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Fitness to drive following cerebral pathology: The Rookwood Driving Battery as a tool for predicting on-road driving performance

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The use of neuropsychological testing to determine fitness to drive in people with neuropathology is likely to be an increasingly attractive alternative to on-road testing for many candidates for assessment. The Rookwood Driving Battery has been shown to have good predictive value for determining some who are likely to fail an on-road test in early studies. This study replicated earlier research by examining the predictive value and theoretical validity of the battery on a larger sample of 391 participants, as well as extending earlier analysis by examining the effect of older age (over 70 years) and the interaction between age and pathology on battery and on-road performance. The battery demonstrated good positive and negative predictive values for predicting on-road performance. There were significant effects of older age on both the Rookwood Battery performance and the on-road test, with older adults performing significantly poorer on both. There was no interaction between age and pathology on the Rookwood Battery but on-road age interacted with some pathologies to produce significantly poorer performances. Furthermore, correlation and regression analysis indicate that the battery is a powerful instrument that encompasses tests of core neuropsychological functions needed for driving.

There has been at least 30 years of research on using neuropsychological testing to determine fitness to drive following brain injury or pathology (review in Christie, 1996). For the most part, these efforts have been unsuccessful with poor methodology identified as the predominant factor (BPS Multidisciplinary Working Party, 2001) and the tests not being applied in the clinical setting. One exception is the Stroke Drivers Screening Test (SDST; Nouri & Lincoln, 1993; Radford & Lincoln, 2004) that can be used as a screening tool to assess fitness to drive in people recovering from either right or left hemisphere stroke. However, it has proved less useful in other neurological cases (Lincoln, 2001) and replication studies have also found varying rates of sensitivity, specificity and positive

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and negative predictive values, which were considered to be unacceptable for screening purposes without further amendments or additional tests (Lundberg, Caneman, Samuelsson, Hakamies-Blomqvist, & Almkvist, 2003; Sentinella & Read, 2005).

One difficulty only now beginning to be fully appreciated is that the 'gold standard' method of determining fitness to drive (i.e. the on-road driving test) is also far from being 'cast iron'. Though rich in face validity, the on-road assessment is a process of decision making by the assessor that, to a great extent, is subjective and has never been fully validated. For example, a change in driving instructor was identified as being potentially responsible for the variable pass/fail rates found in the replication study of the SDST (Nouri & Lincoln, 1992). To help minimize these effects, the requirement for instructors to use a standardized route and procedure and to be specifically trained for assessing on-road has been incorporated into more recent work on the SDST at the Transport Research Laboratory (Sentinella & Read, 2005). In line with these advances, a standardized route and on-road testing protocol was incorporated in the South Wales Driving Assessment Centre at Rookwood Hospital in 1999 both as best practice and as a prerequisite for validation of the Rookwood Cognitive Driving Battery.

The Rookwood Battery has evolved over the past 15 years and has been used in its present form in the South Wales Driving Assessment Centre since 1999, when on-road assessment became possible. The principles on which the driving battery is based are derived from the school of neuropsychological practice of Professor Elizabeth Warrington and are described by McKenna (1998). The battery conforms to the need for simple, short tests of the neuro-psychological functions most centrally involved when controlling a car in space and in traffic. These are considered to be those involved in (a) visually perceiving the environment correctly and quickly; (b) carrying out appropriate movements in the car on demand and (c) negotiating the traffic situation appropriately. The tests were also chosen to be passed by adults across the range of the normal distribution of ability and to be relatively age independent within existing norms. However, adults over the age of 70 were barely represented within these norms.

The battery addresses only the cognitive level of functioning and does not incorporate measures of physical or sensory disability. It screens only for the central processing of information in visual, praxic and executive systems. These cognitive functions are deemed to be essential for driving safely but they are not the full story. Clearly, adequate cranial nerve and motor control systems are also necessary. The battery, for instance, would not be sensitive to the earlier stages of some neurological diseases when physical symptoms predominate. Examples would be when distorted movement causes difficulty with brake and accelerator control, producing erratic, poorly timed pressure on the pedals (say, in the early stages of Huntingdon's chorea), or lack of effective pressure on the pedals (which may result from a pontine lesion). Other factors beyond the scope of a cognitive battery include being tested too soon following cerebro-vascular accident (CVA), when physical and cognitive fatigue can occur rapidly during the on-road experience, causing poor concentration and/or car control. The latter observation by our driving team has led to us to advise people who have suffered a significant stroke to wait at least 6 months to a year before referral to the Centre, even when hemiplegia has resolved quickly.

Furthermore, the battery is not designed for every conceivable combination of idiosyncratic risk. Difficulties in other cognitive skills, such as topographical or episodic memory, may have the potential for influencing driving negatively on some occasions. These difficulties are not a *sufficient* condition to produce regular unsafe driving,

however, and do not constitute those core skills needed to drive safely. Such attempts to incorporate the more tangential skills in testing fitness to drive may have contributed to the conflicting results in the long history of neuropsychological testing for driving fitness (BPS Multidisciplinary Working Party, 2001; Christie, 1996).

McKenna, Jefferies, Dobson, and Frude (2004) investigated the potency of the Rookwood Battery in predicting driving safety in terms of the results of the in-car on-road test on 142 brain-injured clients. The positive predictive value was .92, meaning that when the battery predicted a fail on-road, it was correct in 92% of the cases. The negative predictive value was .71, meaning that when the battery predicted a pass on-road, it was correct in 71% of the cases. This study reports our findings on 543 clients with cerebral pathology requiring cognitive screening who attended the South Wales Driving Assessment Centre at Rookwood Hospital from March 2000 to July 2005. As in the first study, this sample represents people who held a driving licence and had been driving for much of their adult life but does not include those people who wanted to learn driving.

The question of the older adult beyond the age of 70 was also found to be highly relevant and age, apart from pathology, was a significant factor in the results of both the Rookwood Battery and the on-road test. The need for specific norms for adults in the age range 70–90 years on the battery and on-road is now of increasing importance, as longevity beyond the 70s is an increasing phenomenon. For this reason, further studies (McKenna *et al.*, 2005; Rees *et al.*, 2006) have produced norms on the cognitive battery for adults within these age groups. The present study replicates the methodology of the original study on a much larger sample that allows closer inspection of the effects of age and pathology.

Method

Participants

Of the 543 clients referred to the South Wales Driving Assessment Centre at Rookwood Hospital from March 2000 to July 2005, 507 people completed every test on the cognitive battery. However, only 422 completed the on-road tests. Some voluntarily dropped out before going on-road, but most were to gain further practice before taking or re-taking the on-road, and did not return for their retest appointment.

The participants were all previous drivers with diagnosed neuropathology, referred to the Rookwood Driving Assessment Centre for an evaluation of driving fitness. Table 1 shows the demographics of the participants broken down by the type of pathology. Right or left unilateral cerebral vascular accidents (RCVA, LCVA), traumatic brain injury (TBI) and dementia are the four largest groups with clear diagnoses, but these account for less than 60% of the total sample. Nearly 20% were classified as having either 'mixed' or 'other' pathology (e.g. left cerebellar infarct and subarachnoid haemorrhage; subarachnoid haemorrhage and epilepsy; psychosis with dementia; diabetes with memory difficulties). Table 2 shows the age distribution of the total client group. Notably, 37% of the participants were over 70, in line with the previously highlighted need for data on the performance of older adults.

Driving centre assessment protocol

Clients attend the Driving Assessment Centre for a period of 3–4 hours. This incorporates an interview and questionnaire, the Rookwood Battery, an assessment on a driving simulator and an in-car, on-road driving assessment. This paper reports only

Table 1. Demographics of client sample

			Age		
Pathology	%	Total *N* (males/females)	Mean	*SD*	Range
Right CVA	20.4	111 (91/20)	63.7	11.2	36–84
Left CVA	16.8	91 (82/9)	64.2[1]	11.5	24–85
Other	16.4	89 (60/29)	61.7	17.8	24–92
Dementia	12.5	68 (63/5)	72.9	8.7	50–88
TBI	9.9	54 (46/8)	42.4	15.3	19–79
Parkinson's and Huntingdon's disease	6.4	35 (30/5)	64.1	13.4	36–85
CVA (bilateral or unspecified)	6.4	35 (30/5)	65.1	12.6	29–89
Mixed	3.3	18 (17/1)	67.3	13	34–84
Sub-cortical pathology	2.8	15 (10/5)	54.1	12.6	29–71
MS	2.4	13 (10/3)	45.7	7.5	34–59
Anoxia, meningitis or encephalitis	1.8	10 (8/2)	41.0	16.7	22–79
Missing diagnoses	0.7	4 (2/2)	47.0	5.5	41–53
Total	100	543 (449/94)	61.5[1]	15.6	19–92

CVA, cerebrovascular accident; TBI, traumatic brain injury; MS, multiple sclerosis.
[1] Age is missing for one participant in the LCVA group.

Table 2. Distribution of ages in client group ($N = 543$)

Age range	*N*	%
19–29	20	3.7
30–39	37	6.8
40–49	56	10.3
50–59	105	19.3
60–69	124	22.8
70–79	141	26.0
80–92	59	10.9
Missing	1	.2
Total	543	100

the results of the Rookwood Battery and the in-car assessment. In the in-car assessment, the client is taken to a large, usually empty, car park to become accustomed to the car and to carry out spatial manoeuvres off road before completing a prescribed route on-road. Higher scores on the on-road test indicate worse performance.

The Rookwood Battery

The Rookwood Driving Battery is described in full in McKenna *et al.* (2004) and is composed of tests of visual perception and attention, praxis, executive function including divided attention. These are listed in Table 3.

The aim of the cognitive battery is not to identify everyone who will fail on-road as there are factors other than those cognitive functions represented by the battery that will cause a fail, some of which we have outlined above. The purpose of the battery is twofold: first, to contribute to the information in the clinical assessment of fitness to drive at the centre and the second, to obtain a cut off that will confidently predict a fail

Table 3. Tests included in The Rookwood Battery

Executive function tests	
Weigl sorting test	Newly standardized and adapted version of Weigl Test from Goldstein and Scheerer (1941)
Rule Shift Cards Action Programme, Key Search Task	From *The Behavioural Assessment of the Dysexecutive Syndrome* (Wilson, Alderman, Burgess, Emslie, & Evans, 1996)
Tapping and Sequencing	Newly standardized and adapted version of Warrington's protocol derived from a qualitative test of Luria (1973) *The Working Brain*. Penguin, London
Divided attention	Repeat of the 'Es and Fs' test with simultaneous listening task requiring detection of auditory target which occurs nine times (auditory task originally devised within Forum group by Lynn O'Toole, psychologist, Banstead Assessment Centre). Simple pass/fail dependent on clinical observation of missed targets and excessive slowness (allowing for age). Normative data available only for over 70s as yet)
Visual perception tests	
Incomplete Letters Position Discrimination, Cube Analysis	*from The Visual Object and Space Perception Battery* (Warrington & James, 1991)
'Es and Fs'	Task of visual attention and cognitive speed involving letter cancellation (normative data available only for over 70s to date). Simple pass/fail dependent on clinical observation of missed targets and excessive slowness (allowing for age)
Praxis tests	
Copying hand movements, producing gesture, miming use of objects, tapping and sequencing	Newly standardized version of Warrington's protocol for hand movements adapted from Luria (1973)
Comprehension	
Modified token test	Shortened version of the Modified Token Test (Coughlin & Warrington, 1978)

on road because of cognitive deficit (for possible use within the primary care setting). The statistical calculation to allow this is termed positive predictive value (PPV) and for passing on road, negative predictive value (NPV).[1]

Results

Homogeneity over time of cognitive and on-road scores

The data were collected over three distinct phases of expansion in practice at the Driving Assessment Centre. Table 4 shows the means of both the total Rookwood Battery score and on-road test score across the three phases. When compared using a one-way independent sample ANOVA, there was no significant effect of phase on

[1] *The terms 'sensitivity' and 'specificity' were incorrectly applied in the previous study (McKenna* et al.*, 2004) and were corrected in a later edition. See also discussion section.*

cognitive battery score ($F_{(2, 504)} = 0.324$; $p = .723$). However, when using the same analysis of on-road scores there was a significant effect of phase ($F_{(2, 419)} = 5.024$; $p = .007$). When further analysed using *post hoc* Scheffe tests, the only significant difference was between the second and the third phases ($p = .007$) with a tendency for larger on-road scores in the third period. The age of participants was not significantly different throughout the test phases ($F(2, 397) = 1.815$; $p = .164$). In the absence of other apparent hypotheses, this suggests that (unlike the cognitive battery) the on-road test is more likely to be influenced by a change in the assessor, as was suggested by Nouri and Lincoln (1992).

Table 4. Scores across the three testing phases.

Testing phase	Mean on-road score (*SD*)	Mean battery score (*SD*)
March 1999–April 2002	21.3 (16.7)	6.0 (5.0)
Total *N* = 142	*N* = 126	*N* = 137
May 2002–September 2003	17.7 (15.2)	5.6 (5.2)
Total *N* = 201	*N* = 133	*N* = 187
October 2003–July 2005	23.8 (17.1)	5.9 (5.2)
Total *N* = 200	*N* = 163	*N* = 183
All Phases Total *N* = 543	21.1 (16.6)	5.8 (5.1)
	N = 422	*N* = 507

Given the variability of on-road scoring across the three phases, we calculated the positive, negative and total predictive values separately for each to establish the most appropriate cut-off score on the Rookwood Battery based on selecting the cut-off with maximum total predictive value. The results were as follows: Phase 1 (PPV = .92, NPV = .71, TPV = .75, optimal cut-off > 10), Phase 2 (PPV = .84, NPV = .82, TPV = .83, optimal cut-off > 10) and Phase 3 (PPV = .78, NPV = .78, TPV = .78, optimal cut-off > 7). Notably, the final phase had a lower optimal cut-off score than Phases 1 and 2, in keeping with our observation that the errors scores on the Phase 3 on-road test were given more frequently. In this phase, using the previous cut-off of > 10 produced PPV of 0.91 but a NPV of only 0.70, with a TPV of 0.75.

Although 507 clients completed every test on the Rookwood Battery and 422 people completed the on-road test, only 391 completed both the on-road test and the battery. Within this group, there were 325 males and 66 females with a mean age of 61.1 years (*SD* = 15.9; range 19–89; age missing for one male participant). NART IQ was available for 308 participants of this group, which was representative of the general population (mean = 104.04, *SD* = 14.1; range = 69 - 129). In this group, 244 passed the on-road test while 147 failed. It was this data set that we used to obtain the positive and negative predictive values of the cognitive battery for the on-road score.

Relationships between Rookwood Battery scores and on-road driving test

Rookwood Battery correlations

Correlations were computed between the raw scores on each subtest and the total battery score and between the raw scores on each subtest and the on-road score. As can be seen from Table 5, these reveal strong and significant correlations for all the subtests with both the total battery score and the on-road score suggesting a level of validity for

the individual cognitive tests. As in the previous study, the Pearson correlation between overall battery score and the on-road score was particularly strong ($r = .658$; $p < .0001$; $N = 391$), accounting for 43.3% of the variance. The National Adult Reading Test (NART; Nelson, 1991), used for calculating premorbid IQ, was not significantly correlated with on-road performance ($r = -.076$; $p = .174$; $N = 325$) confirming that the relationship between the cognitive battery and on-road performance is not simply a function of the premorbid baseline level of intelligence.

Table 5. Pearson correlations between raw scores on each subtest and (a) the overall battery score and (b) on-road score

	Pearson *r*	
Subtest	On-road score	Total battery score
Weigl	.339	.540
Key Search	.416	.551
Action Programme	.360	.533
Card Rule Shift	.505	.652
Tapping and sequencing	.446	.615
Cube Analysis	.365	.516
Position Discrimination	.262	.350
Incomplete Letters	.283	.344
Visual attention	.460	.559
Divided attention (time)	.482	.550
Divided attention (errors)	.296	.446
Praxis	.353	.539
Comprehension	.448	.637
NART	.076[1]	.310
On-road	1	.674
Total battery score	.674	1

[1] All correlations are significant at the $p < .001$ level (two-tailed), except between NART and on-road score which was not significant.

Multiple regression analysis

A multiple regression analysis was performed between on-road test score as the dependent variable and age, Rookwood battery score and pathology (including the LCVA, RCVA, dementia and TBI groups only) as the independent variables. As age and Rookwood battery score are ordinal variables while pathology is a nominal variable, a categorical regression was used to enable variables of both types to be included in the analysis. Analysis was performed with the SPSS version 13.0.1 software package (SPSS Inc., 2004) and the analysis conducted as described by the procedure in Tabachnick and Fidell (2001).

Correlations between the ordinal variables (on-road score and age: $r = .465$; on-road score and Rookwood battery score: $r = .666$) were below .9 and therefore did not violate the assumptions of multicollinearity or singularity. There were no indications of major deviations from normality on inspection of the normal probability plot and no outliers were found either in the analysis of the scatterplot (cases with standardized residual of greater than 3.3 or less than -3.3) or by inspection of the Mahalanobis distances (using the $p < .0001$ criterion). Inspection of the scatterplot revealed no

significant violations of the assumption of homoscedasticity. The model predicted 60.8% of the variance in on-road test scores ($R^2 = .608$; adjusted $R^2 = .562$) and the overall relationship was significant ($F_{(21,178)} = 13.147$; $p < .0001$). All three independent variables were significantly related to the on-road test score, with score on the Rookwood battery being the single biggest predictor (standardized $\beta = 0.562$; $p < .0001$), followed by age (standardized $\beta = 0.379$; $p < .0001$) with pathology showing the least predictive value (standardized $\beta = 0.103$; $p = .007$). With age removed from the regression, the overall relationship remained significant ($F_{(12,188)} = 8.644$; $p < .0001$) although the predicted variance reduces to 51.6% ($R^2 = .516$; adjusted $R^2 = .485$), indicating that age predicts an additional 9.2% of the variance (a 15.1% proportional increase).

Predictive value of the battery for on-road performance

Predictive value analysis

One purpose of the Rookwood Battery is to screen for clients who would definitely fail the on-road test. As before, the most powerful cut-off for predicting a definite 'fail' on the cognitive battery was an error score greater than 10 (out of a possible error score of 22). Ten out of the twelve tests could be scored 0 (pass), 1 (borderline) or 2 (fail) based on normative data ($N = 200$) collected at an earlier stage of development of the battery (full details in McKenna *et al.*, 2005). Two tests that were developed later, visual attention and divided attention, were scored 0 (pass) or 1 (fail). These tests do not as yet have normative data for all age groups and therefore can only be scored pass or fail according to very clear clinical features. The cut-off of an error score >10 for predicting a clear 'fail' on road was derived from a best-fit analysis in the first study applying the formulae for positive predictive value (PPV) and negative predictive value (NPV) (McKenna *et al.*, 2005). When applied to the entire group in this study, this produced a positive predictive value of .88. That is, out of the 69 people predicted to fail on-road, 61 of them did so. In contrast, if the battery were to be used to predict who would pass on road (negative predictive value) using a cut off error score of 10 or less, only 240 out of the 327 people predicted to pass on road did so, giving a negative predictive value of only .74.

Table 6 shows the positive and negative predictive values for each of the main groups of clients with a diagnosis of stroke, traumatic brain injury and dementia. Notably, the positive predictive value for the stroke and dementia groups (ranging from .78 to .81) is less powerful than the overall value for the population (.88) while results appear perfect for the group with acquired brain injury (1.0). The effect of age had already been noted in an earlier study and was hypothesized to be a confounding factor within the diagnostic groups.

The entire group was split into those aged under 70 and those aged 70 and over. This produced a much stronger positive predictive value for those under 70 (.91) and far greater negative predictive value (.86). For those over 70, the positive predictive value (.86) is only a little below that for the entire group but the negative predictive value (.49) is very poor and highlights the fact that many of the older adults in this group failed the on-road test even though passing the battery. Further inspection of the predictive values for each possible error score in this age group elicited an error score of >6 as the highest total predictive value (see Table 6). Thus, the ability of the battery to correctly predict either fail or pass (TPV) was .86 for the entire group under 70 years of age using an error score of >10 and for those aged over 70 was .69 using an error score of >6.

Table 6. Accuracy rates in predicting on-road fail (PPV) and on-road pass (NPV) for each pathology group (using criterion >10)

					On road	
	PPV	NPV	TPV	Battery	Pass	Fail
Right CVA	.83	.76	.77	Pass	44	14
				Fail	2	10
Left CVA	.78	.78	.78	Pass	39	11
				Fail	2	7
TBI	1	1	1	Pass	36	0
				Fail	0	5
Dementia	.85	.30	.57	Pass	8	19
				Fail	4	22
Age 69 or under	.91	.86	.86	Pass	183	31
				Fail	3	29
Age 70 or over	.86	.49	.58	Pass	52	55
				Fail	5	32
Entire group	.88	.73	.76	Pass	236	86
				Fail	8	61
Age 70 and over using >6 as criterion	.78	.59	.69	Pass	41	29
				Fail	16	58

CVA, cerebrovascular accident; TBI, traumatic brain injury; PPV, positive predictive value; NPV, negative predictive value; TPV, total predictive value.

While the results appear perfect for the group with acquired brain injury (1.0 for both negative and positive predictive values), this is a result of their bimodal distribution. The group fell into extreme camps consisting of the majority who passed all the tests and drove well and five people with severe deficits, evident both on the Rookwood Battery and the on-road test.

Group differences on subtests

Table 7 displays the mean scores and percentage failing each subtest for each of the four main pathology groups. In terms of the overall battery scores, the dementia group performed extremely poorly when compared with the other three groups while the TBI group performed far better than the other three groups. The dementia group had particular difficulty with the Rule Shift Cards, Tapping and Sequencing and Divided Attention. The TBI group had most difficulty on the Action Programme Test, the Comprehension test and, surprisingly, on the Praxis test. In terms of brain-behaviour correlates, the two groups with focal pathology (RCVA, LCVA) had specific neuropsychological profiles that loaded more heavily on subsets of the tests. Thus, the RCVA group was selectively poorer on the visual perceptual tests (Cube Analysis, Position Discrimination and Incomplete Letters) when compared with the LCVA, and the LCVA group was selectively poorer on the language based tests (Rule Shift Cards and Comprehension) and one executive test which involved praxis skills (Tapping and Sequencing) when compared with the right.

The effect of older age and interaction with pathology

Given the distinctive effect of age on the predictive value of the Rookwood Battery found in a previous study (McKenna *et al.*, 2005) it was considered important to

Table 7. Mean scores of the four main pathology groups (RCVA, LCVA, TBI and dementia) on each subtest, and percentage who fail the test (including borderline fails)

	LCVA			RCVA			TBI			Dementia		
	Mean	*SD*	% Fail	Mean	*SD*	% Fail	Mean	*SD*	% Fail	Mean	*SD*	% Fail
Weigl	3.6	0.9	16.4	3.7	0.6	16.4	3.8	0.5	9.5	2.9	1.2	47.2
Key search	11.3	4.6	25.8	10.6	4.5	34.2	12.9	3.3	16.7	9.2	4.7	54.7
Action programme	4.3	1.0	45.2	4.5	0.9	38.5	4.5	1.0	33.3	4.1	1.6	48.1
Rule shift cards	17.3	4.3	52.5	18.7	2.7	39.7	18.8	2.6	23.8	13.7	5.5	81.1
Tapping and sequencing	13.0	3.0	41.9	13.5	2.05	32.9	14.2	1.3	26.2	11.2	3.2	71.7
Cube analysis	9.2	1.5	11.3	8.7	1.5	30.2	9.3	1.1	14.3	8.0	2.5	37.7
Position discrimination	19.7	1.0	12.9	18.4	2.3	36.1	19.2	1.7	9.5	18.9	1.7	28.3
Incomplete letters	19.4	0.8	12.9	18.2	2.9	36.1	19.2	1.1	21.4	17.1	3.9	47.2
Visual attention speed	54.7	16.7	22.6	63.6	16.0	31.5	65.7	17.0	7.1	51.8	19.6	49.1
Visual attention errors	9.0	7.9		10.0	12.4		2.8	6.8		8.5	11.7	
Divided attention speed	44.9	19.9	40.3	55.6	17.6	43.8	60.3	18.4	16.7	38.7	25.0	86.8
Divided attention errors	7.4	14.1		11.2	15.6		3.9	8.7		18.2	27.7	
Divided attention '3's	7.3	2.5		8.0	1.6		8.4	1.7		5.3	3.2	
Praxis	15.0	2.1	35.5	15.3	1.1	39.7	15.3	1.4	30.9	14.3	2.1	62.3
Comprehension	5.4	2.8	44.3	6.8	1.6	27.4	6.6	1.8	35.7	4.8	2.7	64.1
Total battery score	5.7	4.7		5.8	4.6		3.8	3.8		10.9	5.6	

LCVA, left cerebrovascular accident; RCVA, right cerebrovascular accident; TBI, traumatic brain injury.

examine the effect of age on the battery and the on-road test performance in greater detail. Table 6 presents the pass/fail rates and predictive values on the Rookwood Battery for clients under the age of 70 and those who are 70 or over.

Notably, there was no significant difference between groups on NART IQ ($t_{(311)} = -1.96$, $p = .051$), indicating that both groups were similar in terms of premorbid levels of general cognitive ability, although the borderline non-significance is noted. A chi-squared comparison showed that there was an uneven distribution of the four main neuropathologies (LCVA, RCVA, TBI and dementia) in the two age groups ($\chi^2 = 36.75$, $p < .0001$). Only dementia showed a greater prevalence in the over 70s, with all other pathologies being more prevalent in the under 70s.

Two-way ANOVAs were used to examine the potential interaction of age and the four main pathology groups on total Rookwood Battery score and on-road test score. When compared on total Rookwood Battery score (mean scores displayed in Figure 1), there was a significant effect for age ($F_{(1, 221)} = 5.384$, $p = .021$), people over 70 scoring significantly worse than people under 70. There was also a significant effect for pathology ($F_{(3, 221)} = 10.523$, $p < .0001$). *Post hoc* Scheffe tests indicated that the only significant differences between individual neuropathology groups were when the dementia group was compared with all other groups (all $p < .0001$), with the dementia group performing significantly worse. All other *post hoc* comparisons were non-significant. There was no significant interaction between age and pathology on total Rookwood Battery score ($F_{(3, 221)} = 0.528$, $p = .664$), although, notably, the group of clients aged 70 and older with TBI numbered only 4.

When compared on the on-road test score (mean scores displayed in Figure 2), there was again a significant effect for age ($F_{(1, 214)} = 14.446$, $p < .0001$) in that people under 70 scored significantly better than people aged 70 and over. There was also a significant effect for pathology ($F_{(3, 214)} = 11.943$, $p < .0001$). *Post hoc* Scheffe tests indicated significant differences between the dementia group and all other groups (all $p < .0001$), again with the dementia group performing significantly worse. Unlike the results of the

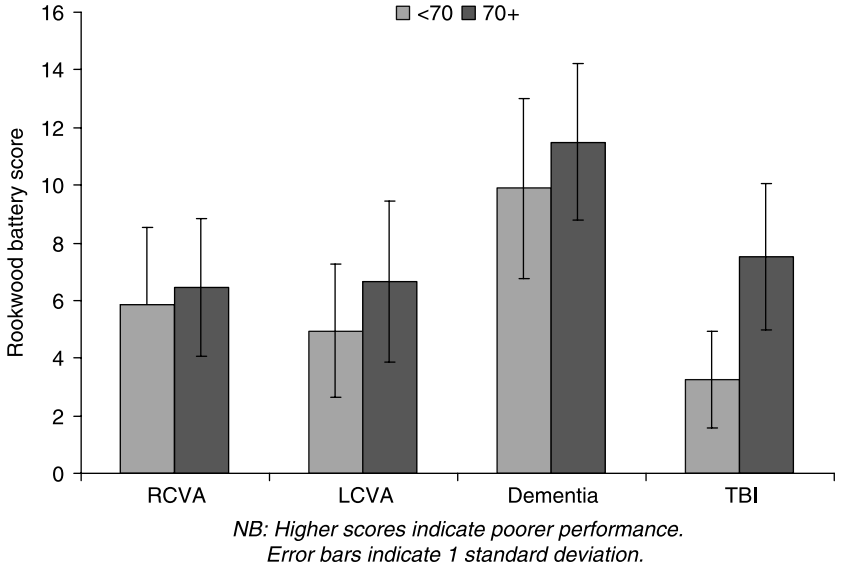

Figure 1. Rookwood Battery scores by major neuropathology type and age group.

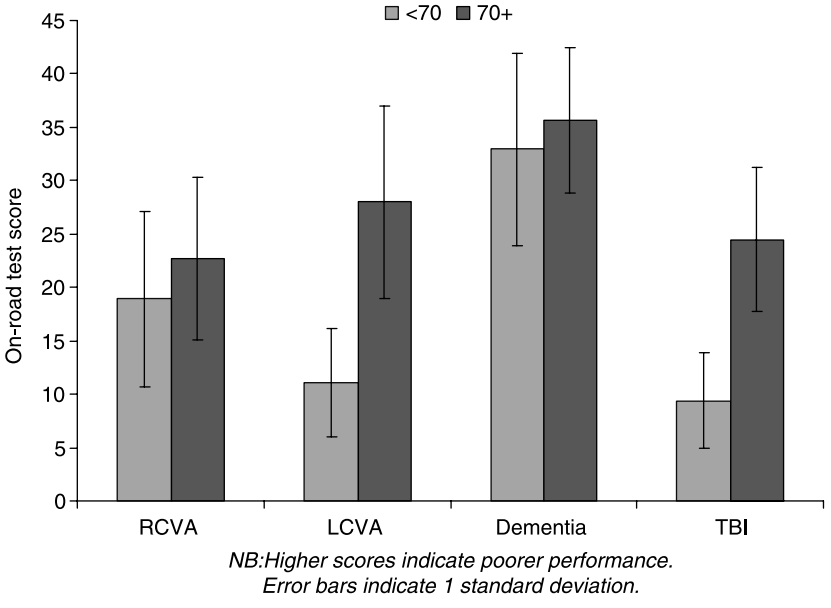

Figure 2. On-road driving test scores by major neuropathology type and age group.

battery scores analyses, an additional significant difference between the RCVA and the TBI group ($p = .015$) was present, with the RCVA group scoring significantly worse. Also, in contrast to the battery score analysis, there was a significant interaction between age and pathology on the on-road test score ($F_{(3, 214)} = 3.041$, $p = .03$), with those with LCVA and TBI scoring much worse if they were over 70.

Discussion

The findings in this study support the use of the Rookwood Battery as a tool in decision-making for fitness to drive, both as a screening tool and as a standard against which to measure consistency of the on-road outcome for diverse diagnostic categories of neurological patients. The predictive value of the battery in determining on-road outcome and the correlation and regression analyses indicate that the battery uses tests of the core neuropsychological functions needed for driving.

The choice of neuropsychological tests for the battery required them to be easy for people with physical disability to carry out. The fact that most clients were able to do every test on the battery confirms its accessibility and appropriateness for most people following cerebral injury or pathology. Far more of the 543 clients in this series were able to complete fully the cognitive battery (507) than could attempt the on-road assessment (422). This suggests that the battery is appropriate as a screening tool in the primary healthcare setting. One proviso, however, is the need for caution when the neurological condition is primarily affecting motor and sensory systems. Many more of the people in the group consisting of Parkinson's disease and Huntingdon's disease failed on road than passed (20/12), the reverse of the pattern found in the CVA groups (54/94) or TBI group (5/38).

The results on the cognitive battery show that the people passing through the driving assessment centre remained cognitively homogeneous throughout the three phases of the 5-year testing period. These results also demonstrate the objective nature

of testing and scoring. In contrast, the changing results on the in-car assessment across the second and the third periods were thought to reflect the subjective nature of the process when interpreting and allotting scores to the observed behaviour on-road. Inspection of mean on-road scores suggested that scoring became harsher in the final phase, reflected in a lower cut-off score of >7 on the battery providing a better fit to predict failure on road than that found in the previous two phases (>10). Certainly, there was often a bigger difference between the two assessors' scores in the last period, with occasions when the approved driving instructor (ADI) awarded a much higher score than the observer sitting in the back. Indeed, at CARA, the specialized assessment unit in Belgium, Akinwuntan *et al.* (2005) found the inter-rater reliability of the in-car assessment for stroke patients comparing real-life observation and video-recordings across three assessors to be, at best, moderately high, ranging from .62 (real life to video) to .80 (video to video) for overall performance.

These variations also reflect the absence of an objective standard against which the fitness to drive can be measured, given that anyone who is driving a car presents a degree of risk. If the standard represents a level of risk that differs significantly from the non-brain-injured driving population, then good normative data on the in-car assessment protocol is needed. If the standard represents a level of risk that produces accidents, then feedback from driving history post-assessment is necessary. This becomes particularly relevant for the older driver who may well fail, given the former criterion, but pass with the latter if self-imposed restriction ensures driving only under conditions which suit competence levels. Results here also contrast with American findings. For instance, Engum and Lambert (1992) found that older drivers were more often judged as better on-road than predicted by the neuropsychological battery compared to younger brain-damaged drivers. This again points to the importance of the difficulty of the on-road test, which may be relatively more difficult and less suited to the older driver in the UK, while being relatively easier and more suited to older drivers in other countries. Furthermore, the battery does well in the main pathology groups excepting the dementia group, where it predicts more on-road success than is actually observed, again pointing to the issue of on-road test difficulty for older drivers. Clearly, there is some way to go in validating the on-road protocol and making it reliable. The predictive value of the cognitive battery is inevitably compromised by an unstable or fluctuating standard but, nonetheless, still produced an overall ability to predict pass or fail in 86% of the cases for people under 70 and 69% of cases for those over 70.

Although the majority of clients fell into the categories of RCVA, LCVA, TBI and dementia, almost 20% were of mixed pathology or classified as 'other'. Referrals to the Driving Assessment Centre typically have minimal information about the pathology. In real-world practice, clinical classification and localization of pathology are very often based on gross symptomatology rather than fine-grained neuropsychological analysis or radiological evidence, particularly in cases of stroke or dementia. In cases of dementia, people referred to the Centre will not be referred with the more specific diagnoses of subgroup presentation (e.g. picks, fronto-temporal variants, semantic dementia, Alzheimer's disease and vascular dementia) that can affect different neuropsychological functions. Nonetheless, the multiple comparisons between the four main groups (RCVA, LCVA, TBI and dementia) produced results that would be expected from known neuropsychological correlates.

Though the RCVA and LCVA groups showed no difference between the overall scores on the battery, subtest comparisons showed that there were significant differences in the expected cognitive domains. Thus, the RCVA group was poorer on the tests of visual

perception (deciphering letter shapes and spatial relations) and in visual scanning and attention; and the LCVA group on those tests that were heavily reliant on verbal processing, such as following instructions in the comprehension task, monitoring their yes/no verbal output according to a rule and detecting auditory targets in a divided attention task.

Within the TBI group, there was a clear split between the majority (37 out of 42), who showed little difficulty on the battery subtests and passed on road with ease and the few (5 out of 47) who did very poorly on the battery and on the road. Most people who have severe cognitive deficits arising from a very severe or severe head injury are unlikely to be encouraged to return to driving. Most of the clients in the TBI group referred to the driving assessment centre were able to do the comparatively simple cognitive tests of the battery and comply easily with the on-road demands of the driving situation. However, Christie *et al.* (2001) describe common problems in this group which affect the social/emotional domain, such as issues of impulsivity, anger control, risk taking and so on, which impact on driving behaviour but do not emerge in the very structured drive of a formal assessment with the ADI. This class of behavioural difficulty on-road would require an altogether different protocol than can be delivered in assessment centres.

Coleman *et al.* (2002) looked at 71 people with moderate to severe TBI for whom they had access to driving records including accidents and offences. They reported that caregivers' perceptions determined whether, and how often, head-injured persons drove while, in terms of accidents, neuropsychological testing and medical status were the best predictors of driving safety. The authors further emphasized that the on-road test has not been validated against driving records and subjective reports of driving safety.

One interesting finding was that when the four main pathology groups were examined, there was an interaction between age and pathology type for the on-road test but not the cognitive battery. One possibility is that the on-road test is demanding in a wider range of areas which the Rookwood Battery is not intended to test (such as fine sensory or motor function), so that older adults may be additionally disadvantaged by these in combination with any cognitive deficit.

The specific needs of the older adult remain an urgent issue as there can be little doubt that age was a contributory factor in failing the on-road test. The older adults, aged over 70, did significantly poorly on both the cognitive battery and the on-road tests, regardless of pathology. This is in line with the multiple regression analysis which suggested that Rookwood Battery score is the single biggest predictor of on-road test score, although age predicts more of the variance than pathology. Notably, on examination of the standardized betas, age predicts over three times more variance on the on-road test score than pathology, suggesting that information about diagnosis adds little to predicting driving success than the combination of neuropsychological performance and age. This is, perhaps, a welcome result, considering that (as mentioned earlier) clients' neuropathology is often poorly defined on referral.

The poor negative predictive value of only .59 for people over 70 years of age meant that 41% of those who passed the cognitive battery nonetheless failed the on-road test. This raises the question of appropriateness of the on-road route for the older driver. The present route conforms to that specified by Forum (the association of accredited driving centres in the UK) to include the complete range of complexity which can be found on the roads in traffic. If the natural progression in driving history with greater age is to drive in quiet times or on simplified routes as an adaptive strategy, then it may not be appropriate to use a route which incorporates the complete range of highly complex and demanding situations. It may be more appropriate to use a route that is matched to a different standard. At the South Wales

Driving Centre at Rookwood, these results have led to a change in the on-road protocol for adults aged over 70 who, henceforth, follow a different route. Only one of the local routes for the driving test used for novice drivers incorporates the harder elements of our route (e.g. multiple lane roundabouts with fast flowing traffic) and most load more heavily on controlling the car in twisty lanes which narrow periodically and where on-coming traffic is less frequent but just as demanding on driving skill within the road layout. This is the route we have now adapted for older adults. However, there is a lack of clarity in the expected standards from central government and DVLA, in particular as to whether different standards should apply with greater age. A concomitant study (Rees *et al.*, 2006) is providing normative data on the battery for healthy, older adults in order to look at the effects of normal ageing on performance.

Conclusions

The Rookwood Battery was shown to be a powerful tool both in terms of practicality and ability to predict on-road performance. It could be carried out in full by the vast majority of people with neurological conditions who attended for a driving assessment (93.4%) and there were strong correlations between all subtests and the on-road score for the entire group. The Rookwood Battery showed no significant difference in results for three separate cohorts over 6 years while the on-road test results were significantly worse for the third cohort. This fluctuation in results was considered to reflect the intrinsically subjective nature of the process. The battery can be used, therefore, to help check consistency of scoring on-road within and between driving assessment instructors.

The battery's validity in detecting impairment in neuropsychological functions considered to be important for driving were shown in the selective patterns of impairments revealed by core subgroups of clients. Thus, those clients who have right hemisphere pathology did selectively worse on tests of visual perception, including shape and spatial appreciation, and visual attention. Those with left hemisphere pathology did selectively worse on tests where verbal mediation is needed (comprehension, verbal monitoring, detecting verbal targets). The group with dementia performed selectively poorer than the other main groups on most of the subtests. The TBI group was an exception and did not show the expected selective difficulty on the executive tasks. This group may need a completely different protocol to screen for the emotional aspects of driving behaviour over time without the element of structured surveillance inevitable in an on-road test.

Finally, clients over the age of 70 were found to perform significantly poorer than younger clients on the Rookwood Battery and on-road regardless of the type of pathology. Once again, these results highlight the specific needs of the older adult and that a different assessment protocol may be warranted to assess their driving safety on-road. Nonetheless, the battery correctly predicted pass or fail in 86% of the cases for people under 70 and 69% of cases for those over 70. Furthermore, the on-road course at the South Wales Driving Assessment Centre has now been changed for the older adult to more closely match the context in which older adults drive.

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