Applied Neuropsychology
2007, Vol. 14, No. 4, 296–304

Measurement of Recovery after Traumatic Brain Injury: A Cognitive-Neuropsychological Comparison of the WAIS-R with the Cognitive Assessment System (CAS) in a Single Case of Atypical Language Lateralization

Simon M. McCrea
Department of Biomedical Engineering, University of Alberta, Edmonton, Canada

A 20-year-old preferentially left-handed male suffered an extensive right, focal, medial, prefrontal hematoma and contusion with associated swelling, and an initially undetected progressive loss of consciousness following trauma to the forehead. Performance on the Cognitive Assessment System (CAS) at 1 and 6 months after traumatic brain injury was compared with performance on the WAIS-R at 6 months post-injury. The patient demonstrated significant residualized impairment on selected subtests of the CAS at 6 months post-injury (all ps < 0.05). The patient was also significantly impaired on the Information, Vocabulary, Arithmetic and Comprehension verbal subtests of the WAIS-R. The magnitude of these WAIS-R subtest discrepancies occurred with a low base rate ($< 1\%$) in the WAIS-R standardization sample. In addition there was a significant VIQ versus PIQ discrepancy favouring PIQ of a magnitude occurring in less than 5% of the WAIS-R standardization sample. These findings could not be explained on the basis of any prior learning disability, poor educational opportunities, medication use, response bias, confabulation, or low level of general ability. The low scores on the verbal subtests of the WAIS-R in conjunction with the impairment on the CAS subtests are highly suggestive of lasting frontal-executive dysfunction in this patient. Incidental findings of persisting anomia, impaired processing of proverbs, acalculia, and fluctuating verbal attention, as well as impaired retrieval of verbal information in the context of intact PIQ and superior constructional praxis suggest some degree of bilateral representation of linguistic functions. The differential assessment of cognitive domains by these two instruments as well as theoretical concordance in the pattern of results is also addressed.

Key words: Cognitive Assessment System, language lateralization, TBI, WAIS-R

The Cognitive Assessment System (CAS; Naglieri & Das, 1997) has been used in studies of recovery from brain injury (Gutentag, Naglieri, & Yeates, 1998). Recently it has been shown to be selective and specific in the assessment of localized cortical lesions based on extant knowledge of brain regions involved in various cognitive processes at the CAS subtest level (McCrea, 2006; McCrea & Scott, 2002). In this study, the course of longitudinal recovery in a case of focalized traumatic brain injury was compared using the CAS and the WAIS-R. The goal of this study was to determine the ability of specific CAS subtests to detect insult during the assessment of a brain-injured patient using a larger sample of cortical and non-cortical lesion patients ($n = 32$) as the control group as well as to compare these effects with a known neuropsychological instrument for an examination of convergent validity. An examination of the method and rationale of the study in conjunction with an illustration of the complexities of calculation of premorbid ability of this unusual patient and

Address correspondence to Simon M. McCrea, Department of Neuroopthalmology, University of British Columbia, 2550 Willow Street, Vancouver, British Columbia, Canada V5Z 3N9. E-mail: smccrea@interchange.ubc.ca

subsequent case presentation of findings and implications are discussed below.

CASE STUDY

Case Description

The patient (TF) selected for this case study was a 20-year-old preferentially left-handed male who had suffered an extensive right, focal, medial, prefrontal hematoma and contusion with associated swelling, and an initially undetected progressive loss of consciousness following trauma to the forehead. He had attained a high school education and a 2-year journeyman's certificate as a highly skilled heavy equipment operator (education = 14 years). TF's occupation entailed driving large trucks with a top-tier rated speciality driver's license and several years of step-wise on-the-job training and apprenticeship. His occupation required substantial competency, responsibility, and drug screening. TF did not report any drug or alcohol use although he reported that he occasionally drank socially and this did not appear to be of concern for the purposes of this case presentation.

TF was "punched" in the forehead after an unprovoked altercation. He had been drinking at the time of the incident. After being hit, he slumped forward and fell to the ground although reliable informants indicated that he did not he hit his head. It is reported that TF lost consciousness for a period of 20 min afterward and he was amnesic for the entire incident. TF's jaw was found to have a simple fracture and he was originally discharged from the hospital after being prescribed an anti-inflammatory agent for the swelling. He presented initially to the hospital in a stupor and the local physician reported a Glasgow Coma Scale (GCS) score of 14/15 on admission and before air-ambulance transfer to a large neurology unit of a university hospital. The following day he returned to the hospital approximately 24 hr after the initial injury. TF had been complaining of progressively worsening headaches with accompanying nausea, severe vomiting, and photophobia. It was reported by the local attending physician that he opened his eyes to voice commands only and he was found to have a sluggish left pupil and a GCS of 14/15, weak peripheral motor responses, and vertigo. There were inconsistencies in the report by the attending physician that TF had landed on the back of his head and suffered a contre-coup injury; however, there was no clinical neurological, reliable informant, nor neuroradiological evidence to support this statement. It was reported that he had no abnormalities on neurological exam. Some hours later, after the attending physician decided that a CT scan might be advisable, an expanding large right frontal lobe hematoma was discovered.

TF was immediately airlifted to a large university hospital for pre-emptive neurosurgical observation and neurologists there were consulted by phone while in transit over the 1 1/2 hr air trip. Upon arrival at emergency of the university hospital it was reported in his medical chart that TF was found to have a GCS of 14/15. After an undisclosed length of time after admission it was reported that TF's GCS improved to 15/15, yet it is not clear from the patient record as to when this improvement occurred. A follow-up CT scan revealed no sign of deterioration and he was prescribed Advil™ for his headache.

He reportedly was lethargic, stuporous, vomiting, unsteady of gait, and his speech was slurred and his "state of consciousness was fluctuating" upon admission to the hospital. TF's hematoma gradually began to resolve and there was significant re-absorption of blood over the month in hospital as revealed by serial non-contrast enhanced CT scanning. During his stay as an inpatient in acute care his jaw was reset and subsequently rewired. TF received 3 mg of morphine intravenously and 25 mg of Gravol™ while his jaw was reset.

TF was taking a maintenance dose of 300 mg/day of Dilantin™ intravenously at the time of the first assessment 2 weeks after his injury. TF had gradually been tapered off Dilantin over the next 6 months and was not taking this anti-epileptic medication at the time of his second assessment. He did not experience any seizures during or at any time after his accident. Stein and Strickland (1998) note that very high doses of Dilantin can induce mild adverse cognitive effects on attentional, psychomotor speed, and memory, yet all of these upper bound estimates are based on studies in epilepsy patients often presenting with premorbid neuropsychological deficits. TF's dosage of 300 mg of Dilantin per day for a male Caucasian patient of 5′ 8″ in height and moderate build weighing 160 pounds is a very low maintenance dosage of 4 mg/kg/day.

TF was referred for a non-contrast enhanced CT immediately after his accident (see Figure 1) and repeatedly during his lengthy stay in the acute care setting. The scan closest to the first assessment revealed a very large subacute intracerebral haemorrhage within the right mid-frontal lobe. An associated mass effect was present with obliteration of the anterior horn of the right lateral ventricle. There was substantial subfalcine tentorial herniation to the left. The hemorrhage was reported to be heterogeneous in density and there was a moderate amount of surrounding vasogenic edema to the extent that the sulci in the right frontal lobe were completely effaced. In addition there was some hemorrhagic and non-hemorrhagic parenchymal contusion in the inferior left frontal lobe just above the gyrus rectus, although this was substantially less significant. The vasogenic edema in the right frontal cortex extended up to the mid-frontal lobe under both superior and middle frontal gyri. The second region of non-hemorrhagic contusion in the left mid-frontal lobe was adjacent to the falx just under the superior frontal gyrus. Subsequent CTs revealed substantial resorption of the hemorrhage; however there was no note as to whether there were any lasting necrotic changes, ischemia or residualized hemmorhaging. At no time did TF, past the acute phase, undergo an MRI when evidence of more subtle and lasting necrotic changes might have become evident.

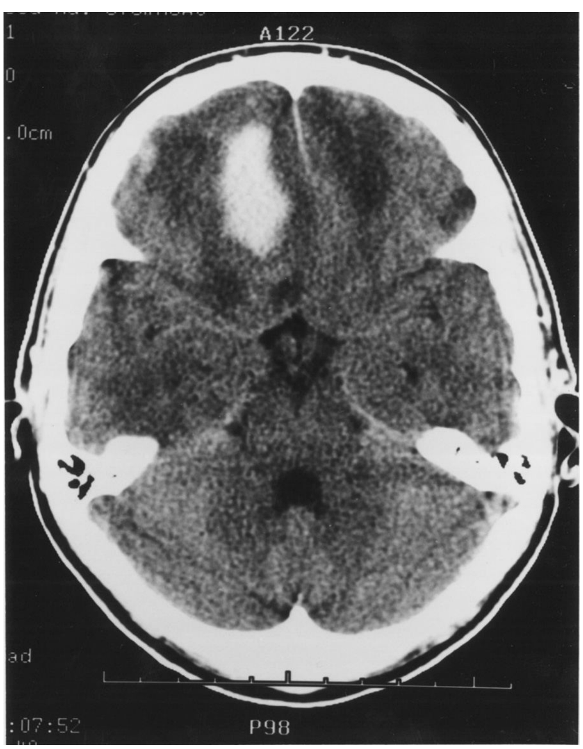

Figure 1. Axial CT image of TF's brain depicting a focal large intracerebral haemorrhage measuring 5.5 × 2.3 × 3.5 cm identified within the right mid-frontal lobe. Left is right and right is left, according to neuroradiological convention.

ASSESSMENT RESULTS AND DISCUSSION

At the initial assessment at 2 weeks post-injury TF demonstrated lower than expected scores on Planned Connections and Expressive Attention, which were found to be due to errors rather than psychomotor speed slowing per se. On Planned Connections TF made two errors and was required to start over twice, whereas on Expressive Attention TF made 7 errors. TF's total reaction times were in the superior range for both of these attentional tapping tasks at the initial assessment. Relatedly, Dodrill (1991) found that when psychomotor speed was factored out no significant effects on any other cognitive domains were found in his study of epileptics on high dosages of seizure medications. In this context the motor speed tapping tasks of Matching Numbers, Planned Codes, Number Detection, and Receptive Attention were all in the unimpaired range at the time of the first CAS testing period, when TF was on 300 mg of Dilantin per day. These facts in conjunction with unimpaired performance on Digit Symbol at 6 months post-injury when TF was off Dilantin suggest that medication effects are not a likely account for the ipsatively measured significant discrepancies in performance in this previously neuropsychologically normal and healthy individual.

TF was additionally assessed with the CAS and the WAIS-R approximately 6 months post-injury. TF demonstrated some difficulties on the initial assessment in understanding complex instructions; however, his intact initiative, self-monitoring, and insight were evident in requests to start tasks over again. At 6 months post-injury family members reported that he demonstrated some residual difficulties in remembering daily tasks such as chores and planned events after his accident. It is reported by family members that TF never had any such cognitive difficulties before his accident.

Table 1 shows all assessment results. TF demonstrated significant initial impairment on the Planned Connections, Expressive Attention, and

Verbal-Spatial Relations subtests of the CAS[1] as revealed by sequential testing. Behaviorally, TF demonstrated clear perseveration on the initial Planned Connections subtest of the CAS suggestive of some loss of mental flexibility (D'Esposito, Alexander, Fischer, McGlichey-Berroth, & O'Connor, 1996). The impairment on the Expressive Attention subtest was expected because Vendrell, Junque, Pujol, Angeles Jurado, Molet, & Grafman (1995) found that right frontal lesions were most detrimental to performance on the Stroop task. TF made numerous errors on the Expressive Attention subtest; however, for both Planned Connections and Expressive Attention TF's times to complete the subtests were in the superior range for someone of his demographic.

The poorer performance on the Verbal-Spatial Relations subtest is more speculative. TF demonstrated a highly significant and atypical lack of improvement on this test on subsequent retesting, as well as a low initial score much below that typical for someone of his ability. Verbal-Spatial Relations is composed of 27 items that require the comprehension of grammatical and syntactical descriptions of spatial relationships depicted in accompanying sets of pictures and stimulus sentences. The Verbal-Spatial Relations subtest is timed and for each item 30 s is allotted. However, evidence from the standardization sample suggests that extra time in performance on this subtest does not significantly influence performance for examinees since subjects usually answer the questions within the time interval (Naglieri & Das, 1997). Moreover, the question can be repeated once and is provided both in written and oral spoken format so that amodal syntactic verbal comprehension is emphasized rather than reading or spoken language modalities of input. In this sense the Verbal-Spatial Relations subtest does not appear to be unduly influenced by time constraints. That is, the sentences are provided multimodally (e.g., pictorially, read orally by the examiner and provided at the bottom of the page for each item in the accompanying text) emphasizing verbal comprehension rather than reading or hearing, per se. In addition, TF demonstrated significant improvement on the Planning scale of the CAS indicative of some homogeneity of this scale in terms of measured cognitive functions assessed.

TF was administered the WAIS-R (Canadian version) at 6 months post-injury. Estimates of the magnitude of differences obtained by various percentages of the WAIS-R standardization sample between each subtest score and the average subtest score were calculated (Silverstein, 1984). TF demonstrated highly significant impairment on the Information, Vocabulary, Arithmetic, and Comprehension subtests of the verbal scale and the frequency of these occurrences in the WAIS-R standardization sample was less then 1% for each of these four subtests. Recall that Information subtest represents an attempt to sample an examinee's fund of general knowledge acquired through academic exposure.

For TF, Information was his second lowest score on the WAIS-R. An analysis of items scored correctly before the ceiling was reached showed that TF often used circumlocutions to describe nouns with frequent pauses raising the possibility of a residualized anomic aphasia that is rarely localizable (Basso & Cubelli, 1999, p. 190) or a specific difficulty in activating retrieval mechanisms to access specific bits of information (Kaplan, Fein, Morris, & Delis, 1991, p. 76). Familial informants and the patient himself reported no problems in school whatsoever and, in fact, he was described as an "excellent student" with grade 12 matriculation with 2 years of post-secondary trade-school training. The latter required specific advanced mechanical aptitude, mathematical, and journeyman training. Based on these reliable informants' reports there is no reason to conclude that TF had (i) premorbid inadequate educational opportunities, (ii) any prior learning disability, (iii) exhibited effort or response bias problems, or (iv) low level of general ability.

On the Vocabulary subtest TF often produced adequate descriptions. However, like with the Information subtest, he used excessive numbers of circumlocutions by giving properties and functions of the object in question without using more exact

[1]The sample control group consisted of 32 brain-lesioned patients of mean age 46 years ($SD = 13$); male = 23, female = 9; mean educational level = 12 years ($SD = 3$); and handedness: left = 8, right = 24. Previous analysis demonstrated no significant differences in these demographic variables on subtest T-scores at the aggregate sample level (McCrea, 2006). The localizing patterns of performance with specific lesions in this initial study along with the finding of minimal to negligible practice effects on the CAS beyond 3-month retesting intervals (Naglieri & Das, 1997) suggests that this sample is suitable for qualitative comparative purposes with the WAIS-R as a means of examining convergent validity at the single case level (Yin, 1994).

Table 1. *Assessment Results*

Cognitive Assessment System (CAS) Subtest Scores	**T1**	**T2**	**T2 – T1**	**Ipsative Score**	**Probability (T-Scores)**
Matching Numbers	58	69	11		*ns*
Planned Codes	56	71	15		*ns*
Planned Connections	53	74	21	$z = 2.1$	$p < 0.05$
Expressive Attention	45	63	18	$z = 1.8$	$p < 0.05$
Number Detection	62	73	11		*ns*
Receptive Attention	65	67	2		*ns*
Non-Verbal Matrices	55	65	10		*ns*
Verbal-Spatial Relations	48	46	-2 ($T2_x - T2$)	$z = 1.7$	$p < 0.05$
Figure Memory	58	63	5		*ns*
Word Series	50	50	0		*ns*
Sentence Repetition	56	56	0		*ns*
Sentence Questions	54	57	3		*ns*
Mean Subtest Score	55	63	8		*ns*

Cognitive Assessment System (CAS) Composite Scale Scores

CAS Composite Scale	**T1**	**T2**	**T2 – T1**	**Ipsative Score**	**Probability**
Planning	55	72	15	$z = 1.7$	$p < 0.05$
Attention	57	68	11	–	*ns*
Simultaneous	54	58	4	–	*ns*
Successive	53	54	1	–	*ns*
Mean	55	63	8	–	*ns*

WAIS-R Subtest Scores

Percentage of Sample	**(Age Scaled Scores) Difference**	**Ipsative Score**	***z*-score**	**WAIS-R**
Information	6	8	$z = 2.67$	<1
Digit Span	10	-4		*ns*
Vocabulary	8	-6	$z = 2.00$	<1
Arithmetic	5	-9	$z = 3.00$	<1
Comprehension	8	-6	$z = 2.00$	<1
Similarities	13	-1		*ns*
Picture Completion	11	-3		*ns*
Picture Arrangement	11	-3		*ns*
Block Design	15	$+1$		*ns*
Object Assembly	13	-1		*ns*
Digit Symbol	10	-4		*ns*
Premorbid Ability Estimate	14			

WAIS-R Composite Scale Scores

	VIQ = 90, 25th percentile	**PIQ = 114, 82nd Percentile**
VIQ	–	–
PIQ	24, $<5\%$	–
Premorbid FSIQ = 119, 90th percentile	29, $<5\%$	4, *ns*

nouns and verbs in the phrases. TF used overly general words like "*something*" on almost every one of the items attempted, which is a marker for a residualized and moderately severe anomia (Kaplan et al., 1991, p. 85). However, this impairment on retrieving specific information did not appear to result from confabulation since TF was able to circumspectfully describe the target concept or word in a roundabout way and he was completely and properly orientated to person, place, time, and situation at both testing sessions (e.g., see Schnider & Gutbrod, 1999 for a description of posttraumatic amnesia and confabulation associated with orbitofrontal damage). Although it is clear that TF had some degree of anterograde posttraumatic amnesia related to the half-hour immediately following his accident, the fact that he was unable to retrieve distant and remote specific bits of information does not lend to an explanation of a variable graded retrograde amnesia since he used circumlocution to unambiguously describe the objects in question in accordance with a residual anomia. Moreover, unlike confabulatory amnesia, TF's focal lesion was in the dorsal aspect of the right frontal lobe and did not involve the corticothalamic pathways, orbital regions, or the temporal lobe (Schnider & Gutbrod, 1999).

On the Comprehension subtest there was evidence that he did not pay adequate attention to the cue questions. For instance, on item 10 it did not appear that he retained part of the cue sentence phrase "*in the daytime*" for on this item he answered "*look at the sun, moon and the stars*" (Kaplan et al., 1991, p. 98). TF answered one of the most difficult items (16) of Comprehension correctly, yet incorrectly answered items that were relatively simple (e.g., items 4, 7, and 8). In other words, his verbal attention seemed to be fluctuating. Difficult proverb items 14 and 15 were responded to with "*don't know*" despite evidence of obvious adequate premorbid intelligence (see below) to understand proverbs, suggesting some possible impairment in understanding metaphorical speech. Patients with right frontal lesions are particularly apt to be impaired on proverbs (Benton, 1968).

TF was most severely impaired on the Arithmetic subtest. He answered basic calculation questions accurately (e.g., items 1–4); however, answers requiring multi-step operations and calculation tapping mental control were answered incorrectly. TF responded to item 9 of the Arithmetic subtest with an answer of $11.50, which may be considered a marker for impulsivity (Kaplan et al., 1991, p. 94). On the basis of mathematical coursework that he had completed at the post-secondary level as well as excellent performance in high school math, there is no reason to conclude that he had a prior premorbid mathematical learning disability. Deloche and Seron (1982) and Seron and Deloche (1983) found that aphasia and acalculia have a high degree of concordance; these investigators concluded that these cormorbidities result from damage to a shared linguistic component. This high comorbidity between language disorders and acalculia was further examined in a large sample of right and left hemisphere patients administered comprehensive acalculia and aphasia batteries (Basso, Burgio, & Caporali, 2000). Over 50 percent of Wernicke's and Broca's aphasics were acalculic, while only 12% of right hemisphere-lesioned patients were.

TF's scores on the Performance scale subtests were all within the normal range, whereas 4 of 6 Verbal subtests were in the impaired range. The pattern of errors and scores on these four subtests is readily interpretable in terms of damage consequent to a large right medial prefrontal cortex lesion. Digit span is usually considered a measure of immediate auditory memory and is considered to be subserved by left posterior perisylvian regions (Black & Strub, 1978). TF had no evidence of damage to either the left or right posterior perisylvian regions and he performed normally on Digit Span, with evidence of residualized anomia, acalculia, impairment on proverbs, lapsing verbal attention, and impairment in verbal retrieval of information. It is possible that TF is either right-hemisphere dominant for language and praxis (given his strong left-handedness) or much more likely he has some degree of bilateral representation of linguistic functions in both hemispheres.

The fact that TF's Performance scale subtests are all in the normal range could possibly suggest reversed asymmetry given that his Block Design performance was higher than expected, although opinion varies as to whether there is complete reversal of functions (e.g., spatial functions to LH and language functions to RH) in such cases. The literature suggests that rather than complete asymmetry for some subjects the right hemisphere has acquired some degree linguistic functions while retaining its dominance for spatial skills leading to the "crowding hypothesis" sometimes manifested as visuospatial neglect and/or constructional apraxia in an unspecified proportion of subjects (Cappa & Vignolo, 1999, p. 168). On the contrary, Chee and Caplan (2002) provided only weak support for the crowding hypothesis in three completely right hemisphere–language dominant healthy normal dextrals of high ability.

The size of the WAIS-R Verbal-Performance IQ discrepancy required (regardless of direction to be abnormal) at various levels of occurrence in the normal population by modal IQ category was found using Kaufman's (1990) tabled values. TF's Verbal IQ of 90 was significantly less than his Performance IQ of 114. Less than 5% of the WAIS-R standardization sample demonstrated a VIQ-PIQ difference of 24 points of magnitude (Grossman, 1983). TF's estimated premorbid Full-Scale IQ of 119 was also significantly greater than his actual measured Verbal IQ of 90. Again, less than 5% of the WAIS-R standardization sample had a FSIQ/VIQ difference of this magnitude. This PIQ > VIQ differential contrasts with Hawkins, Plehn, and Borgaro's (2002) comprehensive study of performance of traumatic brain injury patients on the WAIS-R. In a meta-analytic review of three studies of total sample size equal to 119 subjects of mean GCS = 9.4 ($SD = 1.2$) tested on average 6 weeks post-injury the Verbal IQ was larger than the PIQ – [VIQ mean = 84, $SD = 5$; PIQ mean = 80, $SD = 2$; VIQ – PIQ = 4, $SD = 3$]. TF's poor VIQ of 90 was within this range; however, his PIQ far surpassed this sample that was tested 4 months earlier than him.

Estimates of Premorbid Functioning

TF is a complex case for the calculation of premorbid ability. An estimate of his premorbid ability was undertaken using the Barona Index (Barona, Reynolds, & Chastian, 1984) and was calculated as an FSIQ = 108. TF's actual Full-Scale IQ at 6 months post-injury was 111, with a Verbal IQ score of 90 and Performance IQ score of 114. Thus it is possible that the lower bound mean estimate of 108 is lower than the actual "high score method" value of a PIQ of 114. Thus the PIQ may provide a better estimate of TF's "true" premorbid ability level especially since demographic estimates underestimate true scores in the higher ability spectrum (Lezak, 1995).

TF's performance at ceiling on the Non-Verbal Matrices subtest (raw score = 30/33: last three most difficult items correct) at 6 months post-injury is also a marker for a higher level of premorbid ability than anticipated based on either the demographic or actual measurements using the WAIS-R. In essence, TF's upper level of general ability on this subtest without any time limits was not able to be determined since he performed at ceiling. There are negligible practice effects on Non-Verbal Matrices past 3 month test/retest intervals (Naglieri & Das, 1997). The Non-Verbal Matrices' most similar predecessor is the Raven's Coloured Progressive Matrices (RCPM), which is highly correlated [$r > 0.70$] with WAIS-R FSIQ scores (O'Leary, Rusch, & Guastello, 1991) and is considered the best culture-free measure of general ability or Spearman's g (Llabre, 1984) available.

TF scored at a scaled score of 15 within the superior range on Block Design at 6 months post-injury. TF's score on the last and most difficult item of Block Design was again also at near ceiling. TF similarly scored in the high average range on Similarities and 3 out of 4 of his errors were on lower-level items [1, 2, 8] of this 14-item subtest and the last three items were scored correctly. Thus TF scored high on the Similarities subtest like the Non-Verbal Matrices and Block Design. Since Similarities tends to be more sensitive than most other Verbal subtests to the effects of brain damage (irrespective of lesion localization), his high score on this test implies that, like his Block Design subtest score, there are clear indicators for higher than anticipated premorbid ability compared to demographic, hold subtest algorithms, and/or composite scale scores (c.f., Hirchenfang, 1960).

Lezak (1995) additionally suggests that for some individual patients Similarities is actually a better indicator of premorbid ability than Vocabulary (p. 606). Warrington, James, and Maciejewski (1986) found that Similarities was the best indicator of left hemisphere disease in the WAIS battery and Rzechorzek (1979) found that left frontal patients scored lower on this subtest than those patients with right anterior lesions. In the context of TF's left-handedness, which is a marker for more bilateral representation of language in men (Heilman & Valenstein, 2003), his scaled score of 13 is likely a lower bound premorbid ability estimate for this high score on the Verbal scale. TF's responses to Similarities items 1 (orange/banana: peels) and item 2 (dog/lion: fur coats) imply an attention bias toward superficial detail and/or a lack of self-monitoring. Adding these three basal items (with the safe assumption that TF knew them) would provide him with a scaled score of 16 on Similarities. Since Similarities and Block Design are among those subtests revealing the highest correlations with FSIQ (Lezak, 1995), prorating these two scales would provide for mean scaled score of 15 with an estimated FSIQ of 124 (Spreen & Strauss, 1998, p. 107). This is equivalent to a percentile rank of 95 within the superior range of performance on the WAIS-R and would be a conservative lower bound estimate of his premorbid FSIQ.

CONCLUSION

In summary, the CAS and WAIS-R profiles provide some degree of differential assessment of cognitive domains as well as theoretical concordance in the expected pattern of results across the two tests. This concordance is congruent with known patterns of performance on the WAIS-R with specific brain lesions (e.g., Kaplan et al., 1991), as well as with analogs of CAS subtests discussed herein and previously published in the neuropsychological literature. The findings also highlight the unique and different domains of cognitive functioning covered by these two instruments and perhaps point toward the use of specific CAS subtests in neuropsychological assessment in the context of serial assessments of brain injury.

ACKNOWLEDGMENTS

A Social Sciences and Humanities Research Council of Canada (SSHRC) grant #752-2000-1344 and National Sciences and Engineering Research Council of Canada (NSERC) grant #241750 supported this research. This project was approved by the institutional ethical review committee of the University of Alberta Hospital and was conducted in accordance with the Declaration of Helsinki.

REFERENCES

Barona, A., Reynolds, C. R., & Chastain, R. (1984). A demographically based index of pre-morbid intelligence for the WAIS-R. *Journal of Consulting and Clinical Psychology*, *52*, 885–887.

Basso, A., Burgio, F., & Caporali, A. (2000). Acalculia, aphasia, and spatial disorders in left and right brain-damaged patients. *Cortex*, *36*, 265–280.

Basso, A., & Cubelli, R. (1999). Clinical aspects of aphasia. In G. Denes & L. Pizzamiglio (Eds.), *Handbook of clinical and experimental neuropsychology* (pp. 181–193). East Sussex, UK: Psychology Press.

Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. *Neuropsychologia*, *6*, 53–60.

Black, F. W., & Strub, R. L. (1978). Digit repetition performance in patients with focal brain damage. *Cortex*, *14*, 12–21.

Cappa, S. F., & Vignolo, L. A. (1999). The neurological foundations of language. In G. Denes & L. Pizzamiglio (Eds.), *Handbook of clinical and experimental neuropsychology* (pp. 155–179). East Sussex, UK: Psychology Press.

Chee, M. W. L., & Caplan, D. (2002). Face encoding and psychometric testing in healthy dextrals with right hemisphere language. *Neurology*, *59*, 1928–1934.

Deloche, G., & Seron, X. (1982). From three to 3: A differential analysis of skills in transcoding quantities between patients with Broca's and Wernicke's aphasia. *Brain*, *105*, 719–733.

Dodrill, C. B. (1991). Effects of antiepileptic drugs on psychological abilities. In J. K. Penry (Ed.), *Epilepsy and life performance*. New York: Raven Press.

D'Esposito, M., Alexander, M. P., Fischer, R., McGlichey-Berroth, R., & O'Connor, M. (1996). Recovery of memory and executive function following anterior communicating artery rupture. *Journal of the International Neuropsychological Society*, *2*, 565–570.

Grossman, F. M. (1983). Percentage of the WAIS-R standardization sample obtaining verbal-performance discrepancies. *Journal of Clinical and Consulting Psychology*, *51*, 641–642.

Gutentag, S., Naglieri, J. A., & Yeates, K. (1998). Performance of children with traumatic brain injury on the Cognitive Assessment System. *Assessment*, *5*, 263–272.

Hawkins, K. A., Plehn, K., & Borgaro, S. (2002). Verbal IQ-performance IQ differentials in traumatic brain injury samples. *Archives of Clinical Neuropsychology*, *17*, 49–56.

Heilman, K., & Valenstein, E. (2003). *Clinical neuropsychology* (4th ed.). New York: Oxford University Press.

Hirchenfang, S. (1960). A comparison of WAIS scores of hemiplegic patients with and without aphasia. *Journal of Clinical Psychology*, *16*, 351–352.

Kaplan, E., Fein, D., Morris, R., & Delis, D. C. (1991). *WAIS-R as a neuropsychological instrument*. San Antonio, TX: The Psychological Corporation.

Kaufman, A. S. (1990). *Assessing adolescent and adult intelligence*. Boston: Allyn & Bacon.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Llabre, M. M. (1984). Standard progressive matrices. In D. J. Keyser & R. C. Sweetland (Eds.), *Test Critiques* (Volume 1, pp. 595–602). Missouri: Test Corporation of America.

McCrea, S. M., & Scott, M. (2002). A case study of strategic infarct dementia investigated with the Cognitive Assessment System. *Brain and Cognition*, *49*, 207–210.

McCrea, S. M. (2006). A nonparametric study of the performance of cortical lesion patients on the Cognitive Assessment System. *Archives of Clinical Neuropsychology*, *21*, 321–325.

Nagleri, J. A., & Das, J. P. (1997). *Cognitive assessment system*. Itasca, IL: Riverside Publishing.

Naglieri, J. A., & Paolitto, A. W. (2005). Ipsative comparisons of WISC-IV index scores. *Applied Neuropsychology*, *12*, 208–211.

O'Leary, U. M., Rusch, K. M., & Guastello, S. J. (1991). Estimating age-stratified WAIS-R IQs from scores on the Raven's Standard Progressive Matrices. *Journal of Clinical Psychology*, *47*, 277–284.

Rzechorzek, A. (1979). Cognitive dysfunctions resulting from unilateral frontal lobe lesions in man. In M. Molloy, G. V. Stanley, & K. W. Walsh (Eds.), *Brain Impairment: Proceedings of the 1978 Brain Impairment Workshop*. Melbourne: University of Melbourne.

Schnider, A., & Gutbrod, K. (1999). Traumatic brain injury. In B. L. Miller & J. L. Cummings (Eds.), *The human frontal lobes: Functions and disorders* (pp. 487–506). New York: The Guilford Press.

Seron, X., & Deloche, G. (1983). From 4 to four: A supplement to "From three to 3." *Brain*, *106*, 735–744.
Silverstein, A. B. (1984). Pattern analysis: The question of abnormality. *Journal of Consulting and Clinical Psychology*, *52*, 936–939.
Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests* (2nd ed.). New York: Oxford University Press.
Stein, R. A., & Strickland, T. L. (1998). A review of the neuropsychological effects of commonly used prescription medications. *Archives of Clinical Neuropsychology*, *13*, 259–284.
Vendrell, P., Junque, C., Pujol, J., Angeles Jurado, M., Molet, J., & Grafman, J. (1995). The role of the prefrontal regions in the Stroop task. *Neuropsychologia*, *33*, 341–352.
Warrington, E. K., James, M., & Maciejewski, C. (1986). The WAIS as a lateralizing and localizing diagnostic instrument. *Neuropsychologia*, *24*, 223–239.
Wechsler, D. (1981). *Wechsler Adult Intelligence Scale–Revised*. New York: The Psychological Corporation.
Yin, R. K. (1994). *Case study research: Design and methods* (2nd ed.). Thousand Oaks, CA: Sage.