The assessment of fitness to drive after brain injury or illness

Prepared for Mobility and Inclusion Unit, Department of the Environment, Transport and the Regions

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Executive Summary

People who have experienced a brain injury or illness can have impairments in the areas of general intellect, memory, concentration, decision making, and problem solving. Personality changes, such as increased aggression, may also occur. Traumatically brain injured people can experience impairment of higher order skills such as executive functioning as a result of frontal lobe damage which is commonly caused by the movement of the brain within the cranium during the trauma. Frontal lobe damage has also been associated with impaired insight, which may mean that traumatically brain injured people may feel fit to drive when they are not.

Licence holders have a statutory obligation to notify the DVLA as soon as they become aware of any health condition or disability that may influence their ability to drive. After notification, judgement of the person's subsequent fitness to drive is the responsibility of the DVLA Medical Branch, who may seek information from the driver's General Practitioner or other clinicians, and may also require a report from a Mobility Centre.

The problem of assessing fitness to drive after brain injury or illness is by no means marginal. Over 25,000 licence holders every year notify the DVLA of medical conditions affecting the brain. However, there is much debate about which aspects of cognitive functioning are important in the driving task, and still more debate about which aspects are linked to safe driving. This has resulted in a situation in which there is no standard validated protocol for assessing fitness to drive after brain injury or illness. As a result, current practice of assessing fitness to drive is varied. Information on an individual's fitness to drive may be derived from different neuropsychological tests of different psychological domains, and may or may not include a driving assessment. It is likely that driving assessment is not the first recourse for professionals who are called upon to give opinions on fitness to drive because assessment centres are few and far between and can require a fee. Without a valid protocol, the reliability of the opinions derived from neuropsychological test results alone must be questionable.

The main aims of this study were to look at whether clinical opinions of fitness to drive are predictive of the outcome of an on-road driving assessment, and to identify which neuropsychological tests inform these opinions and could be incorporated into a protocol for assessing fitness to drive in a clinical setting. The objectives were to obtain information on:

1 fitness to drive opinions by professionals working in a clinical setting and at a driving assessment centre;

2 neuropsychological data for a range of psychological domains;

3 the role of higher order cognitive skills, such as hazard perception;

4 experiences of clients returning to driving.

The study involved collaboration between TRL Limited, DETR's Mobility Advice and Vehicle Information Service (MAVIS), and the Community Head Injuries Service (CHIS), Aylesbury Vale Community Healthcare NHS Trust.

The participants were recruited through the head injury clinic and were assessed by a clinical psychologist. If they met the inclusion criteria they undertook further neuropsychological testing. After this the participants visited TRL and were given some laboratory-based tests and then a driving assessment at the MAVIS. The sample comprised 39 people who had received a head injury or had suffered generalized brain damage associated with broadly similar consequences in terms of neurological deficit. The sample ranged from 19-62 in age, and most were male. Just over half of the sample had received a head injury as a result of being involved in a road traffic accident.

There was a high correlation between the clinician's and driving adviser's judgements of fitness to drive. From a wide range of measures, six variables were found to be significant predictors of the driving adviser's judgement; four of these were of higher order cognitive skills. It was possible to accurately classify over 80% of cases using a discriminant function based on three higher order skills: executive functioning with respect to the ability to plan, monitor and regulate performance, the ability think abstractly, and the ability to divide attention. A possible interpretation of these findings is that the strategic allocation of attention resources was particularly impaired in drivers who were judged unfit to drive in the driving assessment.

None of the 'routine' neuropsychological tests emerged as important in the discriminant analysis. Composite scores of driving skill were not significant predictors of the driving adviser's assessment of fitness to drive, nor were measures of hazard perception.

Information from the driving interview suggests that driving is a highly emotive issue for brain injured clients, and is regarded as a key milestone in returning to a normal life. Few respondents regarded themselves as impaired, though many reported considerable anxiety and effort to drive safely. At the time of the interview less than half of the sample had had a driving assessment, though the majority had informed DVLA about their condition. Information from DVLA was not regarded by participants as particularly clear or timely.

The small sample size means that the results of this study are only indicative and will need validation amongst different services and assessment centres.

1 Introduction

Injuries or illnesses affecting the brain have been associated with cognitive deficits in the domains of general intellect, memory, concentration, decision making, and problem solving. Personality changes, such as increased aggression, may also occur (e.g. Wilkinson *et al.*, 1989). Traumatically brain injured people can experience impairment of higher order skills such as insight and executive functioning (the ability to plan, monitor and self-regulate behaviour) as a result of frontal lobe damage caused by the movement of the brain within the cranium during the trauma. Frontal lobe damage has also been associated with impaired insight (Lezak 1995) which may mean that a traumatically brain injured person may feel fit to drive when they are not.

At face value, it would seem obvious that cognitive impairments should affect a person's ability to drive safely. The driving task requires the driver to be attentive, to concentrate, to make judgements quickly in rapidly changing circumstances, and to be able to cope when the situation is demanding. Yet, at present, there is little statistical evidence on whether people who have experienced brain injury or illness and returned to driving are at increased risk of having an accident or are more likely to commit traffic offences.

By law, licence holders have to notify the Driver and Vehicle Licensing Agency (DVLA) as soon as they become aware of any health condition that may influence their ability to drive safely. DVLA guidelines assume that health conditions which impair cognitive functioning must impair the ability to drive safely. After notification, judgement of the person's subsequent fitness to drive is the responsibility of the DVLA Medical Branch, who may seek information from the driver's General Practitioner or other clinicians, and may also require a report from a Mobility Centre.

However, there is much debate about which aspects of cognitive functioning are important in the driving task, and still more debate about which aspects are linked to safe driving. This situation has meant that there is no standard validated protocol for assessing fitness to drive after brain injury or illness. As a result, current assessment is varied. Information on an individual's fitness to drive may be derived from a range of different neuropsychological tests of different psychological domains, and may or may not include a driving assessment. It is likely that driving assessment is not the first recourse for professionals who are called upon to give opinions on fitness to drive because assessment centres are few and far between and may require a fee. Without a valid protocol, the reliability of the opinions derived from neuropsychological test results alone must be questionable. The costs of making the wrong judgement are potentially high. If individuals are judged fit to drive when they are not, then their safety and that of other road users may be compromised. If they are judged unfit to drive when they are fit, the loss of driving may mean unemployment, loss of independence, and social isolation.

The problem of assessing fitness to drive after brain injury or illness is by no means marginal. Over 25,000 licence holders every year notify the DVLA of medical conditions affecting the brain.[1] Fitness to drive is most likely to be discussed in a clinical setting as part of the rehabilitation process, and it is in this context that a simple, cost-effective, and valid assessment of fitness to drive is most needed. A potential solution is to identify a small number of neuropsychological tests that correlate highly with the ability to drive safely.

Much research has been carried out to investigate the relationship between cognitive deficits and driving performance. The main aim of research in the area has been the development of 'off-road' tests that are safe and cost-effective ways to screen drivers (or potential drivers) for fitness to drive following brain injury or illness. The objectives of this previous research have been:

1 to develop a non-driving test or tests which can predict driving performance in a standard 'on-road' test;

2 to identify cognitive deficits associated with brain injury which influence performance in the driving task, and to establish how the pattern of deficits varies with type of injury, i.e. diagnostic group;

3 to develop remedial programmes to improve cognitive functions identified as important in the driving task, using subsequent performance in an 'on-road' test as the criterion of improvement.

A criticism of much of this previous research is that few of the cognitive tests used in the experimental procedures relate to a model of cognitive skills required in driving and how deficits in these skills are linked to accident liability - the most important objective criterion. Other research has been theory-driven using the model of driving behaviour proposed by Michon (1985). However, this research has over-emphasised the importance of operational skills and not fully evaluated the effects of brain injury on higher order cognitive skills, such as the identification of hazards and the appropriate response to them. These skills have been linked with the accident liability of non-brain injured drivers (e.g. Quimby *et al.*, 1986).

It is also very difficult to compare the results of research studies because numerous different neuropsychological tests have been used, and the research has often not adequately controlled for differences in diagnostic group, time post injury, or age of the participants. In addition, different external criteria have been used to assess the validity of cognitive tests, including the measurement of driving skills in traffic free closed circuits, in simulators, or in actual traffic. Rarely has accident liability been used as a criterion of driving safety. This is not surprising given that accidents are very rare events and would be an impractical criterion, especially as sample sizes tend to be small when sampling clinical populations. The next best criterion is to measure actual driving performance in real traffic conditions, which few studies have undertaken.

In summary there is a clear need for a standard, validated protocol to assess fitness to drive after brain injury or illness. In order to develop such a protocol more research is needed to address the predictive validity of fitness to drive assessments made in the clinical setting, the predictive validity of measures of different psychological domains including higher order skills, and which of these neuropsychological tests can be used to discriminate between fit and unfit drivers.

2 Aims and objectives

The aims of this project were:

1 to investigate whether clinical opinions of fitness to drive are predictive of the outcome of a driving assessment;

2 to identify which tests inform these opinions and could be incorporated into a protocol for assessing fitness to drive in the clinical setting; and,

3 to identify the pattern of driving behaviour associated with driving assessment outcome.

The specific objectives were to obtain:

1 data on fitness to drive opinions from professionals working in a clinical setting and at a driving assessment centre;

2 neuropsychological data for a range of psychological domains;

3 data on higher order cognitive skills such as hazard perception associated with the accident liability of non-brain injured drivers;

4 qualitative information on feelings and experiences of clients returning to driving.

The study is described in the following four sections. Firstly, (Section 3) there is a detailed account of the methodology including procedure, recruitment of participants, and measures used. The next section (4) describes how the analysis was carried out. Section 5 presents the results of the study including a description of the sample, an assessment of potential bias and addresses the aims and objectives of the study stated in Section 2. Finally, (Section 6) the results are discussed in relation to the aims and objectives of the study, how they relate to previous research, its limitations, and implications for further research.

3 Methodology

3.1 Procedure

The project involved collaboration between TRL Limited, DETR's Mobility Advice and Vehicle Information Service (MAVIS), and the Community Head Injuries Service (CHIS), Aylesbury Vale Community Healthcare NHS Trust- a long-term rehabilitation centre for clients who have suffered severe or very severe disability as a result of neurological trauma. The participants were recruited through the head injury clinic and were assessed by the clinical psychologist according to specified inclusion criteria (see section 3.2). If they were suitable they would then undertake further neuropsychological testing. After this the participant visited TRL and undertook some laboratory-based tests and then a driving assessment by the senior driving adviser at the MAVIS. The research proposal was submitted and cleared by the CHIS Local Research Ethics Committee. The progress of a client through the project is shown in Figure 1.

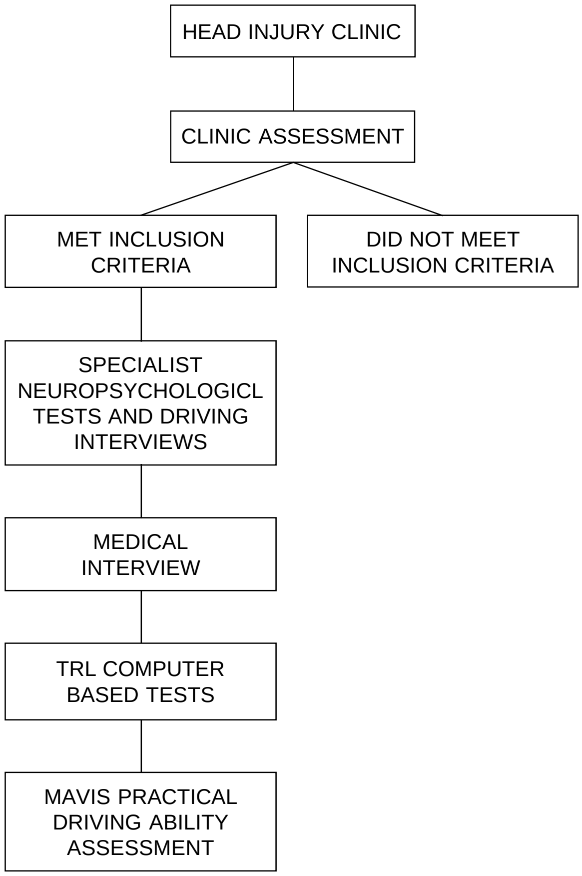

Figure 1 Progress of participant through research study

3.2 Participants

The participants were recruited from head-injured people when seen for assessment or review at the Head Injury Clinic. As an incentive to participate, clients were offered a free driving assessment at the MAVIS Mobility Centre. They were selected according to the following criteria:

1 Aged between 20-55 years. This age group was selected because it is the age group most accessible and where performance is least confounded by the effects of ageing. In addition it was likely that this would mean that most drivers had a minimum driving experience of at least 2 years.

2 At least six months post onset from the head injury when fully assessed. This time period helped to ensure a general stabilisation of participants' neurological conditions.

3 Held a full driving licence.

4 Had potential to return to driving.

5 Primary diagnosis of head injury or clinically analogous generalised brain damage, e.g. from anaesthetic accident, cardiac arrest, etc.

Clients were excluded from the study if there was evidence of marked pre-existing psychiatric illness, evidence of additional neurological conditions or illness, and where there were prescribed disabilities (i.e. a disability or health condition reportable to DVLA Medical Branch). Also excluded were cases where the responsible clinician or head injury service team considered that participation by the client or family member in the research would be clinically inappropriate in any way (e.g. where participation could be anticipated to cause distress to any party).

3.3 Measures

Research on fitness to drive and on the accident liability of normal drivers indicated that a number of measures needed to be included in the study:

- Medical information to gain information on severity of injury
- Neuropsychological clinic test information to cover the range of cognitive deficits that may impact on driving, as indicated by past research
- An interview with the client and, if available, a friend or relative to give a qualitative feel for the client's driving experience
- Hazard perception information (this has been linked with accident liability of non-brain injured drivers)
- Practical driving test performance to provide the external criterion of fitness to drive.
- Dynamic laboratory based divided attention task

3.3.1 Medical information

Medical information about the client was sought from the medical data held at the head injuries unit and included information on severity such as post-traumatic amnesia (PTA). In addition there was a medical interview. The interview was carried out by a local GP who worked as a clinical assistant in the neuropsychological and physical rehabilitation unit of the CHIS. The questions were derived from the DVLA questionnaire that is sent to GPs to complete. The GP was also asked to judge the participant's fitness to drive on the basis of medical information. The medical interview took between 15 to 20 minutes to complete.

3.3.2 Neuropsychological information

General neuropsychological tests

Clients assessed within the Head Injury Clinic were given the neuropsychological assessment battery shown in Table 1. This battery is routinely used in the CHIS as it allows the clinician to develop an initial neuropsychological profile of clients, and helps to determine further assessment and treatment goals.

'Driving' neuropsychological tests

Additional tests were used to cover cognitive domains that are not routinely assessed within the clinic but which have been linked to driving by previous researchers (e.g. Engum *et al.*, 1988; Nouri *et al.*, 1987; Sivak *et al.*, 1981; Schweitzer, 1987). These skills included visual, auditory and spatial attention, object and space perception, spatial judgement and construction, sensory-motor abilities, and executive functioning (see Table 2).

Table 1 'Routine' neuropsychological assessment

	Test	*Skill assessed*
1	Weschler Adult Intelligence Scale – Revised (WAIS-R) (9 sub-tests).	General intellect
	Digit span.	Short term memory and attention.
	Vocabulary.	Pre-morbid ability.
	Arithmetic.	Mental arithmetic/early stage memory.
	Similarities.	Verbal reasoning.
	Picture completion.	Visual selective attention/ scanning/spatial reasoning.
	Picture arrangement.	Visual selective attention/ spatial reasoning.
	Block design.	Visual construction.
	Digit symbol.	Psychomotor speed.
	Object assembly.	Visual construction.
2.	Adult Memory and Information Processing Battery (AMIPB) (5 sub-tests).	Memory and information processing.
	Story recall.	Verbal recall and retention.
	List learning.	Rate of verbal learning.
	Figure recall.	Non-verbal recall and retention.
	Second highest number.	Visual information processing.
	Digit cancellation.	Visual information processing.
3	Visual object and spatial perception battery.	Object and spatial perception.

The 'routine' neuropsychological battery took around two hours to complete, and the 'driving' battery from one and a half to two hours.

3.3.3 Head injury driving interview

The interviews were conducted by CHIS and covered the importance of driving, information and advice received about driving after head injury, DVLA issues, returning to driving, and early difficulties and perceived changes in driving. The interviews were included in this study to provide a qualitative insight into the driving behaviour of the clients. The clients were also asked to rate their own fitness to drive as an indication of insight. The interview took between 30-45 minutes to complete.

3.3.4 Hazard perception testing

In addition to the above neuropsychological test battery, a computerised hazard perception test was used as part of the assessment at TRL. Earlier research (Quimby *et al.*, 1986) has shown a relationship between hazard perception and accident liability. This study used a revised version of the hazard perception test, as described in Quimby *et al.* (1999). It involved a non-interactive driving simulation, used to measure:

driver reaction time to hazardous incidents;

continuous average risk perception of drivers;

drivers' identification and awareness of potential hazards.

Table 2 'Driving' neuropsychological assessment

Test	*Skill*
1 Test of Everyday Attention (TEA).	Attention.
Map search.	Visual attention.
Visual elevator.	Attention switching.
Telephone search.	Auditory attention.
Telephone search-counting.	Divided attention.
Lottery.	Sustained attention.
2 Visual object and spatial battery.	Object and spatial perception.
Screening test.	
Incomplete letters.	
Silhouettes.	
Object judgement.	
Progressive silhouettes.	
Dot counting.	
Position discrimination.	
Number location.	
Cube analysis.	
3 Behavioural Inattention Test (1 sub-test).	Spatial attention.
Line bisection test.	
4 Benton judgement of line orientation test.	Spatial judgement.
5 The Behavioural Assessment of Dysexecutive Syndrome (BADS).	Impulsiveness.
	Disturbed attention.
	Distractibility.
	Difficulty in identifying. the whole picture from. its component parts.
6 Chessington Occupational Therapy Neurological Assessment Battery (COTNAB).	
Dexterity.	
Coordination.	Sensory motor ability.

The test incorporates a video recording depicting a driver's eye view of the road. The recording was made from a moving car driving through a variety of road settings, and includes several staged hazards. The video lasts 12 minutes and includes sound. Participants are required to continuously position a response lever to indicate the level of risk they see in the video. In this way a continuous trace of risk assessment is obtained. The detection of hazards is assumed to have occurred when the slope of the trace exceeds some criterion value.

The continuous average risk measure monitors the participant's perception of how hazardous each road scene is. The score ranges from 0% indicating 'no risk' to 50% indicating 'high risk'. Average risk is sampled at set periods throughout the trial period and expressed in terms of a mean risk level. The responsiveness of the participant to changes in perceived risk is given by the variability in the response measured by the standard deviation. For each participant the average of the mean reaction times was taken to provide an overall risk level and the mean of the standard deviations was taken to obtain an overall responsiveness rating.

3.3.5 Divided attention task

The divided attention task is a laboratory test closely based on a test first used in drug studies by the Californian Research Institute. The aim of the test is to measure the ability to attend to more than one task at a time, which is seen as being relevant to driving.

The test comprises two activities: the Compensatory Tracking Task (CTT) and the Visual Search Task (VST). The CTT requires a vertically moving cursor to be kept on station at the centre of a display by means of ajoystick. Simultaneously, the VST is presented in four TV screens in front of the participant. At random intervals numbers change on the screens, and the participant is asked to press a button to indicate on which screen a 'two' has appeared. Two dependent variables measure participants' performance on this test for a twelve minute period: 1) the 'absolute tracking error', which is compensatory tracking error sampled every 100 milliseconds (ms) and 2) the response times to the 48 target 'twos' where the measurement accuracy is 10ms. The sum of the mean absolute tracking error and the mean of the response times were the figures used in the analyses. The task took approximately 12 minutes to complete.

3.3.6 On-road driving assessment

The on-road driving assessment took place at the MAVIS Mobility Centre on the TRL site on a different day to the neuropsychological tests. It was the standard assessment currently in use, and required the client to undertake two batteries of driving exercises, one on the private road system at TRL and one in the traffic conditions of the Sandhurst, Crowthorne and Bracknell areas.

If a person was successful in the driving exercises carried out on the closed road system the test-driving moved out into the traffic. The in-traffic tests were thought to assess skills such as judgement making, attention, steering control at 60 mph, and interaction with other road users. The session on the private road system lasted approximately 60 minutes, and the in-traffic session approximately 45 minutes. The adviser was 'blind' to the results of the neuropsychological assessment.

There were ten scored exercises on the private road system and eight scored exercises in the traffic conditions. Each exercise was given a score on a scale 1 to 4. A score of 4 indicates definitely safe, a score of 3 indicates probably safe, a score of 2 indicates probably unsafe and a score of 1 indicates definitely unsafe.

3.4 Ethical considerations

The project methodology was approved by the Aylesbury Vale Local Research Ethics Committee. Prospective participants were informed that:

- Participation by the client and family member or friend was voluntary.
- Information from the assessments would benefit the rehabilitation process – could?
- The outcome of all the assessments would be routinely communicated to the CHIS and the participants' relatives and friends, and GP.

Table 3 Closed course exercises

Short description of exercise	Elements thought to be tested in individual exercises
1 Drive over set route with monitoring of control operation and action taken at junctions.	Operation of car controls, perception of environment, spatial ability.
2 Choice reaction at three passes of traffic lights.	Choice reaction.
3 Following worded sign at traffic lights.	Choice reaction with increased mental load, orientation.
4 Dead- end exercise.	Audio/visual memory, use of car controls, spatial ability and orientation.
5 Reverse round corner from left.	Spatial ability and use of car controls.
6 Reverse into parking space from right.	Spatial ability and orientation.
7 Position moving car with relation to centre line of road.	Spatial ability.
8 Coned circuit.	Spatial ability and motor co-ordination.
9 Follow route shown on map.	Information processing and cognitive mapping.
10 Memorise route from exercise 9.	Memory.

Table 4 In-traffic exercises

Short description of exercise	Elements thought to be tested in individual exercises
1 Behaviour at five roundabouts.	Judgement making.
2 Count at roundabout.	Divided attention.
3 Behaviour at four mini roundabouts.	Judgement making.
4 High Street.	Interaction with other road users.
5 Drive at 60 mph.	Spatial ability.
6 Detect two given signs.	Attention.
7 Behaviour when making two specific lane changes.	Interaction with other road users.
8 Take a route which encounters four roundabouts by following signs to M4.	Information processing under high workload conditions.

- Whether or not they agreed to participate would not affect their treatment.
- Both verbal and written feedback on the assessment would be provided.

4 Analysis

The analysis was conducted in the following stages:

1 Data was screened to assess multivariate normality and to reduce response categories, given the small sample size.

2 The characteristics of the sample and the possibility of non-response bias were examined.

3 The correlation between clinical opinion of fitness to drive and driving outcome was assessed.

4 Logistic regression was used to identify which of the independent variables were important in predicting the outcome.

5 Discriminant analysis was then carried out using all the variables identified in the previous stage to provide a decision rule on fitness to drive.

6 Qualitative information was coded and key themes identified on issues related to the client's feelings and experience on returning to driving.

4.1 Data screening

4.1.1 Dependent variable

The outcome of interest in this study was the judgement on fitness to drive given by the MAVIS driving adviser. The normal procedure for the adviser was to assess a client as being either 'at greater than normal risk of having an accident' or 'not at greater than normal risk of having an accident'. To be consistent with the judgements made by the clinicians in this study, the driving adviser's judgements will be referred to as 'fit' or 'unfit' to drive.

4.1.2 Independent variables

Fitness to drive judgements were also made by a clinical psychologist, the CHIS GP, the client, and the client's relative (if available). The judgements of the clinical psychologist, GP, and clients were made on a 5 point scale indicating: 'definitely fit to drive', 'probably fit to drive', 'borderline', 'probably unfit to drive', and 'definitely unfit to drive'. For the purposes of analysis, the response categories of the clinical psychologist, GP and clients were combined to reflect a judgement of 'fit to drive' comprising 'definitely fit to drive' and 'probably fit to drive' judgements and a judgement of 'unfit to drive' comprising 'probably unfit to drive' and 'definitely unfit to drive' judgements. The judgements of the relatives of the clients were not included because they were only available for some of the sample.

The independent variables were inspected to see if there was enough variability in the data to indicate differences between those who were judged fit or unfit to drive. This examination led to data on the visuo-spatial tests (The Visual Object and Spatial Perception Battery) and Benton line bisection test being excluded from the analyses, as most participants did not show any impairment on them.

Descriptive statistics for all the variables used in the study are shown in Appendix A.

5 Results

5.1 Participants

The sample comprised 39 people associated with broadly similar consequences in terms of neurological deficit (e.g. damage caused by subarachnoid haemorrhage, anaesthetic accidents resulting in anoxia).

During the sampling period (August 1997 to November 1999), 187 people who had received a head injury or generalised brain damage attended the CHIS. Of these, 78 did not meet the inclusion criteria and therefore were not invited to take part in the project. Of the remaining 109, twenty-eight participants were invited but did not respond, despite follow up letters, 15 refused involvement, and a further 22 were not included because they had an incomplete assessment, had been referred to different services, or had not turned up for the assessment. Of the remaining 44 people, one withdrew before the study began. These exclusions meant that a total of 43 head injured drivers took part in the study. Four of these participants were used in the piloting of the study and were not included in the main analysis, therefore the following results are based on 39 participants.

The overall response rate is shown in Table 5.

Table 5 Response rate

Response	*Number (%) (N=109)*
Invited but no response	28 (26)
Not participated for miscellaneous reasons	22 (20)
Refused	15 (14)
Willing to participate	44 (39)
Withdrew	1
Number included	43

5.2 Bias

It was possible that those who did not participate in the research study were different from those who agreed to participate. In particular, it was possible that those who thought their driving might be impaired may not have wished it to be studied in case they might be reported to DVLA and have their licence revoked[2]. To provide an indication of the neurological representativeness of the sample, a comparison was made between the distribution of post-traumatic amnesia (PTA) scores - a clinical measure of severity - of the sample and the first 100 clients who had attended the clinic when it was first set up in 1991. This measure was only known for 30 of the 39 clients, as it had not been recorded on medical notes. The scores were compared using the Kolmogorov-Smirnov test, which showed that at least with respect to severity of injury there was no significant difference between the two samples.

5.3 Characteristics of the sample

During the sampling period it became clear that the number of participants was very small and therefore the inclusion criteria were slightly relaxed in order to increase numbers. This meant that two of the participants were older (aged 59 and 62 years) and one was younger (aged 19) than the original age range. It also meant that three participants were less than six months post-injury. The ages of the sample thus ranged from 19-62; nineteen were aged under 40 years, and 20 were aged 40 or over. Most of the sample (27) were male, and over half (20) had received a head injury as a result of being involved in a road traffic accident, mostly as a car driver or passenger, while five were pedestrians and two were motorcyclists. Three participants had received injuries during leisure activities, and six had received brain damage as a result of anoxia caused by a haemorrhage or surgical procedures. Other causes of head injury were assault (3) and falls (3). For four participants the cause of the injury was not recorded.

The driving interview showed that 22 participants had returned to driving and 22 people had informed DVLA of their condition, though only 12 had received a response. Of the 22 people who had returned to driving only 10 had had a driving assessment. Of the 16 participants who had not returned to driving only 5 had had a driving assessment.

5.4 Correlation between clinical judgements of fitness to drive and driving outcome

Table 6 shows that whilst the professionals judged around a quarter to a third of the participants as being unfit to drive, only one of the participants thought that they were unfit to drive.

Table 6 Judgements of fitness to drive by different raters

Rating	*Clinician*	*Clinical service GP*	*Driving adviser*	*Client*
Definitely or probably fit	24	28	30	35
Definitely or probably unfit	11	10	9	1
Borderline or unsure	4	1		3
Total	39	38	39	39

To examine the level of agreement between these judgements Kendall's Tau (a correlation measure of concordance) was carried out on the above data by looking at the concordance coefficients between each 'judge' (clinician, GP, client, driving adviser) and excluded borderline cases. This showed that the concordance coefficient between the judgements of the clinician and driving adviser was 0.8 (significant at the 5% level), meaning that there was a good level of agreement between the judgements of the clinical psychologist and driving adviser. However, no significant relationships were found between the other judgements. The fitness to drive assessments made by each judge are shown for each case in Table 7.

5.5 Variables that predict driving outcome

The next stage of the analysis involved using logistic regression[3] to assess which independent variables were important predictors of fitness to drive as assessed by the driving adviser. However, there were many more variables than there were participants - a situation that causes problems in statistical analyses. Therefore the analysis was carried out in a staged approach. Firstly, each battery of tests

Table 7 Casewise judgements of fitness to drive

Case	*Clinician*	*Clinical service GP*	*Client's friend or relative (NA=Not available)*	*Client*	*Driving adviser*
1	Unfit	Fit	NA	Unsure	Unfit
2	Fit	Fit	Fit	Fit	Fit
3	Fit	Fit	Fit	Fit	Fit
4	Unfit	Fit	NA	Fit	Unfit
5	Fit	Fit	Unsure	Fit	Fit
6	Unsure	Unfit	NA	Fit	Unfit
7	Unsure	Fit	NA	Fit	Fit
8	Fit	Fit	Fit	Fit	Fit
9	Fit	Unfit	Unsure	Unfit	Fit
10	Unfit	Unfit	Unsure	Fit	Unfit
11	Unfit	Unfit	Unfit	Unsure	Unfit
12	Unsure	Fit	NA	Fit	Fit
13	Fit	Fit	Fit	Fit	Fit
14	Unsure	Fit	Fit	Fit	Fit
15	Fit	Fit	NA	Fit	Fit
16	Unfit	Fit	NA	Fit	Fit
17	Unfit	Unfit	Fit	Fit	Fit
18	Fit	Unfit	Fit	Fit	Fit
19	Unfit	Fit	Fit	Fit	Unfit
20	Unfit	Fit	Fit	Fit	Unfit
21	Fit	Unfit	NA	Fit	Fit
22	Fit	Fit	Fit	Unsure	Fit
23	Fit	Fit	NA	Fit	Fit
24	Fit	Fit	Fit	Fit	Fit
25	Fit	Fit	NA	Fit	Fit
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28	Fit	Unfit	NA	Fit	Fit
29	Fit	Fit	NA	Fit	Fit
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33	Fit	Fit	Fit	Fit	Fit
34	Fit	Fit	Fit	Fit	Fit
35	Unfit	Fit	NA	Fit	Unfit
36	Fit	Fit	NA	Fit	Fit
37	Fit	NA	NA	Fit	Fit
38	Fit	Fit	Fit	Fit	Fit
39	Fit	Fit	Fit	Fit	Fit
Total	39	38	24	39	39

was analysed using logistic regression using a forward stepwise procedure, with the outcome of interest being those who were judged unfit to drive by the driving adviser.

The two neuropsychological test batteries and the driving and laboratory based batteries were submitted to logistic regression separately to predict which variables were important in explaining fitness to drive judgements. The aim of this analysis was to identify which, if any, of the sub-tests would be useful in explaining the outcome variable (the driving adviser's judgements on fitness to drive), and the size and direction of that effect.

Table 8 shows those variables that were significant at the 5% level in predicting the driving adviser's judgement. Of the six significant variables, two (WRPPC and FIGIMM) came from the 'routine' neuropsychological test battery, three (TEATELS, BADS6ELM, and BADDEXS1) came from the 'driving' battery, and one (MART) from the laboratory based tests of divided attention. None of the laboratory tests of hazard perception was significant.

The results can be interpreted in the following way:

1 'WRPPC' The lower the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to impaired visual selective attention.

2 'TEATELS' The lower the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to impaired spatial awareness and visual selective attention.

3 'MART' The higher the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to impaired ability to divide attention.

4 'BADS6ELM' The lower the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to impaired ability to plan, monitor and regulate their performance.

5 'FIGIMM' The lower the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to impaired visual memory.

6 'BADDEXS1' The lower the score on this test the more impaired the client's performance. This indicates that unfitness to drive is related to a *low* level of reported difficulty in understanding abstract ideas.

The tasks from which these variables are derived are described in Appendix B.

Table 8 Variables that predict the driving adviser's judgement of fitness to drive

Variable name	*Coefficient*	*Standard error*	*Probability*
'WRPPC' a sub-test of the WAIS R tests of general intellect which measures spatial awareness and visual selective attention.	-.93	.34	.0074
'TEATELS' a sub-test of the Tests of Everyday Attention battery - a measure of selective attention.	-.50	.20	.0148
'MART' mean reaction time to targets in laboratory based divided attention task.	1.43	.59	.0154
'BADS6ELM' (sub-test of Behavioural Assessment of Dysexecutive Syndrome Battery) a measure of the client's ability to plan, organise and monitor behaviour.	-.87	.38	.0227
'FIGIMM' (sub-test of Information Processing Battery) which measures visual memory.	-.92	.41	.0250
'BADDEXS1' (a question from the BADS Dysexecutive Questionnaire) - a measure of a client's reported ability to think abstractly.	-1.47	.69	.0356

5.6 Discriminant analysis

The next stage of the analyses involved using all the variables selected in the logistic regression analyses in a discriminant analysis[4]. Discriminant analysis is favoured by clinicians because it can be used as a diagnostic tool (i.e. a discriminant function) to assess new cases. In the context of this study discriminant analysis has been used to identify a set of variables which could act as a guide to whether or not a client is judged fit to drive.

The discriminant analysis used the prior probabilities of being in either the fit or unfit group and Fisher's linear discriminant function coefficients.

Table 9 shows that the variables BADS6ELM, BADDEXS1, and MART were selected in the stepwise procedure as significant predictors of group membership. The linear combination of these variables accurately classifies 84% of cases. As a validation of this functional relationship the analysis can take one case out in turn, and see how it is classified based on the functions derived from all cases other than that case. This technique was used in this analysis, and showed that 84% of the cross-validated cases were correctly classified as either fit or unfit to drive.

Two of the variables that contributed significantly to the discriminant function came from the 'driving' neuropsychological test battery, and the third was from the divided attention task. None of the tests in the 'routine' battery or the hazard perception battery was significant.

The discriminant function calculated for the driving outcome accounted for all of the variation between the two groups. The chi square value of the strength of the association between groups and predictors was 22.9 (df=3) p<.0001, indicating a highly reliable relationship. As stated earlier, 84% of the cross-validated cases were classified correctly. Of the six mis-classified cases, four were judged unfit to drive by the driving adviser though classified fit to drive in the model, and two were judged fit by the driving adviser though classified unfit by the model.

5.6.1 Borderline cases

The results of the discriminant analyses using the driving adviser's judgement as the dependent variable allowed discriminant scores to be computed for the borderline cases (see Table 10). Inspection of these scores and their predicted group membership indicated whether these cases were more like those judged fit to drive or more like those judged unfit to drive. The discriminant scores for borderline cases suggest that all four should be classified as fit to drive.

Table 10 Discriminant scores for borderline cases and cases where the judgement differed

Case	*Clinician's judgement*	*Driving adviser's judgement*	*Predicted group with driving adviser's judgement as outcome (Discriminant score)*
1	Borderline	Unfit	Fit (-.21)
2	Borderline	Fit	Fit (.71)
3	Borderline	Fit	Fit (2.29)
4	Borderline	Fit	Fit (.99)

5.7 Pattern of driving behaviour associated with driving assessment outcome

The driving assessment aimed to examine the range of driving behaviours which drivers may experience on a daily basis. It was important to investigate which of these specific behaviours were associated with an unsafe performance and whether their corresponding psychological domains were similar to those associated with the clinician's judgement. Tables 11 and 12 show the number of people who performed the exercises unsafely and whether the driving adviser had classified them as fit or unfit to drive. This information suggests that the unfit group had particular difficulties with operating car controls, perception of environment, and spatial ability during the exercises on the closed course, and particular problems with high workload situations in actual traffic. These domains were similar to those identified as important predictors of fitness to drive in the analysis of the neuropsychological and laboratory based data.

5.8 The driving interview

5.8.1 Returning to driving

Many respondents felt that they did not have any residual head injury problems or reported that they had sufficiently recovered from any problems. For example, one participant reported '*I…(have)… no problems with concentration or multi-tasking, no visual/physical deficit as a result of my head injury'*, while another stated *' My memory and concentration has improved …also my coordination…physically I feel fit to drive.'* When behavioural changes were reported they tended to suggest attempts at compensatory behaviours such as driving more slowly or cautiously or avoiding driving when tired: '*I drive when I am not tired…I think I am aware when concentration becomes difficult. I generally drive within speed limits'* There was also a suggestion of an anxiety–fuelled compensation process: '*I drive with caution at all times…today it's the other drivers I need to watch out for.'*

Table 9 Discriminant function variables

Variable and description	*Fit to drive*	*Unfit to drive*
'BADS6ELM' (sub-test of Behavioural Assessment of Dysexecutive Syndrome Battery) a measure of the client's ability to plan, organise and monitor behaviour.	-.615	-2.207
'MART' mean reaction time to targets in laboratory based divided attention task.	4.384	.805
'BADDEXS1' (a question from the Behavioural Assessment of Dysexecutive Questionnaire) a measure of a client's reported ability to think abstractly.	.277	-1.121
Constant.	-7.813	-17.794

Table 11 Closed course exercises carried out safely or unsafely by whether judged fit or unfit to drive by driving adviser

Short description of exercise	*Elements thought to be tested in individual exercises*	*Unfit people who performed exercise unsafely (N=9)*	*Fit people who performed exercise unsafely (N=30)*
1 Drive over set route with monitoring of control operation and action taken at junctions.	Operation of car controls, perception of environment, spatial ability.	6	0
2 Choice reaction at three passes of traffic lights.	Choice reaction.	0	0
3 Following worded sign at traffic lights.	Choice reaction with increased mental load, orientation.	0	0
4 Dead-end exercise.	Audio/visual memory, use of car controls, spatial. ability and orientation.	1	0
5 Reverse round corner from left.	Spatial ability and use of car controls.	2	1
6 Reverse into parking space from right.	Spatial ability and orientation.	2	0
7 Position moving car with relation to centre line of road.	Spatial ability.	2	2
8 Coned circuit.	Spatial ability and motor co-ordination.	2	1
9 Follow route shown on map.	Information processing and cognitive mapping.	3	1
10 Memorise route from exercise 9.	Memory.	1	3

Table 12 In-traffic exercises carried out safely or unsafely by whether judged fit or unfit to drive by driving adviser

Short description of exercise	*Elements thought to be tested in individual exercises*	*Unfit people who performed exercise unsafely (N=9)*	*Fit people who performed exercise unsafely (N=29)*
1 Behaviour at five roundabouts.	Judgement making.	3	0
2 Count at roundabout.	Divided attention.	2	0
3 Behaviour at four mini roundabouts.	Judgement making.	2	0
4 High Street.	Interaction with other road users.	0	0
5 Drive at 60 mph.	Spatial ability.	2	0
6 Detect two given signs.	Attention.	3	6
7 Behaviour when making two specific lane changes.	Interaction with other road users.	2	0
8 Take a route that encounters four roundabouts by following signs to M4.	Information processing in high workload situations.	5	2

5.8.2 Importance of driving

The whole issue of driving post injury was clearly highly emotive for both head-injured participants and their families. Driving was regarded as vital in aiding participation in work and family life, reducing isolation, and was a symbolic indicator of physical and emotional recovery. As one respondent commented: *' I had one and a half years off driving …I felt cut off and isolated…(driving)…is a way of getting back to normal, to work..(driving) improved the way I felt about myself.'* Family members were also concerned about the return to driving; as one family respondent commented *' She needs driving for independence and a boost to her self-esteem. The house is like a prison…(with driving)… she would be able to take more of a lead role in the family'.* For those respondents who had not returned to driving, the importance was again clearly emotive. One respondent reported feeling: *'Frustrated and quite annoyed. Happy to use public transport but it doesn't always go where you want to go…to see my brother takes 2-3 hours by bus and 25 minutes by car'* and another saying: *'I feel terrible …I feel so like having my legs cut off. Sometimes it makes me feel I wish I were dead'.*

5.8.3 Information and advice received

Many respondents did not feel that they were given clear information or advice about returning to driving. The following comments were fairly typical: *'Discussed (driving) with several people, including a neurologist, and then referred to my GP. My GP's advice was not to drive because of the type of my injury and because I got motion sick'.* Interestingly, family members reported particular issues such as feeling *'there is an onus on me to inform (the DVLA) and feel if there are any problems I'll get the blame'* and suggesting *'It's been very difficult to get any advice, it's a grey area. The DVLA wrote a standard letter saying they were unsure if he should drive.….. he's not in any of the categories like surgery or fits.'*

5.8.4 The DVLA response

Most respondents said that the DVLA had responded to their contact by written communication, sending a questionnaire and informing the head-injured person they were contacting the relevant professionals. There was some concern from a number of family members about clarity of advice from the DVLA: *'..we only heard after 10 months when I informed. They contacted the GP and*

CHIS. We're continuing to have correspondence and they're monitoring his condition. There's been no advice on how to proceed'.

5.8.5 Returning to driving and early difficulties

When asked about the process of returning to driving and early difficulties, respondents suggested there was an anxiety which resolved with practice and time for some but not others. One respondent reported feeling *'A bit nervous the first couple of times'*, and another that they *'enjoyed it at first but like it less each time'*. One respondent said: *'Seeing anyone coming towards me makes me feel they're going to hit me…I feel sick, have pins and needles, can't get it out of my mind.'* The other predominant theme was ongoing tiredness and fatigue.

5.8.6 Perceived driving changes

When discussing perceived driving changes many respondents refer to possible compensation behaviours such as increased concentration, reduced speed, cautiousness and increased vigilance. One respondent reported *'… constantly looking, eyes on stalks/ watch others - are their hands on the steering wheel? It's exhausting'* whilst another reported feeling *'More thoughtful, drive more carefully and relatively slowish…keep to the speed limits…I don't want to go through another crash.'* One family member noted that the head injured person was *' more cautious, takes more time at junctions, reduces speed, she is more critical of other drivers'*.

6 Discussion

Much of the past research on fitness to drive has been based on the premise that drivers with moderate cognitive deficits caused by brain injury or illness have an elevated risk of being involved in road accidents, despite the fact that there is little or no empirical evidence to support this premise (Van Zomeren *et al.,* 1987). A recent review of the field (Christie, 1996) showed that little research has been based on a clear conceptual understanding of the cognitive skills that are required for driving, and that there has been a tendency instead to focus on skills that have *seemed* important, such as reaction time and visuo-spatial abilities.

There have also been methodological problems with previous research. External criteria have often been ill-defined or absent, while confounding factors like age, driving experience, and diagnostic group have not always been adequately controlled for. This project has attempted to address some of the limitations of previous research. A range of both lower and higher order skills were measured, and driving performance in real traffic was used as the external criterion. Inclusion criteria were established to help control for variations in type of injury, driving experience, and age.

The specific aims of this study were to investigate whether a clinician's judgement of fitness to drive was a reliable predictor of the driving outcome of a driving assessment, and to identify which tests of lower and higher order cognitive skills discriminated between drivers classified as fit or unfit. The results showed that the correlation between the driving adviser's judgement of fitness to drive and the clinician's, excluding the borderline cases, was high at 0.8. This suggests that the clinician was able to make reasonably reliable assessments of fitness to drive. The GP was also asked to make the same assessment based on medical information. The correlation between the GP's judgement and other judgements was low, suggesting that medical information alone is not sufficient to inform judgements of fitness to drive for brain injured clients. It is also clear that many of the participants in this study lacked insight into their own fitness, with only one member of the sample considering themselves to be unfit to drive.

A wide range of neuropsychological tests, laboratory based tests, and driving outcome variables covering both low and high order cognitive skills were included in the study. Although visual selective attention was the strongest predictor in the logistic regression, four of the six significant variables in that analysis were higher order skills. Further, it was only variables that measured higher order skills that were important in the discriminant function analysis. These higher order skills were executive functioning with respect to the ability to plan, monitor and regulate performance, the ability think abstractly, and the ability to divide attention. In the discriminant function analyses these variables accurately classified over 80% of cases. Of the participants judged as borderline by the clinician, the decision rule established by the discriminant analysis suggests that all four could have been fit to drive.

These executive function variables were from the 'driving' neuropsychological test battery that contained items the clinician had selected as being particularly relevant to fitness to drive. This group of tests had also included tests of attention and dexterity and coordination that were not important. Few of the 'routine' neuropsychological tests were important predictors of fitness to drive in this study. These tests covered general intellect, information processing, and visuo-spatial skills. Many clinicians use visuo-spatial tests to inform judgements on fitness to drive (Christie *et al.*, (in press)). However, these tests may only be able to show deficits among clients with gross impairments. All the participants in this study were judged to have the potential to return to driving, so it was unlikely that any had gross impairments. As a result, nearly all the sample had given a normal performance on these tests which meant that they were not useful as predictors of fitness to drive. Of the laboratory based tasks only divided attention was a significant variable; none of the hazard perception measures were important predictors.

There was one seemingly counterintuitive finding. Participants judged unfit to drive were less likely than the fit group to report that they had problems understanding what other people mean 'unless they keep things simple and straightforward'. This variable was based on a questionnaire and was not, in the true sense, a neuropsychological test. However, this result may in fact be indicative of impaired insight, because the other significant variable from the executive functioning test battery ('BADS6ELM') showed that those judged unfit to drive had impaired ability to follow simple instructions. A possible interpretation of this finding is that the strategic allocation of attention resources was impaired in drivers who were judged unfit to drive in the driving assessment.

Driving assessment variables of total score in traffic and on the closed course were not significant predictors of driving outcome. However, basic control of the vehicle and performance in high workload traffic situations were worse for participants judged unfit to drive than for those judged fit. The pattern of driving behaviour associated with driving assessment outcome suggests that the unfit group had particular difficulties with operating car controls, perception of environment, and spatial ability during the exercises on the closed course, and particular problems with high work load situations in actual traffic. These domains were also identified in the results of the statistical analysis as important predictors of fitness to drive, which suggests that the driving assessment had content validity. The finding that a global score was not predictive of driving performance suggests that such measures may not be useful as a criterion of driving fitness; instead deficits in particular domains may provide better explanations of driving outcome.

Some of these results are in line with the findings of earlier research. For example, the WAIS-R Picture Completion task was identified by Sivak *et al.*, (1981) as one of the test items most strongly correlated with their measure of driving performance. At the higher order level, Lundqvist and Alinder (1997) showed that people who had suffered brain damage after trauma performed significantly worse on tests of executive function and divided attention than did a group of matched controls. Deficits in divided attention have been shown to be predictive of driving performance for individuals who have received closed head injury, especially where there is a time pressure element (Withaar, 2000).

This study, like most in the field, has limitations. The sample size was small, and while in terms of severity of injury, the sample was not significantly different from those who attended the clinic, the findings of this study cannot be generalised to the traumatically brain injured population. In addition, this study was based on one clinic involving one clinician's judgement, and one driving assessment centre and one adviser, though both the professionals were highly experienced in dealing with the issue of brain injury and driving.

Finally, whilst researchers working in the area of fitness to drive after brain injury or illness should draw on research into the accident liability of normal drivers, the converse is also true. Dysfunction often reveals function. Research into cognitive impairment and fitness to drive has the potential to furnish the driving theorist with valuable insights into the relationships between cognitive abilities, driving skills, and accident liability.

7 Summary and conclusions

This study investigated a sample of 39 people who had had a brain injury or illness but who had already returned to driving or were deemed by the clinician to have the potential to return. The ages of the sample ranged between 19-62 years; most were male, and just over half had received a head injury as a result of being involved in a road traffic accident. Twenty-two of the participants had returned to driving.

The aims of the study were to investigate whether clinical opinions of fitness to drive were predictive of the outcome of a driving assessment, and to identify which tests informed these opinions.

There was a high correlation between the clinician's and driving adviser's judgements of fitness to drive. From a wide range of measures, six variables were found to be significant predictors of the driving adviser's judgement; four of these were of higher order cognitive skills. It was possible to accurately classify over 80% of cases using a discriminant function based on three higher order skills: executive functioning with respect to the ability to plan, monitor and regulate performance, the ability to think abstractly, and the ability to divide attention. A possible interpretation of these findings is that the strategic allocation of attention resources was particularly impaired in drivers who were judged unfit to drive in the driving assessment.

None of the 'routine' neuropsychological tests emerged as important in the discriminant analysis. Global scores of driving skill were not significant predictors of driving outcome, nor were measures of hazard perception.

Information from the driving interview suggests that driving is a highly emotive issue for brain injured clients, and is regarded as a key milestone in returning to a normal life. Few respondents regarded themselves as impaired, though many reported considerable anxiety and effort to drive safely. At the time of the interview less than half of the sample had had a driving assessment, though the majority had informed DVLA about their condition. Information from DVLA was not regarded as particularly clear or timely.

The main conclusions emerging from this study may be summarised as follows:

- A small number of reasonably robust tests of higher order skills could provide a basis to inform a provisional diagnosis of fitness to drive and identify necessary follow up action.
- The neuropsychological tests used in this study are familiar to psychologists working in clinical settings and could be readily incorporated as part of a fitness to drive protocol, though further work is required to develop a more practical measure of divided attention.
- Respondents reported considerable time delays and lack of clear advice and procedures following informing the DVLA of their condition.
- The small sample size means that the results of this study are only indicative, and will need validation amongst different services and assessment centres.
- In future research a multi-centered approach would be desirable in order to validate clinical and driving adviser judgements and to assess the consistency of judgement making across different clinical services and driving assessment centres.

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Notes

[1] These figures do not include chronic dementing illnesses like Alzheimers, which are also notified to DVLA.

[2] The proposal approved by the Ethics Committee stated where concerns about the safety of a head injured person's driving were raised from the assessment protocol, the head-injured person would be encouraged to inform the DVLA.

[3] Logistic regression is a statistical procedure that can predict the presence or absence of an outcome based on the values of a set of predictor variables. It is similar to linear regression, but is used where the dependent variable is dichotomous.

[4] Discriminant analysis is a statistical procedure that can provide a predictive model of group membership. It generates a discriminant function based on combinations of the predictor variables that provide the best discrimination between the groups.

Appendix A: Descriptive statistics for variables used in study

	N	*Minimum*	*Maximum*	*Mean*	*Std. deviation*
AGE	39	19	62	39.77	10.84
Attention-TEA Lottery –Scaled Score	39	4	13	9.13	3.18
Attention-TEA Map Search 1 Minute - Scaled Score	39	2	14	8.03	2.82
Attention-TEA Map Search 2 Minutes - Scaled Score	39	0	18	7.90	4.47
Attention-TEA Telephone Search – Scaled Score	39	2.0	13.0	7.256	2.975
Attention-TEA Telephone Search + Counting – Scaled Score	39	4.0	19.0	9.333	4.045
Attention-TEA Visual Elevator Accuracy – Scaled Score	37	2	14	9.24	3.62
Attention-TEA Visual Elevator Timing - Scaled Score	37	.0	18.0	7.189	3.624
COTNAB coordination ability dominant hand	39	1	3	1.33	.62
COTNAB coordination ability non dominant hand	39	1	3	1.26	.59
COTNAB coordination overall score dominant hand	39	2	5	4.18	.85
COTNAB coordination overall score non dominant hand	38	1	5	4.42	.95
COTNAB coordination timing dominant hand	39	1	5	3.31	1.00
COTNAB coordination timing non dominant hand	39	0	5	3.10	1.02
COTNAB dexterity overall score both hands	39	3	5	4.28	.89
COTNAB dexterity overall score dominant hand	39	3	5	4.31	.89
COTNAB dexterity overall score non dominant hand	39	1	5	4.46	.91
COTNAB dexterity time both hands	39	1	5	3.64	1.01
COTNAB dexterity time dominant hand	39	2	5	3.64	.96
COTNAB dexterity time non dominant hand	39	2	5	3.38	.88
Driving assessment- total score in traffic	37	14	32	28.70	3.60
Driving assessment -total score on closed circuit	39	23	40	37.13	3.66
Executive functioning-ADS dex questionnaire qu4 – self	38	0	4	1.50	1.35
Executive functioning-BADS 6 Elements – Z score	39	-2.65	.65	-.1962	1.0843
Executive functioning-BADS dex qu. Factor 1 behaviour – self	38	0	25	8.66	5.67
Executive functioning-BADS dex qu. Factor 2 cognition – self	38	0	15	5.50	3.75
Executive functioning-BADS dex qu. Factor 3 emotion – self	38	0	8	3.32	2.12
Executive functioning-BADS dex questionnaire qu1 – self	38	0	4	1.39	.97
Executive functioning-BADS dex questionnaire qu10 – self	38	0	4	1.11	1.23
Executive functioning-BADS dex questionnaire qu17 – self	38	0	4	.92	1.05
Executive functioning-BADS total-self	38	2.00	61.00	22.4474	14.0841
General intellect-Wais-r full scale IQ - pro-rated	39	74	136	98.92	14.24
General intellect-Wais-r performance –block design	39	6	18	10.69	2.74
General intellect-Wais-r performance digit symbol	39	3	16	8.28	2.74
General intellect-Wais-r performance IQ	39	71	145	100.95	18.41
General intellect-Wais-r performance –object assembly	39	2	16	9.79	3.50
General intellect-Wais-r performance picture arrangement	39	3	16	10.54	3.07
General intellect-Wais-r performance picture completion	39	4	17	9.95	3.17
General intellect-Wais-r verbal- arithmetic	39	5	15	9.72	2.44
General intellect-Wais-r verbal –digit span- age scaled scores	39	3	16	9.28	2.80
General intellect-Wais-r verbal IQ – pro-rated	39	76	124	97.54	11.58
General intellect-Wais-r verbal- similarities	39	5	15	10.26	2.96
General intellect-Wais-r verbal –vocab	39	3	17	9.56	2.79
Information processing-AMIPB Figure Delayed Recall	39	-3.09	1.26	-.3192	1.1331
Information processing-AMIPB Figure Immediate Recall	39	-3.42	1.21	-.4264	1.1190
Information processing-AMIPB Figure Retention	39	-2.80	1.76	-9.4872E-03	.8478
Information processing-AMIPB information processing A adjusted score- Z scores	39	-2.34	2.48	-.3854	.9391
Information processing-AMIPB information processing B adjusted score	39	-1.93	2.68	-.5295	.9640
Information processing-AMIPB Lists errors (+ and – reversed)	39	-2.44	1.40	-1.5385E-03	1.0377
Information processing-AMIPB Lists Trial 6	39	-3.08	1.32	-1.0382	1.4071
Information processing-AMIPB Lists trials 1-5	39	-3.63	1.67	-1.2403	1.4033
Information processing-AMIPB motor speed information processing A - Z scores	39	-3.86	2.10	-.6267	1.2478
Information processing-AMIPB motor speed information processing B	39	-3.67	1.82	-.2856	1.2077
Information processing-AMIPB Story Delayed Recall	39	-2.30	1.82	-.6918	1.0917
Information processing-AMIPB Story Immediate Recall	39	-2.58	1.68	-.5567	1.1310
Information processing-AMIPB Story Retention	39	-3.63	3.93	-.4633	1.6060
Laboratory tests-Divided attention-mean reaction time	38	2.04	7.38	3.6321	1.0082
Laboratory tests-Divided attention-mean tracking error	38	-.98	4.13	.1626	.9476
Laboratory tests-Hazard perception-mean average risk	36	.40	50.80	24.7894	12.2377
Laboratory tests-Hazard perception-mean RT to hazards	36	.00	7.38	1.1476	1.1438
Medical data- PTA -	31	.00	24.00	3.7238	5.1282
Medical data-Time post injury (years)	39	.2	14.0	3.021	3.015

Appendix B: Description of predictive variables

1 The Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson *et al.*, 1996)

Dysexecutive Syndrome resembles frontal lobe syndrome. Often there is considerable variation in the deficits observed among clients but there are a number of stable deficits, which characterise the condition, namely: impulsiveness, disturbed attention, distractibility and difficulty in identifying the whole picture from its component parts. Impairment of executive function leads to deficits in the ability to plan, organise, and monitor behaviour.

'BADS6ELM' requires participants to organise their activities in order to carry out 3 tasks -dictation arithmetic and picture naming from two parts (thus 6 tasks in total) in a limited period of time without breaking certain given rules. The participant is required to attempt at least something from each of the 6 tasks, but they are not allowed to do the two parts of the same task consecutively.

'BADDEXS1' relates to question 1 on the Dysexecutive questionnaire, which is associated with abstract thinking. Participants are presented with the statement 'I have problems understanding what people mean unless they keep things simple and straightforward', which they are asked to rate on a five point scale of 'never', 'occasionally', 'sometimes', 'fairly often', 'very often'.

2 Adult Memory and Information Processing Battery (AMIPB) (Coughlan and Hollows, 1985)

This battery assesses verbal memory (including story recall and list learning), visual memory (figure recall and design learning), information processing (number cancellation tasks).

'FIGIMM' immediate figure recall assesses the immediate registration of visual information representing the early stage of working memory. The participant has to copy a complex 2-D figure and reproduce it 30 minutes later.

3 The Weschler Adult Intelligence Scale-Revised (WAIS-R)

'WRRPC' In this task the participant is presented with a series of sketched figures and scenes and asked to say what is missing. The test is thought to measure spatial reasoning and visual selective attention.

4 Tests of Everyday Attention (TEA) (Robertson *et al.*, 1994)

Scores on these tests are sensitive to selective, sustained and divided attention.

'TEATELS' telephone search is a measure of visual selective attention. In this task participants have to look for key symbols while searching through pages of a simulated telephone directory.

5 Dynamic laboratory based tests

'MART' This variable represents the reaction to time to respond to peripheral targets during the tracking task and is a measure of divided attention.

References

Coughlan A K and Hollows S E (1985). *Adult memory and information processing battery (AMIPB)*. Leeds: Psychology Department, St James University College Hospital.

Robertson I H, Ward T, Ridgeway V and Nimmo-Smith I (1994). *The test of everyday attention*. Bury St.Edmunds: Thames Valley Test Company.

Wilson B A, Alderman N, Burgess P W, Emslie H and Evans J J (1996). *Behavioural assessment of the dysexecutive syndrome*. Bury St. Edmunds: Thames Valley Test Company.

Abstract

There is no standard validated protocol for assessing fitness to drive after brain injury or illness. The problem of assessing fitness to drive is by no means marginal. Over 25,000 licence holders every year notify the DVLA of medical conditions affecting the brain. The main aims of this study were to assess whether clinical opinions of fitness to drive are predictive of the outcome of an on-road driving assessment, and to identify which neuropsychological tests inform these opinions. The sample comprised 39 drivers who had experienced brain injury or illness. Neuropsychological data was obtained for each participant at a community head injury clinic. Computer based tests of hazard perception and divided attention were conducted at TRL, and a driving assessment was carried out at a mobility centre. The results showed a consistent relationship between assessments of fitness to drive made by the clinician and the driving adviser. The results also indicated that a small number of tests covering executive functioning and divided attention could provide a basis to inform a provisional diagnosis of fitness to drive. The small sample size means that the findings are only indicative and will need validation over a range of different services and assessment centres.

Related publications

TRL326 *Drivers' speed choice: an in-depth study* by A R Quimby, G Maycock, C Palmer and G B Grayson. 1999. (price £25, code E)

TRL208 *Assessing driving fitness following brain injury or illness: a research review* by N Christie. 1996 (price £25, code E)

PR50 *The contribution of cognitive and visual assessments to the prediction of driving performance* by B Simms and L O'Toole. 1994 (price £35, code J)

PR27 *The long term driving patterns of people with disabilities* by L O'Toole and B Simms. 1993 (price £35, code H)

CR276 *Driving after a stroke* by B Simms. 1992 (price £25, code E)

RR27 *Perceptual abilities of accident involved drivers* by A R Quimby, G Maycock, I D Carter, R Dixon and J Wall. 1986 (price £20, code C)

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