateralised arteriovenous malformations: Comparisons with ischaemic stroke. The Clinical Neuropsychologist, 3, 340-352.

Capitani E, Della Sala S, Spinnler H (1986) Neuropsychological approach to dementia. In Poeck K, Freund HJ, Gaensehirt H (Eds) Neurology, Springer, Berlin Heidelberg.

Capitani E, Della Sala S, Spinnler H (1990) Controversial neuropsychological issues in Alzheimer's disease: Influence of onset age and hemispheric asymmetry of impairment. Cortex, 22226, 133-145.

Carr D, Jackson T, Alquire P (1990) Characteristics of an elderly driving population referred to a geriatric assessment centre. Journal of the American Geriatric Society, 38, 1145–1150.

Carr DB, LaBarge E, Dunnigan K, Storandt M (1998) Differentiating drivers with dementia of the Alzheimer type from healthy older persons with a traffic sign naming test. Journal of Gerontology: Medical Sciences, 53A(2), M135-M139.

Carr D, Schmader K, Bergman C, Simon T, Jackson T, Haviland S, O'Brien J (1991) A multidisciplinary approach in the evaluation of demented drivers referred to geriatric assessment centres. Journal of the American Geriatric Society, 39, 1132-1136.

Chapman P and Underwood G (1998) Visual search of driving situations: danger and experience. Perception, 27, 951-964.

Chui HC and Perlmutter LS (1992) Pathological correlates of dementia in Parkinson's disease. In Huber SJ and Cummings JL (Eds), Parkinson's Disease: Neurobehavioural Aspects, Oxford University press, New York.

Cohen J (1960) A coefficient of agreement for nominal scales. Education and Psychological. Measurement, 20, 37-46.

Comalli PE (1965) Cognitive functioning in a group of 80-90 year old men. Journal of Gerontology, 20, 14-17, cited by Trenerry MR, Crosson B, DeBoe J, Leber WR (1989) The Stroop Neuropsychological Screening Test. Psychological Assessment Resources Inc., Odessa, Florida, USA.

Comalli PE, Wapner S, Werner H (1962) Interference effects of Stroop Colour-Word test in childhood, adulthood and ageing. Journal of Genetic Psychology, 100, 47-53, cited by Spreen O and Strauss E (1991) A Compendium of Neuropsychological Tests. Oxford University Press, New York.

Conn DK (1989) Neuropsychiatric syndromes in the elderly: An overview. In Conn DK, Grek A, Savadoy J (Eds) Psychiatric Consequences Of Brain Disease In The Elderly: A Focus On Management. Plenum Press, New York.

Coolidge FL, Middleton PA, Griego JA, Schmidt, MM (1996) The effects of interference on verbal learning in multiple sclerosis. Archives of Clinical Neuropsychology 11: 605-611.

Coyne AC, Feins LC, Powell AL, Joslin BL (1990) The relationship between driving and dementia. Paper presented at the Third Biennial Cognitive Ageing Conference, Atlanta, GA.

Cornwell M, Hatton B, Marsh M, Beeton A (1999) Forum of Regional Mobility Centres Annual Report 1998/1999. Banstead Mobility Centre, Surrey.

Coughlan AK and Hollows SE (1985) The Adult Memory and Information Processing Battery (AMIPB) Psychology Department, St James's University Hospital, Leeds, UK.

Croft D and Jones RD (1987) The value of off-road tests in the assessment of driving potential of unlicensed disabled people. British Journal of Occupational Therapy, 50(10) 357-361.

Crosson B, Barco P, Velozo CA Bolesta MM, Cooper PV, Werts D, Brobeck TL (1989) Awareness and compensation in post acute head injury rehabilitation. Journal of Head Trauma Rehabilitation, 4, 46-54.

Crundall D, Underwood G, Chapman P (1999) Driving experience and the functional field of view. Perception, 28, 1075-1087.

Cummings JL (1986) Subcortical dementia: Neuropsychology, neuropsychiatry and pathophysiology. British Journal of Psychiatry, 149, 682-697.

Das JP (1970) Changes in Stroop-Test responses as a function of mental age. British Journal of Clinical and Social Psychology, 9, 68-73

Deeg DJ, Hofman A, Van Zonneveld RJ (1990) The association between cognitive function and longevity in Dutch elderly. American Journal of Epidemiology, 132(5), 973-982.

DelBecq-Derouesné J and Beauvois MF (1989) Memory processes and ageing: A defect of automatic rather than controlled processes? Archives of Gerontology and Geriatrics, (suppl.1), 121-150.

Della Sala S, Freschi R, Lucchelli F, Muggia S, Spinnler H (1996) Retrograde amnesia: No past, new life. In Halligan PW and Marshall JC (Eds) Method In Madness: Case Studies In Cognitive Neuropsychology (pp209-233), Psychology Press, Hove.

Diamond BJ, DeLuca J, Kim H, Kelly SM (1997) The question of disproportionate impairments in visual and auditory information processing in multiple sclerosis. Journal of Clinical and Experimental Neuropsychology, 19, 34-42.

Diesfeldt HFA (1990) Recognition memory for words and faces in primary degenerative dementia of the Alzheimer type and normal old age. Journal of Clinical and Experimental Neuropsychology, 12, 931-945.

Doege TC, Engelberg AL (Eds) (1986) Medical Conditions Affecting Drivers. American Medical Association, Chicago.

Doty RL, Deems DA, Stellar S (1988) Olfactory dysfunction in Parkinsonism: A general deficit unrelated to neurologic signs, disease stage, or disease duration. Neurology, 38, 1237-1244.

Dubinsky RM, Gray C, Husted D, Busenbark K, Vetere-Overfield B, Wiltfong D, Parrish D, Koller WC (1991) Driving in Parkinson's disease. Neurology, 41(4), 517-520.

Drachman DA (1988) Who may drive? who may not? who shall decide? Annals of Neurology, 24, 787-788.

Drachman DA and Swearer JM (1993) Driving and Alzheimer's disease: The risk of crashes. Neurology, 43, 2448-2456.

Driver and Vehicle Licensing Agency (1998) For Medical Practitioners: At a Glance Guide To The Current Medical Standards Of Fitness To Drive, Drivers Medical Unit, DVLA, Swansea.

Driver and Vehicle Licensing Agency (2000), personal communication 2000

Duchek JM, Hunt L, Ball K Buckles V, Morris JC (1998) Attention and driving performance in Alzheimer's disease. Journals of gerontology: Series B: Psychological Sciences and Social sciences, 53B(2), 130-141.

Dyer FN (1973) The Stroop phenomenon and its use in the study of perceptual, cognitive and response processes. Memory and Cognition, 1, 106-120.

Ebrahim S, Nouri F, Barer D (1985) Cognitive impairment after stroke. Age and Ageing, 14, 345-350.

Edmans JA and Lincoln NB (1987) The frequency of perceptual deficits after stroke. Clinical Rehabilitation, 1, 273-281.

Edmans JA, Towle D, Lincoln NB (1991) The recovery of perceptual problems after stroke and the impact on daily life. Clinical Rehabilitation, 5, 301-309.

Egan V (1988) PASAT: Observed correlation with IQ. Personality and Individual Differences, 9, 179-180.

Ellis DW and Zahn BS (1985) Psychological functioning after severe closed head injury. Journal of Personality Assessment, 49, 125-128.

Enderby P, Phillips R. (1986) Speech and language handicap: Towards knowing the size of the problem. British Journal of Disorders of Communication, 21, 151-165.

Engum ES, Cron S, Hulse CK, Pendergrass TM and Lambert W (1988) Cognitive Behavioural Drivers Inventry. Cognitive Rehabilitation, Sept/Oct, 34-36.

Engum ES, Lambert EW and Scott K (1990) Criterion related validity of the Cognitive Behavioural Drivers Inventry: brain injured patients versus normal controls. Cognitive Rehabilitation, March/April, 20- 26.

Engum ES, Lambert EW, Scott K, Pendergrass TM and Womac J (1989) Criterion related validity of the Cognitive Behavioural Drivers Index. Cognitive Rehabilitation, 7, 22-31.

Ernst J (1987) Neuropsychological problem solving skills in the elderly. Psychology and Ageing, 2, 363-365.

Ernst J, Warner MH, Townes BD, Peel JH (1987) Age group differences on neuropsychological battery performance in a neuropsychiatric population. Archives of Clinical Neuropsychology, 2, 1-12.

Evans DA, Funkenstien HH, Albert A , Sherr PA, Cook NR, Chown MJ, Hebert LE, Hennekens CH, Taylor JO (1989) Prevalence of Alzheimer's disease in a community population of older persons: Higher than previously reported. Journal of the American Medical Association 262, 2551– 2556.

Evans L (1988) Older driver involvement in fatal and severe traffic crashes. Journal of Gerontology, 43, S186-S193.

Evans L (1991) Traffic Safety and the Driver. Van Nostrand Reinhold, New York.

Fairclough SH and Graham R (1999) Impairment of driving performance caused by sleep deprivation or alcohol: A comparative study. Human Factors, 41(1), 118-128.

Falmer E and Chambers EG (1939) A Study of accident proneness among motor drivers. Industrial Health Research Board Report 84, London.

Fattal C, Théry JM, Gania L, Coulon JM, Layre JC, Enjalbert M (1998) Vue de la Reprise de la Conduite automobile chez les cérébrolésés. Ann de Réadaption et de Medicin Physique, 41, 77-83.

Finn P and Bragg BWE (1986) Perception of the risk of an accident by young and older drivers. Accident Analysis and Prevention, 18(4), 289-298.

Fischer JS (1989) Objective memory testing in multiple sclerosis. In Jensen K, Knudsen L, Stenager E, Grant I (Eds), Current problems in neurology (Vol. 10) Mental Disorders, Cognitive Deficits, And Their Treatment In Multiple Sclerosis. Libbey, London.

Fish MJ and Co., (1995) Personal Communication.

Fisk GD, Owsley C, Pulley LV (1997) Driving after stroke: Driving exposure, advice, and evaluations. Archives of Physical medicine and Rehabilitation, 78, 1338-1345.

Fisk GD, Schneider JJ, Novack TA (1998) Driving following traumatic brain injury: Prevalence, exposure, advice and evaluations, 12(8), 683-695.

Fitten LJ, Perryman KM, Wilkinson CJ, Little RJ, Burns MM, Pachana N, Mervis JR, Malmgren R, Siembieda DW, Ganzell S (1995) Alzheimer and vascular

dementias and driving A prospective road and laboratory study. Journal of the American Medical Association, 273(17), 1360-1365.

Fleiss JL (1981) The measurement of inter-rater agreement. Statistical Methods For Rates and Proportions. John Wiley and Sons, New York.

Foley DJ, Wallace RB, Eberhard J (1995) Risk factors for motor vehicle crashes among older drivers in a rural community. Journal of the American Geriatric Society, 43, 776-781.

Folstein ME, Folstein SE, McHugh PR (1975) Mini-Mental State. A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12, 189-195.

Fox GK, Bashford GM, Caust SL (1992) Identifying safe versus unsafe drivers following brain impairment: The Coorabel Programme. Disability and Rehabilitation, 14, 140-145.

Fox GK, Bowden SC, Bashford GM, Smith DS (1997) Alzheimer's disease and driving: Prediction and assessment of driving performance. Journal of The American Geriatric Society, 45, 949-953.

Fox GK, Bowden SC, Smith DS (1998) On-road assessment of driving competence after brain impairment: Review of Current Practice and Recommendations for a standardised Examination. Archives of Physical Medcine and Rehabilitation, 79, 1288-1296.

Freidland RP, Koss E, Kumar A, Gaine S, Metzler D, Haxby JV, Moor A (1988) Motor vehicle crashes in dementia of the Alzheimer's type. Annals of Neurology, 24, 782 – 786.

Frye A (1995) Guide to Services For Disabled and Elderly Motorists in the UK. Department of Transport, Crowthorne, Berkshire.

Galski T, Bruno RL, Ehle HT (1992) Driving after cerebral damage: A model with implications for evaluation. American Journal of Occupational Therapy, 46(4), 324-332.

Galski T, Bruno RL, Ehle HT (1993) Prediction of behind-the-wheel driving performance in patients with cerebral brain damage: A discriminant function analysis. American Journal of Occupational Therapy, 47, 391-396.

Galski T, Ehle HT, Bradley W (1997) Off-road driving evaluations for persons with cerebral damage. American Journal of Occupational Therapy, 51, 352-358.

Galski T, Ehle HT, Bruno RL (1990) An assessment of measures to predict the outcome of driving evaluations in patients with cerebral damage. American Journal of Occupational Therapy, 44, 709-713.

Gilley DW, Wilson RS, Bennett DA, Stebbins GT, Bernard BA, Whalen ME, Fox JH (1991) Cessation of driving and unsafe motor vehicle operation by dementia patients. Archives of Internal Medicine, 151, 941–946.

Golden JC (1976) Identification of brain disorders by the Stroop Colour and Word Test. Journal of Clinical Psychology, 32, 654-658.

Golper LAC, Rau MT, Marshall RC (1980) Aphasic adults and their decisions on driving: An evaluation. Archives of Physical medicine and Rehabilitation, 61, 34-40.

Goodenough DR (1976) A review of individual differences in field dependence as a factor in auto safety. Human Factors, 18,53-62.
Goodkin DE, Rudick RA, Ross JS (1994) The use of brain magnetic resonance imaging in multiple sclerosis. Archives of Neurology, 51, 505-516.

Gouvier WD, Maxfield MW, Schweitzer JR, Horton CR, Shipp M, Neilson K, Hale PN (1989) Psychometric prediction of driving performance among the disabled. Archives of Physical Medicine and Rehabilitation, 70, 745-750.

Graca J (1986) Driving and ageing. Clinics in Geriatric Medicine, 2, 583.

Granerus AK (1990) Update on Parkinson's disease: Current considerations and geriatric aspects. In Bergener M, Finkel SI (Eds) Clinical And Scientific Psychogeriatrics (Vol. 2): The Interface of Psychiatry and Neurology. Springer, New York.

Grattan E and Jeffcoate GO (1968) Medical factors and road accidents. British Medical Journal, 1, 75.

Graftman J and Salazar S (1987) Methodological considerations relevant to the comparison of recovery from penetrating and closed head injuries. In Levin HS, Grafman J and Eisenberg HM (Eds) Neurobehavioural Recovery From Head Injury, Oxford University Press, New York.

Greenwood P and Parasuraman R (1991) Effects of ageing on the speed of attentional cost of cognitive operations. Developmental Neuropsychology, 7, 421-434.

Grewell F (1953) Le test de Bourdon-Wiersma. Folia Psychiac Neurol Neurochir Neerl, 56, 694.

Grimm LG and Yarnold PR (1997) Reading and Understanding Multivariate Statistics. American Psychological Association, London.

Gronwell DMA (1977) Paced Auditory Serial-Addition Task: A measure of recovery from concussion. Perceptual and Motor Skills, 44, 367-373.

Gronwell DMA and Sampson H (1974) The psychological effects of concussion. Auckland University Press, Auckland, NZ.

Grossman M (1988) Drawing deficits in brain damaged patients' freehand pictures. Brain and Cognition, 8, 189-205.

Gurgold GD and Harden DH (1978) Assessing the driving potential of the handicapped. American Journal of Occupational Therapy, 32, 1, 41-46.

Hakamies-Blomqvist L (1996) Research on older drivers: a review IATSS Research, 20, 90-101.

Hakkinen S (1976) Traffic accidents and psychomotor test performance: A follow-up study. Mod. Probl. Pharmacopsych, 11, 51-56.

Hannen P, Hartje W, Skreczek W (1998) Assessment of driving ability after brain damage. Neuropsychological examination and on-road driving test. Nervenarzt, 69(10), 864-872.

Harano RM, Peck RC, McBride RS (1975) The prediction of accident liability through biographical data and psychometric tests. Journal of Safety Research, 7, 16-52.

Harrington DL and Haaland KY (1992) Motor sequencing with left hemisphere damage: Are some cognitive deficits specific to limb apraxia? Brain, 115, 857-874.

Hartje W, Willmes K, Pach R, Hannen P, Weber E (1991) Driving ability of aphasic and non aphasic brain-damaged patients. Neuropsychoilogical Rehabilitation, 1, 161-174.

Hawkins K (1998) Validation of the Stroke Drivers Screening Assessment: What does it measure in traumatic brain injury patients? Unpublished, BSc Thesis, University of Nottingham.

Hazelkorn JK, Mueller BA, Rivara FA (1998) Characteristics of drivers and driving record after traumatic and non traumatic brain injury. Archives of Physical Medicine and Rehabilitation, 79, 738-742.

Heaton RK, Thompson LL, Nelson LM, Filley CM, Franklin GM (1990). Brief and intermediate-length screening of neuropsychological impairment pp 149-160. In Rao SM (Ed.) Neurobehavioural aspects of multiple sclerosis, Oxford University Press, New York.

Heikilla VM, Korpelainen J, Turkka J, Kallanranta T, Summala H (1999) Clinical evaluation of the driving ability in stroke patients. Acta Neurologica Scandinavica, 99(6), 349-355.

Heikkila VM, Turkka J, Korpelainen J, Kallanranta T, Summala H (1998) Decreased driving ability in people with Parkinson's disease. Journal of Neurology, Neurosurgery and Psychiatry, 64(3), 325-330 .

Hills BL (1980) Vision, visibility and perception in driving. Perception, 9, 183-216.

Holst P and Vilkki J (1988) Effect of frontomedial lesions on performance on the Stroop Test and word fluency tasks. Journal of Clinical and Experimental Neuropsychology, 10,79 (Abstract).

Hopewell CA and Price RJ (1985) Driving after head injury. Journal of Clinical and Experimental Neuropsychology, 7, 148.

Hoyle LA (1993) A study of driving and disability. MPhil Thesis, University of Northumbria.

Huber SJ, Paulson GW, Shuttleworth EC Chakeres D, Clapp LE, Pakalnis A, Weiss K, Rammohan K (1987) Magnetic Resonance Imaging correlates of dementia in multiple sclerosis. Archives of Neurology, 44, 732-735.

Huber SJ, Shuttleworth EC, Paulson GW, Bellchambers MJ, Clapp LE (1986) Cortical vs. subcortical dementia. Archives of Neurology, 43, 392-394.

Huber SJ and Shuttleworth EC (1990) Neuropsychological assessment of subcortical dementia. In Cummings JL (Ed) Subcortical Dementia. Oxford University Press, New York.

Hunt L, Morris JC, Edwards D, Wilson BS (1993) Driving performance in persons with mild senile dementia of the Alzheimer type. Journal of The American Geriatric Society, 41, 747-753.

Hunt LA (1994) Driving and the demented person. in Morris JC (Ed) Handbook of Dementing Illnesses, Marcel Dekker Incorporated, USA.

Ince PG, Perry EK, Morris CM (1998) Dementia with Lewy bodies. A distinct non-Alzheimer dementia syndrome? Brain Pathology, 8, 299-324.

Jennet B and Bond M (1975) Assessment of outcome after severe brain damage. A practical scale The Lancet, 1, 480-484.

Jenson AR and Rohwer WD (1966) The Stroop Colour-Word Test: A review. Acta Psychologica, 25, 36-93.

Johansson K, Bronge L, Lundberg C, Persson A, Siedeman M, Viitanen M (1996) Can a physician recognise an older driver with increased crash risk potential? Journal of the American Geriatric Society, 44, 1198-1204.

Johansson K, Bogdanovic N, Kalimo H, Winblad B, Viitanen M, (1997) Alzheimer's disease and apolipoprotein E ε4 allele in older drivers who died in automobile accidents. The lancet, 349, 1143-1144.

Jones MH (1978) Driver performance measures for safe performance curriculum. Technical report 78-3, March 1978. Los Angeles (CA), University of Southern California.

Jones R, Giddens H, Croft D (1983) Assessment and training of brain damaged drivers. American Journal of Occupational Therapy 37(11), 754-760.

Joynt RJ, Benton AL, Fogel M (1962) Behavioural and pathological correlates of motor impersistence. Neurology (Minneap), 12, 876-881.

Kahneman D, Ben Ishai R, Lotan M (1973) Relation of a test of attention to road accidents. Journal of Applied Psychology, 58, 113-115.

Kasniak AW (1991) Dementia and the older driver. Human Factors, 33 (5), 527–537.

Kasniak AW, Nussbaum P, Allender JA (1990) Driving in elderly patients with dementia or depression. Paper presented at the annual meeting of the American Psychological Association, Boston MA.

Katz RT, Golden RS, Butter J, Tepper D, Rothke S, Holmes J, Sahgal V (1990) Driving safety after brain damage: Follow-up of 22 patients with matched controls. Archives of Physical Medicine and Rehabilitation, 71, 133-137.

Keller CE and Sutton JP (1991) Specific mathematics disorders. In JE Obrzut and GW Hynd (Eds.) Neurospychological foundations of learning disabilities: A handbook of issues, methods and practice. Academic Press, SanDiego, CA.

Kenny DA (1979) Correlation and causality. John Wiley and Sons, New York.

Kertesz A, Nicholson I, Cancelliere A Kassa K, Black SE. (1985) Motor Impersistence: A right hemisphere syndrome. Neurology 35, 662-666.

Kewman D, Seigerman C, Kintner H, Chu S, Henson D, Reeder C (1985) Simulation training of psychomotor skills: teaching the brain injured to drive. Rehabilitation Psychology 30(1), 11-27.

Kimura D and Archibald Y (1974) Motor functions of the left hemisphere. Brain, 97, 337-350.

Klavora P, Gaskovski P, Martin K, Forsyth RD, Heslegrave RJ, Young M, Quinn RP (1995) The effects of Dynavision rehabilitation on behind the wheel driving ability and selected psychomotor abilities of persons after stroke. American Journal of Occupational Therapy, 49(6), 534-542.

Knecht J (1977) The multiple sclerosis patient as a driver. Schweizerische Medizinische Wochenschrift. Journal Suisse de Medicine, 107(11), 373-378.

Koller WC (1984) Sensory symptoms in Parkinson's disease. Neurology, 34, 957-959.

Korteling JE (1990) Perception response speed and driving capabilities of brain damaged and older drivers. Human Factors, 32, 95-108.

Korteling JE and Kaptein MA (1996) Neuropsychological driving fitness tests for brain damaged subjects. Archives of Physical Medicine and Rehabilitation, 77, 138-146.

Koss E, Ober BA, Delis DC, Freidland RP (1984) The Stroop Colour-Word Test: Indicator of dementia severity. International Journal of Neuroscience, 24, 53-61.

Kumar R, Powel B, Tani N, Noliboff B, Metter EJ (1991) Perceptual dysfunction in hemiplegia and automobile driving. The Gerontologist, 31(6), 807-810.

Lambert EW and Engum ES (1992) Construct Validity of the Cognitive Behavioural Drivers Inventry: age, diagnosis and driving ability. Cognitive Rehabilitation, May/June 32-45.

Landy FJ (1986) Stamp collecting versus science. American Psychologist, 41, 1183-1192.

Lang AER and Fahn S (1989) Assessment of Parkinson's disease. In Munsat TL (Ed) Quantification Of Neurologic Deficit, Chapter 21, pp 49-67. Butterworths, Stoneham, MA.

Legh-Smith J, Wade DT, Langton-Hewer R (1986) Driving after a stroke. Journal of the Royal Society of Medicine, 79, 200-203.

Leininger BE, Gramling SE, Farrell AD Kreutzer JS, Peck EA (1990). Neuropsychological deficits in symptomatic minor head injury patients after concussion. Journal of Neurology, Neurosurgery and Psychiatry, 53, 293-296.

Leng NRC and Parkin AJ (1990) The assessment of memory disorders: A review of some current clinical tests. Clinical Rehabilitation, 4, 159-165.

Lester J (1991) Individual differences in accident liability: A review of the literature. Research Report 306, Transport Research Laboratory, Crowthorne, Berkshire.

Lezak MD (1995) Neuropsychological Assessment. Third Edition. Oxford University Press, Oxford.

Lezak MD (1978) Living with the characterologically altered brain injured patient. Journal of Clinical Psychiatry, 39, 592-598.

Lijmer JG, Mol BW, Heisterkamp S, Bonsel GJ, Prins MH, van der Meulen JHP, Bossuyt PMM (1999) Empirical evidence of design-related bias in studies of diagnostic tests. Journal of the American Medical Association, 282, 1061-1066.

Lincoln NB (1981) Discrepancies between capabilities and performance of activities of daily living in multiple sclerosis patients. International rehabilitation medicine, 3, 84-88.

Lincoln NB and Tinson DJ (1989) The relation between subjective and objective memory impairment after stroke. British Journal of Clinical Psychology, 28, 61-65.

Lincoln NB and Radford KA. Driving and Parkinson's Disease (Chapter 15) In Percival R and Hobson P (Eds) Parkinson's Disease Studies in Psychological and Social Care, British Psychological Society, Leicester and The Parkinson's Disease Society, London.

Lings S and Dupont E (1992) Driving with Parkinson's disease. A controlled laboratory investigation. Acta Neurologica Scandinavica, 86, 33-39.

Ling S and Jensen PB (1991) Driving after stroke: A controlled laboratory investigation. International Disability Studies, 13, 74-82.

Litvan I, Grafman J, Vendrell P, Martinez JM (1988) Slowed information processing in multiple sclerosis. Archives of Neurology, 45, 281-285.

Lucas-Blaustein MJ, Filipp CL, Dungan C, Tune L (1988) Driving in patients with dementia. Journal of the American Geriatric Society, 36, 1087-1091.

Lundberg C, Johansson K, Ball K, Bjerre B, Blomqvist C, Braekhus A, Brouwer WH, Bylsma FW, Carr DB, Englund L, Friedland R, Hakamies-Blomqvist L, Klemetz G, O'Neill D, Odenheimer GL, Rizzo M, Schelin M, Seidman M, Tallman K, Viitanen M, Waller P, Winblad W (1997) Driving and dementia: An attempt at consensus. Alzheimer's disease and associated disorders, 11, 28-37.

Lundqvist A, Alinder J, Alm H, Gerdle B, Levander S, Ronnberg J (1997) Neuropsychological aspects of driving after brain lesion: Simulator study and on road driving. Applied Neuropsychology, 4, 220-230.

Lundqvist A, Gerdle B, Ronnberg J (2000) Neuropsychological aspects of driving after a stroke - in the simulator and on the road. Applied Cognitive Psychology, 135(14), 16-21.

Lyon-Caen O, Jouvent R, Hauser S, Chanu MP (1986). Cognitive function in recent onset demyelinating diseases. Archives of Neurology, 43, 1138-1141.

Luria AR (1966) Higher Cortical Functions In Man. Tavistock, London.

Mahler ME (1992) Behavioural manifestations associated with multiple sclerosis. Psychiatric Clinics Of North America, 15, 427-438.

Madeley P, Hulley JL, Wildgust H, Mindham RHS (1990) Parkinson's disease and driving ability, Journal of Neurology, Neurosurgery and Psychiatry, 53, 580-582.

Marottoli RA, Richardson ED, Stowe MH, Miller EG, Brass LM, Cooney LM, Tinetti ME (1998) Development of a test battery to identify older drivers at risk for self-reported adverse driving events. Journal of the American Geriatric Society, 46, 562-568.

Marsden CD (1984) Function of the basal ganglia as revealed by cognitive and motor disorders in Parkinson's disease. Canadian Journal of Neurological Sciences, 11(1 Suppl), 129-135.

Matthews ML and Moran AR (1986) Age differences in male drivers' perception of accident risk: The role of perceived driving ability. Accident Analysis and Prevention, 18(4), 299-313.

Mayeux R, Stern Y, Rosen J, Benson DF (1983) Is "subcortical dementia" a recognisable clinical entity? Annals of Neurology, 14, 278-283.

Mayeux R, Stern Y, Rosen J, Leventhal J (1981) Depression, intellectual impairment and Parkinson's disease. Neurology, 31, 645-650.

Mazaux JM, Masson F, Levin HS, Alaoui P, Maurette P, Barat M (1997) Long term neuropsychological outcome and loss of social autonomy after traumatic brain injury. Archives of Physical Medicine and Rehabilitation, 78, 1316-1320.

Mazer BL, Korner-Bitensky NA, Softer S (1998) Predicting ability to drive after stroke. Archives of Physical Medicine and Rehabilitation, 79, 743-750.

McFarlin DE and McFarland HF (1982) Multiple Sclerosis. New England Journal of Medicine, 307, 1183-1188 .

McFie J and Zangwill OL (1960) Visual construction disabilities associated with lesions of the left cerebral hemisphere. Brain, 83, 243-260.

McKenna FP and Crick J (1991) Hazard Perception: Can it be trained? Department of Psychology, University of Reading, Berkshire.

McKenna FP and Crick J (1994) Hazard Perception in Drivers: A methodology for testing and training. TRL Report 313, Crowthorne Berkshire.

McKenna FP, Duncan J, Brown ID (1986) Cognitive abilities and safety on the road: A re-examination of individual differences in dichotic listening and search for embedded figures. Ergonomics, 29, 649-663.

McKenna P (1998) Fitness to drive: A neuropsychological perspective. Journal of Mental Health, 7(1), 9-18.

McKhann G, Drachman D, Folstein M, Katzman M, Price D, Stadlan E (1984) Clinical diagnosis of Alzheimer's disease. Neurology,34, 939-944.

McKinlay WW and Gray JM (1992) Assessment of the severely head injured. In Crawford JR, Parker DM and McKinlay WW (Eds) A Handbook of Neuropsychological Assessment. Lawrence Erlbaum Associates Ltd., Hove.

McKnight AJ and Adams BB (1971) The development of driver education objectives through an analysis of the driving task. Professional Paper 4-71, Human Resources Research Organisation, Virginia, USA.

McLay P (1989) The Parkinsonian and driving. International Disability Studies, 11(1), 50-51.

Mehta Z, Newcombe F, Ratcliff G (1989) Patterns of hemispheric asymmetry set against clinical evidence. In Crawford JR and Parker DM (Eds), Developments In Clinical and Experimental Neuropsychology. Plenum, New York.

Melly S (1997) What does the Stroke Drivers Screening Assessment actually measure?: A comparison with other cognitive assessments. Unpublished BSc Thesis, University of Nottingham.

Mendez MF, Mendez MA, Martin R, Smyth KA, Whitehouse PJ (1990). Complex visual disturbances in Alzheimer's disease. Neurology, 40, 439-443.

Michon JA (1985) A critical view of driver behaviour models. What do we know, what should we do? In Evans L and Schwing R (Eds) Human Behaviour and Traffic Safety (pp 485-520). Plenum Press, New York.

Michon JA, (1979) Dealing with danger. Summary report of a workshop in the Traffic Research Center, State University, Groningen, The Netherlands, cited in Van Zomeren AH, Brouwer WH, Minderhoud JM (1987). Acquired brain damage and driving: A review. Archives of Physical Medicine and Rehabilitation, 68, 697-705.

Mihal WL and Barrett BV (1976) Individual differences in perceptual information processing and their relation to automobile accident involvement. Journal of Applied Psychology, 61, 229-233.

Miller Fisher (1956) Left hemiplegia and motor impersistence. The Journal of Nervous and Mental Disease, 123(3), 201-218.

Milner B (1966) Amnesia following operation on the temporal lobes. In Whitty, CWM and Zangwill OL (Eds.) Amnesia. Butterworths, London.

Minden SL, Moes EJ, Orav J, Kaplan E, Reich P (1990) Memory impairment in multiple sclerosis. Journal of Clinical and Experimental Neuropsychology, 12, 566-586.

Minderhoud JM (1987) Acquired brain damage and driving: A review. Archives of Physical Medicine and Rehabilitation, 68, 697-705.

Mirsky AF (1989) The neuropsychology of attention: Elements of a complex behaviour. In Perecman E (Ed) Integrating Theory and Practice In Clinical Neuropsychology. Lawrence Erlbaum, Hillsdale, NJ.

Mitchell RK, Castleden CM, Fanthome YC (1995) Driving, Alzheimer's disease and ageing: A potential cognitive screening device for all elderly drivers. International Journal of Geriatric Psychology, 10, 865-9.

Mollenkopf H, Marcellini F, Ruoppila I, Flaschentreger P, Gagliardi C, Spazzafumo L (1997) Outdoor mobility and social relationships of elderly people. Archives of Gerontology and Geriatrics, 24(3), 295-310.

Monga TN, Ostermann HJ, Kerrigan AJ (1997) Driving: A clinical perspective on rehabilitation technology. Physical Medicine and Rehabilitation: State of the Art Reviews, 11(1), 69-92.

Montgomery D and Hunter J (1987) A comparison of simulated and realistic emergency stop responses: Relevance of driving assessment. International Journal of Rehabilitation Research, 10 (4), 276-279.

Monti J (1981) The neuropsychology of advanced multiple sclerosis. Paper presented at the European conference of the International Neuropsychological Society, Bergen, Norway.

Multiple Sclerosis Society (1999) About Multiple Sclerosis: What is MS? Internet www page at: <http://www.mssociety.org.uk/html/about/whatis.htm> (Accessed 06.07.00, Revised 27.06.00)

Naatanen R and Summala H (1976) Road user behaviour and traffic accidents. North Holland Publishing Company, New York.

National Traumatic Brain Injury Study (1998) Centre for Research Services Studies, University of Warwick, CV4 7AL.

Nehemikis AM, Lewinsohn PM (1972) Effects of left and right cerebral lesions on the naming process. Perceptual and Motor Skills, 35, 787-798.

Nelson HE, (1978) A modified card sorting test sensitive to frontal lobe deficits. Cortex, 12, 313-324.

Newcombe F (1969). Missile Wounds Of The Brain. Oxford University Press, London.

Norušis MJ/SPSS Inc. (1996) SPSS for Windows, Release 6.1, SPSS Inc., Chicago, USA.

Norušis MJ/SPSS Inc. (1994) SPSS Professional Statistics 6.1, SPSS Inc., Chicago, USA.

Nouri FM (1988) Fitness to drive and the general practitioner. International Disability Studies, 10, 101-103.

Nouri FM (1991) Driving after stroke. PhD Thesis, University of Nottingham.

Nouri FM and Lincoln NB (1994) The Stroke Drivers Screening Assessment. Nottingham Rehab. UK.

Nouri FM and Lincoln NB (1992) Validation of a cognitive assessment: Predicting driving performance after stroke. Clinical Rehabilitation, 6, 275-281.

Nouri FM and Lincoln NB (1987) An extended activities of daily living scale for stroke patients. Clinical Rehabilitation, 1, 301-305.

Nouri FM and Lincoln NB (1993) Predicting driving performance after stroke. British Medical Journal, 307, 482-483.

Nouri FM and Tinson DJ (1988) A comparison of a driving simulator and a road test in the assessment of driving ability after stroke. Clinical Rehabilitation, 2, 99-104.

Nouri FM, Tinson DJ, Lincoln NB (1987) Cognitive ability and driving after stroke. International Disability Studies, 9, 110-115.

Nutt JG, Hammerstad JP, Gancher ST (1992) Parkinson's Disease. 100 Maxims. Mosby Year Book, St. Louis, MO.

O'Neill D (1992) Physicians, elderly drivers and dementia. Lancet, 339, 41-43.

O'Neill D, Neubauer K, Boyle M, Gerrard J, Surmon D, Wilcock GK (1992) Dementia and driving. Journal of The Royal Society of .Medicine, 85, 199-213.

Odenheimer GL (1993) Dementia and the older driver. Clinics in Geriatric Medicine, 9(2), 349-364.

Odenheimer GL, Beaudet M, Jette AM, Albert MS, Grande L, Minaker KL (1994) Performance based driver evaluation of the elderly driver: Safety, reliability and validity. Journal of Gerontology, 49(4), M153-M159.

Office for National Statistics (1996) Key Health Statistics from General Practice 1996 (Series MB6 No.1) Office for National statistics, London.

Office for National Statistics (1998) Mortality Statistics, cause: England and Wales 1997 Series DH2 No.24. The Stationary Office, London.

Ogden JA, Growdon JH, Corkin S (1990) Deficits on visuospatial tests involving forward planning in high functioning Parkinsonians. Neuropsychiatry, Neuropsychology and Behavioural Neurology, 3, 125-139.

Olver JH, Ponsford JL, Curran CA (1996) Outcome following traumatic brain injury: A comparison between 2 and 5 years after injury. Brain Injury, 10(11), 841-848.

Owsley C, Ball K, Keeton DM (1994) Relationship between visual sensitivity and target localisation in older adults. Investigative Opthalmology and Visual Science (supplement), 35.

Owsley C, Ball K, McGuin G, Sloane ME, Roenker DL, White MF, Overley T (1998) Visual processing impairment and risk of motor vehicle crash among older adults. Journal of the American Medical Association, 279(14), 1083-1088.

Owsley C, Ball K, Sloane M, Roenker D, Bruni J (1991) Visual/cognitive correlates of vehicle accidents in older drivers. Psychology and Ageing, 6 (3), 403-405.

Parasuraman R and Nestor PG (1991) Attention and driving skills in ageing and Alzheimer's disease. Human Factors, 33(5), 539-557.

Parker C, on behalf of the TOTAL study group (2000) Does leisure therapy improve outcomes of stroke patients 6 months after hospital discharge? Clinical Rehabilitation, 14(2), 224.

Parkinson's Disease Society of the UK, (1999) Internet www page at: <http://www.keme.co.uk/~sharwood/htmdocs/pdsl1.html> (Accessed 10.11.99, Revised 27.06.00).

Paty DW and Li DKB (1988) Neuroimaging in multiple sclerosis. In Theodore WH (Ed) Clinical Neuroimaging. Frontiers of Clinical Neuroscience (Vol. 4), Alan R Liss, New York.

Pentland B, Barnes MP, Findlay LJ, Oxtaby M, Pearce VR, Quinn NP, Scott S (1992) Parkinson's disease the spectrum of disabilities. Journal of Neurology, Neurosurgery and Psychiatry, 55 (3 Suppl.), 32-35.

Perret E (1974) The left frontal lobe of man and the suppression of habitual responses in verbal categorical behaviour. Neuropsychologia, 12, 323-330.

Pidikiti RD and Novack TA (1991) The disabled driver: An unmet challenge. Archives of Physical Medicine and Rehabilitation,72, 109-111.

Pillon B, Dubois B, Lhermitte F, Agid Y (1986) Heterogeneity of cognitive impairment in progressive supranuclear palsy, Parkinson's disease and Alzheimer's disease. Neurology, 36, 1179-1185.

Pillon B, Dubois B, Bonnet A-M, Esteguy M Guimaraes J, Vigouret JM, Lhermitte F, Agid Y(1989) Cognitive slowing in Parkinson's disease fails to respond to levodopa treatment: The 15-objects test. Neurology ,39, 762-768.

Ponds RWHM, Brouwer WH, van Wolfflelaar PC (1988) Age differences in divided attention in a simulated driving task. Journal of Gerontology: Psychological Sciences, 6, 151-156.

Ponsford J and Kinsella G (1992) Attentional deficits following closed head injury. Journal of Clinical and Experimental Neuropsychology, 14 (5), 822-838.

Poser CM (1994) The epidemiology of multiple sclerosis: A general overview. Annals of Neurology 36(Suppl. 2), 180-193

Powell GE (1979) The relationship between intelligence and verbal and spatial memory. Journal of Clinical Psychology, 35; 335-340. cited by Coughlan AK, Hollows SE (1985) The Adult Memory and Information Processing Battery (AMIPB) Psychology Department, St James's University Hospital, Leeds, UK.

Priddy DA, Johnson P, Lam CS (1990) Driving after a severe head injury. Brain Injury, 4 (3), 267-272.

Prigatano GP, Altman IM, and O'Brien KP (1990) Behavioural limitations that traumatic brain-injured patients tend to underestimate. The Clinical Neuropsychologist, 4, 163-176.

Pursuit Rotor. Fourth Instruments. Corn Exchange Dalkeith, Lothian.

Quimby AR, Maycock G, Carter ID, Dixon R, Wall JG (1986) Perceptual abilities of accident involved drivers. Transport Research Laboratory Report RR27. Transport Research Laboratory, Crowthorne, Berkshire.

Rabbitt P, Carmichael A, Jones S, Holland C (1996) When and why older drivers give up driving. Summary report. AA Foundation for Road Safety Research.

Radford KA, Lincoln NB, Murray-Leslie C (1999) Validation of the Stroke Drivers Screening Assessment for patients with Traumatic Brain Injury. Clinical Rehabilitation, 13, 81.

Raine CS (1990) Neuropathology. In Rao SM (Ed) Neurobehavioural Aspects of Multiple Sclerosis. Oxford University press, New York.

Ranney TA (1994) Models of driving behaviour: A review of their evolution. Accident Analysis and Prevention, 26(6), 733-750.

Rao SM (1986) Neuropsychology of multiple sclerosis: A critical review. Journal of Clinical and Experimental Neuropsychology, 8, 503-542.

Rao SM (1990a) Multiple Sclerosis. In Cummings JL (Ed) Subcortical Dementia. Oxford University Press, New York.

Rao SM (Ed) (1990b) Neurobehavioural Aspects of Multiple Sclerosis. Oxford University Press, New York.

Rao SM, Grafman J, DiGuilio D, Mittenberg W, Bernardin L, Leo GJ, Luchetta T, Unverzagt F (1993) Memory dysfunction in multiple sclerosis: Its relation to working memory, semantic encoding, and implicit learning. Neuropsychology, 7, 364-374.

Rao SM, Leo GJ, Ellington L, Nauertz T, Bernardin L, Unverzgt F (1991). Cognitive dysfunction in multiple sclerosis II: Impact on employment and social functioning. Neurology, 41, 692-696.

Rao SM, St. Aubin-Faubert P, Leo GJ (1989) Information processing speed in patients with multiple sclerosis. Journal of Clinical and Experimental Neuropsychology, 11, 471-477.

Raskin SA, Borod JC, Tweedy JR (1992) Set-shifting and spatial orientation in patients with Parkinson's disease. Journal of Clinical and Experimental Neuropsychology, 14, 801-821.

Reason JT, Manstead ASR, Stradling SG, Parker D, Baxter JS (1991) The social and cognitive determinants of aberrant driving behaviour. Contractor Report 253, Transport Research Laboratory, Crowthorne, Berkshire.

Rebok GW, Bylsma FW, Keyl P (1990) The effects of Alzheimer's disease on elderly drivers. Paper presented at the annual meeting of the Gerontological Society of America, Boston.

Recognition Memory Test (faces) (1984) NFER-Nelson, Berkshire, England.

Reder AT and Anetel JP (1983) Clinical spectrum of multiple sclerosis. In Anetel JP (Ed) Neurologic Clinics: Symposium On Multiple Sclerosis (Vol.1, No.3). W.B. Saunders Co., Philadelphia.

Regard M (1981) Cognitive rigidity and flexibility: A neuropsychological study. Un-published PhD dissertation, University of Victoria, British Columbia. cited by Spreen O, Strauss E (1991) A compendium of neuropsychological tests. Oxford University Press, New York.

Reitan, RM (1958) Validity of the Trail Making Test as an indicator of organic brain damage. Perceptual and Motor Skills, 8, 272-278.

Reitan, RM (undated) Instructions and procedures for administering the psychological test battery used at the Neuropsychology Laboratory, Indiana University Medical Center. Unpublished manuscript. Indianapolis, IN.

Reitan RM and Wolfson D (1993) The Halstead-Reitan Neuropsychological Test Battery: Theory and Clinical Interpretation. Neuropsychology Press, Tucson, AZ.

Reuben DB (1992) Dementia and driving. Journal of the American Geriatric Society, 39, 1137-1138.

Rey A (1959) Le test de copie figure complexe. Editions Centre de Psychologie Applique, Paris.

Rey A (1964) L'examen clinique en psychologie. Presses Universitaires de France, Paris.

Richardson JTE (1990) Clinical and Neuropsychological aspects of closed head injury. Taylor and Francis Ltd., London.

Ritter G and Steinberg H (1979) Parkinsonism and driving fitness. Munch Med Wochenschr 121(41), 1329-1330.

Rizzo M, Reinach S, McGehee D, Dawson J (1997) Simulated car crash predictors in drivers with Alzheimer's disease. Archives of Neurology, 54(5), 545-551.

Ron MA, Callanan MM, Warrington EK (1991) Cognitive abnormalities in multiple sclerosis: A psychometric and MRI study. Psychological Medicine, 21, 59-68.

Rumar K (1982) The human factor in road safety. Proceedings of the 11th Australian Road Research Board Conference, Volume 2.

Rumar K (1990) The basic driver error; late detection. Ergonomics 33, 1281-1290.

Sabey BE and Taylor H (1980) The known risks we run: The highway. TRRL Report SR567, Transport and Road Research Laboratory, Crowthorne, Berkshire.

Saint-Cyr JA and Taylor AE (1992) The mobilisation of procedural learning: The "key signature" of the basal ganglia. In Squire LR and Butters N (Eds) Neuropsychology Of Memory (2nd Edition). Guilford Press, New York.

Salazar AM, Martin A, Grafman J (1987) Mechanisms of traumatic unconsciousness. Progress in Clinical Neurosciences, 1, 225-239.

Schear JM and Sato SD (1989) Effects of visual acuity and visual motor speed and dexterity on cognitive test performance. Archives of Clinical Neuropsychology, 4, 25-32.

Schweitzer JR, Gouvier WD, Horton CR, Maxfield M, Shipp M, Hale PN (1994) Assessment of the cognitive components of driving performance among disabled individuals. In Mital A, Karwaski W (Eds), Ergonomics in Rehabilitation, pp 85 - 96. Taylor and Francis, Philadelphia (PA).

Shallice T and Evans ME (1978) The involvement of the frontal lobes in cognitive estimation. Cortex, 14, 294-303.

Shanke AK, Grimsmo J, Sundet K (1995) Multiple Sclerosis and prerequisites for driver's licence. Tidsskr Nor LŒgeforen, 115, 1349-1352.

Shaw L and Sichel H (1971) Accident proneness. Pergamon Press, Oxford.

Shore D, Gurgold G and Robbins S (1980) Handicapped driving: Overview of assessment and training. Archives of Physical Medicine and Rehabilitation, 61, 481.

Shum DHK, McFarland KA, Bain JD (1990) Construct validity of eight tests of attention: Comparison of normal and head injured samples. The Clinical Neuropsychologist, 4, 151-162.

Simms B (1985) Perception and driving: Theory and practice. British Journal of Occupational Therapy, December, 363-366.

Simms B and O'Toole L (1994) The contribution of cognitive and visual assessment to the prediction of driving performance. Project report 50, Transport Research Laboratory, Crowthorne, Berkshire.

Simms B (1994) Cognitive assessment for driving following brain damage: A review of the literature. Banstead Mobility Centre, Surrey.

Sivak M, Hill CS, Henson DL, Butler BP, Silber SM, Olson PL (1984) Improved driving performance following perceptual training in persons with brain damage. Archives of Physical Medicine and Rehabilitation, 65, 163-167.

Sivak M, Olson PL, Keuiman DG, Won H, Henson DL (1981) Driving and perceptual/cognitive skills: behavioural consequences of brain damage. Archives of Physical Medicine and Rehabilitation, 62, 476-483.

Sivak M (1987) Human factors and road safety: Overview of research at The University of Michigan Transportation Research Institute between 1977 and 1986. UMTRI 1, 1-18.

Skilbeck CE, Welch J, Woods RT (1982) The Wechler Memory Scale: Factor scores for neurological patients. Proceedings of the 5th INS European Conference, Deauville, France.

Smith T (1980) Assessing safe driving ability of head injured drivers: A pilot study. Cranfield Institute of Technology, MSc Thesis.

Smith E (1974) Influence of site of impact on cognitive impairments persisting long after severe closed head injury. Journal of Neurology, Neurosurgery and Psychiatry, 37, 719-726.

Snowdon DA, Kemper SJ, Mortimer JA, Greiner LH, Wekstein DR, Markesbery WR (1996) Linguistic ability in early life and cognitive function and Alzheimer's disease in late life. Findings from The Nun Study. Journal of the American Medical Association, 275(7), 528-532.

Spinnler H (1985) Il decadimento demenziale. Inquadramento Neurologico E Neuropsicologico. Il Pensiero Scientifico, Roma.

Spinnler H (1999) Alzheimer's Disease (chapter). In Denes G and Pizzamiglio L (Eds) Handbook of Clinical and Experimental Neuropsychology, Psychology press, Hove.

Spreen O and Strauss E (1991) A Compendium of Neuropsychological Tests. Oxford University Press, New York.

Spreen O and Benton AL (1965) Comparative studies of some psychological tests for cerebral damage. Journal of Nervous and Mental Disease, 140, 323-333.

Staughton GC and Storie VJ (1977) Methodology of an in depth accident investigation survey. LR768, Transport Research Laboratory, Crowthorne, Berkshire.

Stern Y, Sano M, Mayeux R (1987) Comparisons of dementia and intellectual change in Parkinson's and Alzheimer's disease. Journal of Clinical and Experimental Neuropsychology, 9, 66.

Stevens J (1992) Applied Multivariate Statistics for the Social Sciences. Hillsdale NJ (Ed), Lawrence Erlbaum Associates Inc., New York.

Stewart FM, Sunderland A, Sluman SM (1996) The nature and prevalence of memory disorder late after stroke. British Journal of Clinical Psychology, 35, 369-379.

Stokx LC and Gaillard AWK (1986) Task and driving performance in patients with a severe concussion of the brain. Journal of Clinical and Experimental Neuropsychology, 8, 421-463.

Streiner DL and Norman GR (1998) Health Measurement Scales: A Practical Guide To Their Development and Use (Second Edition) Oxford Medical Publications, Oxford.

Stroop JR (1935) Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 18, 643-662.

Stuss DT (1991) Self awareness and the frontal lobes: A neuropsychological perspective. In
Goethals GR and Strauss J (Eds) The Self: An Interdisciplinary Approach. Springer-Verlag, New York.

Stuss GR, Stethem DT, Poirier CA (1987) Comparison of three tests of attention and rapid information processing across six age groups. The clinical neuropsychologist, 1, 139-152.

Stuss DT, Stethem LL, Hugenholtz H, Richard MT (1989). Traumatic brain injury. The Clinical Neuropsychologist, 3, 145-156.

Sullivan RA, Celikyol F, Commaroto L (1974) Automobile driving evaluation for the brain damaged patient: The test and it's result. Archives of Physical Medicine and Rehabilitation, 55, 590.

Sullivan EV, Sagar HJ, Gabrieli JDE,Corkin S, Growden JH (1989) Different cognitive profiles on standard behavioural tests in Parkinson's disease and Alzheimer's disease. Journal of Clinical and Experimental Neuropsychology, 11,799-820.

Tabachnick BG and Fidell LS (1996) Using Multivariate Statistics (3rd Edition), Harper Collins College Publishers, New York.

Taylor JF (Ed) (1995) Medical Aspects of Fitness to Drive, A guide for Medical practitioners. Medical Commission on Accident prevention, HMSO, London.

Taylor AE and Saint-Cyr JA (1992) Executive function. In Huber SJ and Cummings JL (Eds) Parkinson's Disease: Neurobehavioural Aspects. Oxford University press, New York.

Teasdale G and Jennett B (1974) Assessment of coma and impaired consciousness. The Lancet, 81-84.

Tennant A (1995) The epidemiology of head injury. In Chamberlain MA, Neumann V and Tennant A, Traumatic Brain Injury Rehabilitation, Chapman and Hall Medical, London.

Terman LM and Merrill MA (1973). Stanford Binet Intelligence Scale. Manual for the Third Revision, Form L-M. Houghton-Mifflin Co., Boston.

Test of Everyday Attention (1991) Thames Valley test Company, Suffolk, England.

The Stroke Association (2000) Stroke Facts and Figures statistics: Stroke Fact Sheet . Internet www page at: <http://www.stroke.org.uk/facts.htm> (Accessed 06.07.00).

Tinson DJ and Lincoln NB (1987) Subjective memory impairment after stroke. International Disability Studies, 9, 6-9.

Titmus Vision Tester and Perimeter, Clement Clarke International Limited, 15 Wigmore Street, London W1H 9LA.

Torner JC and Schootman M (1996), Epidemiology of closed head injury. In Rizzo M and Trancel D, Head Injury and Post Concussion Syndrome, pp 19-46, Churchill Livingstone, London.

Tow PM (1955) Personality changes following frontal leucotomy. Oxford University Press, London. cited by Lezak MD (1995) Neuropsychological Assessment. Third Edition. Oxford University Press, Oxford.

Treat JR (1980) A study of pre-crash factors involved in traffic accidents. The HSRI Research Review, 10/11, 6/1, Highway Safety Research Institute, Ann Arbor, MI.

Treat JR, Tumbas NS, McDonald ST, Shinar D, Hume RD, Mayer RE Stanisfer RL and Castellan NJ (1977) Tri-level Study of the causes of traffic accidents. Report DOT-HS-034-3-535-77 (TAL) Indiana University.

Trenerry MR, Crosson B, DeBoe J, Leber WR (1989) The Stroop Neuropsychological Screening Test. Psychological Assessment Resources Inc., Odessa, Florida, USA.

Tromp E and Mulder T (1991) Slowness of information processing after traumatic head injury. Journal of Clinical and Experimental Neuropsychology, 13, 821-830.

Tuokko H, Tallman K, Beattie BL, Cooper P, Weir J (1995) An examination of driving records in a dementia clinic. Journal of Gerontology: Social Sciences, 50B(3), S173-S181.

Tweedy JR, Langer KG, McDowell FH (1982) Effect of semantic relations on the memory deficit associated with Parkinson's disease. Journal of Clinical Neuropsychology, 4, 235-248.

Van der Molen HH and Botticher AMT (1987) Risk models for traffic participants: A concerted effort for theoretical operationalisations. In Rothengatter JA and de Bruin (Eds) Road Users and Traffic Safety. Van Gorcum, The Netherlands.

Van Wolffelaar et P, Brouwer W, Rothengatter T (1990) Divided attention in RTI-tasks for Elderly drivers. DRIVE Project V1006 Factors In Elderly Peoples Driving Abilities. Traffic Research Centre, University of Groningen, Netherlands.

Van Zomeren AH and Brouwer WH (1987) Head injury and concepts of attention. In Levin H and Grafman J (Eds) Neurobehavioural Recovery From Head Injury, pp 398-415. Oxford University Press, New York.

Van Zomeren AH and Brouwer WH (1992) Assessment of attention. In Crawford JR, Parker DM and McKinlay WW (Eds) A Handbook of Neuropsychological Assessment. Lawrence Erlbaum Associates Ltd., Hove.

Van Zomeren AH, Brouwer WH, Minderhoud JM (1987). Acquired brain damage and driving: A review. Archives of Physical Medicine and Rehabilitation, 68, 697-705.

Van Zomeren AH and Van den Berg W (1985) Residual complaints of patients two years after severe head injury, Journal of Neurology, Neurosurgery and Psychiatry, 48, 21-28.

Van Zomeren AH, Brouwer WH, Rothengatter JA, Snoek JW (1988) Fitness to drive a car after recovery from severe head injury. Archives of Physical Medicine and Rehabilitation, 69, 90-96.

Vogenthaler DR (1987) An overview of head injury: It's consequences and rehabilitation. Brain Injury, 1(1), 113-127.

Wade DT, Parker V, Hewer RL (1986) Memory disturbance after stroke: Frequency and associated losses. International Rehabilitation Medicine, 8, 60-64.

Warlow CP, Dennis MS, van Gijn J, Hankey GJ, Sandercock PAG, Bamford JM, Wardlaw J (1996) Stroke: A practical Guide to Management. Blackwell Science, London.

Warrington EK (1984) Recognition Memory Test - faces, NFER-Nelson, Windsor, UK.

Warrington EC and Ackroyd C (1975) The effect of orienting tasks on recognition memory. Memory and Cognition, 3, 140-142.

Warrington EK and James M (1991) The Visual Object and Space Perception Battery. Thames Valley Test Co., Bury St. Edmunds.

Warrington EK and Rabin P (1970) Perceptual matching in patients with cerebral lesions. Neuropsychologica, 8, 475-487.

Weber MA (1986) Measuring attentional capacity. Unpublished PhD thesis, University of Victoria, British Columbia, cited by Spreen O and Strauss E (1991) A Compendium of Neuropsychological Tests. Oxford University Press, New York.

Webster DD (1968) Critical analysis of the disability in Parkinson's disease. Medical Treatment, 5, 257-282.

West R, Elander J, French D (1992) Decision making, personality and driving style as correlates of individual accident risk. Contractor report 309, Transport Research Laboratory, Crowthorne, Berkshire.

Weschler D (1987) Weschler Memory Scale Revised (WMS-R) (1982) Psychological Corporation, Kent, England.

What's in the Square? E J Arnold Ltd, Lockwood Distribution Centre, Parkside Lane, Leeds.

Whitaker JN and Beneveniste EN (1990) Demyelinating diseases. In Pearlman AL and Collins RC (Eds) Neurobiology of Disease. Oxford University Press, New York.

White A, Nicolaas G, Foster K, Browne F, Carey S (1993) Health Survey for England 1991. HMSO, London.

Whiting S, Lincoln NB, Cockburn J, Bhavnani G (1985) Rivermead Perceptual Assessment Battery. NFER_Nelson, Windsor.

Wilde GJS (1982) The theory of risk homeostasis: Implications for safety and health. Risk Analysis, 2, 209-225.

Wilkinson RT and Haughton D (1975) Portable 4-choice reaction time test with magnetic tape memory. Behavioural Research Methods Instruments, 7, 441-446.

Willoughby EW and Paty DW (1990) Brain imaging. In Rao SM(Ed) Neurobehavioural Aspects Of Multiple Sclerosis. Oxford University press, New York.

Wilson T and Smith T (1983) Driving after stroke. International Rehabilitation Medicine, 5, 170-177.

Wright MJ, Burns RJ, Geffen GM, Geffen LB (1990) Covert orientation of visual attention in Parkinson's disease: An impairment in the maintenance of attention. Neuropsychologia, 28, 151-159.

World Health Organisation (1966) Report of Inter-Regional Seminar on Epidemiology Control and Prevention of Road Traffic Accidents/WHO/Accident Prevention 66.6.

Zajano MJ and Gorman A (1986) Stroop interference as a function of percentage of congruent items. Perceptual and Motor Skills, 63, 1087-1096.