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A COGNITIVE NEUROPSYCHOLOGICAL EXAMINATION OF THE DAS-NAGLIERI COGNITIVE ASSESSMENT SYSTEM SUBTESTS: A REPORT OF THREE STROKE CASES STUDIED LONGITUDINALLY DURING RECOVERY

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In this study three patients with unilateral focalized stroke lesions were examined longitudinally on the CAS subtests at 1 month and 6 months postinfarct such that each patient functioned as baseline. Patient 1 with a left temporal pole lesion had a severe syntactic comprehension deficit on Sentence Questions. Patient 2 had a rare right anterior cerebral artery (ACA) aneurysm culminating in a

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classical orbitofrontal syndrome and impairments on Expressive Attention, Word Series as well as a previously undescribed *praxis-based figure ground reversal* phenomenon on Figure Memory. Patient 3 suffered a right frontoparietal lesion with resulting representational as well as elements of motor neglect and impairments on Matching Numbers, Number Detection, and Receptive Attention. The three patient's lesions were all entirely consistent with the nature of cognitive neuropsychological symptoms suggesting that the CAS subtests are not only unique but also sensitive and specific to focalized cortical lesions.

Keywords functional recovery, orbitofrontal syndrome, praxis-based figure ground reversal, representational and motor neglect, stroke lesions, syntactic comprehension

The Cognitive Assessment System is an individually administered test of cognitive abilities for ages five to adult (Naglieri & Das, 1997). This test was standardized on a stratified random sample of 2,200 individuals that were selected to approximate U.S. census data. Classical planning or executive function tasks such as the Tower of Hanoi, Tower of London, Wisconsin Card Sorting Test, Visual Search, Verbal Fluency, and Matching Familiar Figures tests are increasingly being used to study planning abilities in children and adults (Ardila, Pineda, & Roselli, 2000).These authors noted that the Wisconsin Card Sorting Test, letter and category fluency, and the Trail-Making Test generally correlated very poorly with conventional psychometrically measured intelligence as measure by the Wechsler Intelligence Scales. These results suggest that conventional intelligence tests do not appropriately evaluate executive functions, which are arguably the important nonfactorial-derived element of purposeful or intelligent behavior. The planning tasks incorporated on the Cognitive Assessment System have been included to remedy these inadequacies of traditional assessment batteries.

Planning and attention are sometimes grouped under the umbrella term, executive functions, and owing to the extensive reciprocal connectivity between frontal and subcortical regions, the strict dichotomization between these two processes could be problematic (Lyon & Krasnegor, 1996). Others, notably Tupper (1999), have found that the conception of planning as viewed by Das and colleagues may be too limited in that *perspective-taking* and *affective regulatory* aspects central to understanding metacognitive processes are not addressed. However, the focus of this review and series of case studies is to examine the purported neuropsychological properties of the CAS subtests in the context of several unique and rare syndromes. In this study three patients were tested for a median of 1-month poststroke and 6 months poststroke on the Cognitive Assessment System (Naglieri & Das, 1997), such that each subject functioned as their own baseline since there are negligible practice effects on CAS subtests past 3 months.

In their review of neuropsychological recovery following stroke Meirer and Strauman (1991) note that assessment of stroke patients in the postacute phase is not at all without precedence in neuropsychology, since the core features of a specific lesion may be more telling than after functional reorganization has had time to occur. Determinants of stroke outcome include: (i) the localization and extent of the lesion, (ii) age, (iii) time since stroke, (iv) premorbid functioning, (v) cerebral dominance or laterality of language, and (vi) demographic factors (Shuaib & Goldstein, 1999, p. 223). With the single-case study design in which each subject functions as his or her own baseline, many of these key determinants can be properly addressed and controlled. Insofar as functional organization is concerned, the single-case design is superior to that of the group design (Robertson, Knight, Rafal, & Shimamura, 1993; Yin, 1994). Moreover, Lezak (1995, p. 116) has noted that most of the recovery following cerebral infarct occurs spontaneously within the first 6 months of recovery. In this study difference scores, strategy checklists in conjunction with observed qualitative aspects of performance on individual CAS subtests, was used to illustrate the sensitivity and specificity of select CAS subtests. A comprehensive review of the neuropsychological characteristics of tasks similar to those included within the CAS is undertaken first in order to gauge the parameters by which lesion foci might be expected to covary on the basis patterns of performance on subtests.

MATCHING NUMBERS

Matching Numbers is similar (Teuber, Battersby, & Bender, 1951) to visual search tasks in which a subject was to look for a target amidst distracters. Teuber's version involved the presentation of an array of 48 patterns distributed irregularly over a screen within the patient's field of view. Immediately after the appearance of the duplicate test pattern the patient searched for the target object that matched the one on the screen and the person was timed for each search period. These early studies demonstrated reduced speed and efficiency in searching, implying a strategic implementation deficiency, which was especially pronounced after frontal lobe injury. Although Matching Numbers shares the visual search component with Teuber's task, there are important differences between these two tasks. Matching Numbers was created to require the implementation of any number of qualitative strategies for optimal efficiency of completion (Naglieri & Das, 1997) and it also places working memory demands on more difficult items.

Lesions within the right inferior frontal gyrus have been shown to be especially deleterious to performance on such visual search tasks (Binder, Marshall, Lazar, Benjamin, & Mohr, 1992). Husain and Kennard (1997) found that as the number of distracters increased so did the impairment in visual search selectively for a patient with a right frontal lesion as compared with a right frontoparietal infarction. These results imply that parietal lesions degrade the representation of space *per se* in such tasks whereas frontal-lesioned patients may be more prone to manifest elements of motor neglect when the processing burden posed by distracters is high.

Aside from the visual search element of Matching Numbers there is also a mental tracking component. Mental tracking typically involves elements of perceptual tracking, complex mental operations (e.g., remembering the first and last digit of a long series of sequences of numbers) as well as scanning (Lezak, 1995, p. 366). These are all salient aspects of Matching Numbers and these covert mental processes are sometimes referred to as divided or shifting attention tasks. The classic example of such tasks is the reversed span task of the Wechsler Digit Span Backwards. Black (1986) found that left hemisphere patients performed a full point behind right hemisphere patients in a large sample of brain-damaged patients' performance on the Digit Span Backwards task. Leskelae et al. (1999) found significantly poorer performance on Digit Span Backwards in frontal patients compared with nonfrontal patients.

In Gutentag, Naglieri, and Yeates (1998) study Matching Numbers successfully discriminated between demographically matched control and traumatically brain-injured children with anterior pathology (Levin et al., 1989). Matching Numbers also discriminated between a nondemented demographically matched control patient and a right-handed 65-year-old-male vascular dementia patient with an aneurysmal infarct in the left frontal lobe (McCrea & Scott, 2002). Finally, McCrea (2001, 2006) found that Matching Numbers was more sensitive to right hemisphere as opposed to left hemisphere lesions. Collectively these results suggest a distributed dorsal network comprising bilateral frontal eye fields and posterior parietal networks with bilateral, dorsolateral, and prefrontal involvement for more difficult items (Schall, 2004).

PLANNED CODES

Planned Codes is similar to the Wechsler Digit Symbol (DS) subtest (Wechsler, 1981). However, the former unequivocally requires the implementation of strategies (Haddad, 2004). Planned Codes is also analogous to the Symbol Digit Modalities Test (Smith, 1991) and Shum, McFarland, and Bain (1990) found that SDMT was highly correlated with other tests of visuomotor tracking including the Trail Making Test. However, DS and SDMT differ in cues to spatial location contained in the key because in DS the keyed items are arranged numerically whereas in the SDMT the sequence of stimulus symbols are random (Glosser, Butters, & Kaplan, 1977). Therefore SDMT requires greater spatial allocation resources and Planned Codes is more similar to DS, since in both subtests the symbols are arranged sequentially.

Implementation of strategies in Planned Codes would expect to confer upon it greater sensitivity to anterior lesions (Shallice & Burgess, 1991). Among the differences between the Wechsler DS subtest and Planned Codes are that in the former the key contains nonverbal symbols whereas in the latter the response key contains letters implying perhaps more amenability to verbalization in Planned Codes. The SDMT has also been found to be exceptional at detecting dementia in which there are prominent global declines and pervasive memory impairments (Pfeffer et al., 1981; Knopman & Ryberg, 1989). Another significant individual difference variable associated with symbol substitution type tasks is that women reliably outperform men on such tasks (e.g., Lezak, 1995, p. 380). Polubinski and Melamed (1986) demonstrated a main effect of sex on performance on the SDMT that was highly reliable ($p < 0.001$) and the interaction of sex and handedness was also significant ($p < 0.01$).

Schear and Sato (1989) found that Finger Tapping and the Grooved Pegboard predicted unique variance in the Digit Symbol subtest, suggesting that motor speed and dexterity are significant components of Planned Codes. The only definitive effects of focal lesions on tasks similar to the Planned Codes subtest have been those neurodegenerative diseases associated with the basal ganglia. Performance on the Symbol Digit Modalities Test has been found to be significantly associated with neurodegeneration in the caudate in Huntington's disease (Starkstein et al., 1988; Sanchez-Pernaute et al., 2000) as well as with pathological symptoms associated with the substantia nigra in Parkinson's disease (Starkstein, Bolduc, Preziosi, & Robinson, 1989).

Gutentag (1998) found that Planned Codes demonstrated the most pronounced decrements in performance in the TBI child sample. Ryan, Atkinson, and Dunham (2004) found that Planned Codes was successful in measuring executive function in a large mixed-sex sample of mean age 20. Finally, Haddad (2004) found that Planned Codes definitively requires the use of any number of strategies to perform optimally and that therefore this subtest probably measures planning. These findings are largely consistent with the hypothesis that the motor, dexterity, and strategy requirements of Planned Codes tap networks involving subcortical motor planning and action sequencing instantiated by the basal ganglia (Graybiel, 1998).

PLANNED CONNECTIONS

Planned Connections is modeled on the Trail-Making Test (TMT). The main differences between the TMT and Planned Connections are that the graduated level of difficulty of items in the latter (e.g., low floor and high ceilings) makes it well-suited for use in younger children (Gutentag et al., 1998) or perhaps older brain-damaged adults. Older examinees typically use complex strategies such as repeating the alphabet-number sequences covertly and these types of strategies were not generally used by young children (Naglieri & Das, 1997, p. 86). The TMT is a marker neuropsychological test for executive functions and planning and it is among comprises among the most common such neuropsychological tests used in clinical practice (Lezak, 1995; Spreen & Strauss, 1998).

Crowe (1998) factor-analyzed TMT Part A and found that it was predicted by visual search and motor speed; whereas Part B was predicted by visual search and set shifting. Lafleche and Albert (1995) found the TMT to be highly discriminating of mild Alzheimer's disease compared to matched healthy controls. Another dementia study in which the TMT was used found that 67% of Alzheimer's patients' errors were related to an inhibitory deficit, whereas normal elderly adults had only 24% errors of an inhibitory nature, which is a performance pattern that was more obvious on Part B (Amieva et al., 1998). The TMT has also been found to be discriminating of patients with cerebrovascular or Alzheimer's disease (Barr, Benedict, Tune, & Brandt, 1992).

Rasmusson, Zonderman, Kawas, and Resnick (1998) found that Part B accounted for a significant proportion of variance in dementia scores in a large unselected sample of elderly people after statistical correction for age, education, and gender. The TMT is ineffective in lateralizing lesions (Heilbronner, Henry, Buck, Adams, & Fogle, 1991); although it is good at diagnosing diffuse brain damage (Lezak, 1995). Starkstein et al. (1988) suggested that caudate lesions in Huntington's disease result in impairments on the TMT and Alegret et al. (2000) found that dopaminergic agonists administered to Parkinson's disease patients enhanced performance on TMT: B. The reverse pattern was found after pallidotomy, implying a complex interrelationship between pallidal integrity, dopaminergic tone, and executive function for performance on Part B's set shifting.

Johnstone, Leach, Hickey, Frank, and Rupright (1995) found that frontal lobe traumatic brain injury patients tested several years after injury manifested a significant impairment on TMT: B compared to demographically matched control subjects. Finally, D'Esposito, Alexander, Fischer, McGlichey-Berroth, and O'Connor (1996) found that recovery of performance on Part B was significant at 4 months postinjury and that patients with bilateral medial frontal lesions involving the anterior cingulate were most impaired. Planned Connections was one of four subtests of the CAS distinguishing between children with TBI compared to controls (Gutentag et al., 1998). These findings could imply that the task switching between sets in Planned Connections broadly involves corticostriatal loops with the caudate, the dorsolateral prefrontal cortex, and anterior cingulate in conjunction with dopaminergic tone modulated from midbrain projections (Poldrack & Willingham, 2006, p. 137).

EXPRESSIVE ATTENTION

Expressive Attention is similar to Stroop's (1935) original version of the task. Although only item 6 of Expressive Attention is used for scoring purposes, item 4 (word reading time) and item 5 (color naming time) can provide examiners with potentially useful information about the speed of lexical access or mental speed. Therefore examiners should carefully time and observe errors on all three aspects of this subtest. Indeed Spreen and Strauss (1998, p. 214) note that the two initial neutral conditions of word reading and color naming time administered before the interference condition can be used to tease apart motor slowing from genuine cognitive dysfunction.

Wingfield, Goodglass, and Lindfield (1997) noted the case of a primary progressive aphasic subsequent to posterior cortical atrophy whose speed of reading was no faster than his speed of naming but who still demonstrated the Stroop effects. This experiment challenged the identification of automaticity with processing speed. Instead, this finding is congruent with an account based on slowing of this patient's phonological access via the written word (encoding) without weakening the connection strength between semantic associations, such that the interference effect is still observed. Other studies, notably Perret's (1974) widely cited initial finding of performance sensitivity of the Stroop to left frontal lesions has been recently disputed.

In the largest study of its kind Vendrell et al. (1995) found that patients with lesions in the right anterior cingulate performed significantly poorer than patients without these lesions in naming time and in the interference Stroop condition. Patients with right lateral lesions similarly made more errors than patients without such lesions but who still sustained frontal lesions. Patients with left frontal lobectomies performed normally on naming time, the interference condition, and the number of errors compared to controls. It is important to mention that only 71% of patients with frontal lobe lesions performed normally on the Stroop, again reiterating the truism that each cognitive domain requires several different types of tests assessing that domain and that despite its utility—in isolation the Stroop cannot be considered a globally "frontal marker test."

Stuss (1991) found that patients with bilateral orbitofrontal lesions after lobotomy performed normally on the Stroop suggesting the importance of dorsal prefrontal cortex integrity as essential. Ahola, Vilkki, and Servo (1996) came to the same conclusion in a sample of patients with anterior communicating artery rupture who were unimpaired on the Stroop when damage was limited mainly to inferior medial aspects of the frontal lobes. An fMRI Stroop study found that performance activated the anterior cingulate, insula, premotor, and inferior frontal regions and that right hemisphere homologues had an earlier time-course of activation (Leung, Skudlarski, Gatenby, Peterson, and Gore, 2000). Finally, Khateb, Michel, Pegna, Landis, and Annoni (2000) corroborated this pattern of dominancy of the right anterior cingulate for performance on the Stroop using an EEG source localization and event-related potential study. Koss, Ober, Delis, and Friedland (1984) noted a sensitivity of the Stroop to early Alzheimer's disease although in severe cases the interference effect was completely attenuated and attributed to disinhibition and breakdown in the semantic network because of gross cortical atrophy. Finally, Hanes, Andrewes, Smith, and Pantelis (1996) showed that Stroop is sensitive to basal ganglia disease in Parkinson's patients.

NUMBER DETECTION

Number Detection is most similar to line cancellation tests devised by Diller, Ben-Yishay, and Gerstman (1974) to measure sustained attention, visual scanning, and visual neglect. Scoring on such tests can be based on speed, errors or false detections, and omissions for the whole page, or segregated by hemifields. The latter format can be used to quantify visual neglect by calculating the relative proportions of omissions in each hemifield by drawing an imaginary line down the center of the page. A consistent finding is that nonverbal shapes elicit greater inattention and patients with right parietal lesions often manifest left visual neglect on such tasks (Heilman, Watson, & Valenstein, 2003).

Binder, Marshall, Lazar, Benjamin, and Mohr, (1992) found that right frontal or basal ganglia lesions also could result in letter cancellation deficits with unimpaired line bisection due to a predominance of motor neglect rather than representational neglect (Heilman, Watson, & Valenstein, 2003). Della Sala, Laiacona, Spinnler, and Ubezio (1992) deconstructed the digit cancellation task into its cognitive processing components via task analysis and found three sequentially arranged sets of actions: (i) assigning a special salience to the two target digits leading to a privileged representation in a working memory buffer, (ii) scanning the sequence of digits line by line from top to bottom, and finally (iii), penciling out a target.

Analysis of error patterns was undertaken in Alzheimer's patients to infer at which steps the patients were failing the digit cancellation task. There was little impairment in the first step because false detections were relatively rare in this group of patients. An impairment of the second step in Alzheimer's patients—namely the perceptual decision while scanning—seemed to be the hallmark of Alzheimer's patients. Three distinct patterns were noted: (i) unsystematic within-line scanning in spite of the left-right reading procedure suggested by the examiner in practice trials, (ii) another was "looking without seeing" in which patients passively scanned such that perception did not trigger and pace cancellation or gaze shifting (omissions), and finally (iii) Alzheimer's patients were slow at making the discrimination decision.

Collectively then, these results are consistent with the hypothesis that poor cancellation test performance (or more generally, poor performance on divided attention tasks where rapid shifts in attentional resources are required) is mainly due to passive scanning and slowness in the perceptual decision. This hypothesis is corroborated by the similar error pattern of healthy controls when performance is speeded or frontal lobe patients performing the regular scanning task, namely, a greater proportion of omissions in both populations. The poor performance of Alzheimer's disease patients on the digit cancellation test is congruent with prominent deficits on divided attention tasks found by previous investigators (Baddeley, Logie, Bressi, Della Sala, & Spinnler, 1986). Finally, Number Detection was highly predictive of TBI in children in the Gutentag et al. (1998) study. Ryan, Atkinson and Dunham, (2004) successfully used Number Detection in a mixed sex sample of college students and McCrea (2006) found it to be especially sensitive to right anterior lesions. These results imply the importance of a right frontoparietal network as essential for such sustained attention and visual search tasks(Heilman & Valenstein, 2003).

RECEPTIVE ATTENTION

Receptive Attention is modeled on tasks developed by Posner and Mitchell (1967, p. 394), a paradigm in which subjects were required to classify pairs of stimuli [letters] either as the same or different by pressing the key of a tachistoscopic apparatus. Using this protocol, Posner and Mitchell found a consistent average difference in reaction time of 71 ms in favor of physical match as compared to lexical match. Error analysis of false detections for both physical and lexical match as well as separate total time and number correct scores for each of the physical and lexical match subtasks could potentially provide meaningful and useful neuropsychological information. Although separate tables for this type of analysis is not provided in the CAS *Administration and Scoring Manual*.

The lexical-physical identity match task paradigm was popularized in studies of hemispheric asymmetries using divided visual field presentation formats. Kok, van de Vijver, and Bouma (1985) found a right visual field (left hemisphere) advantage in terms of reaction time for lexical matches and a left visual field (right hemisphere) advantage for physical matches. Banich and Belger (1990) also used a divided visual field presentation of physical-lexical identity letter pairs of increasing difficulty. These investigators found that while coordination between hemispheres during simple physical identity task was detrimental to performance, parallel processing of the hemispheres becomes advantageous in more complex tasks such as lexical identity.

Cormier and Tomlinson-Keasey (1991) examined the specialization for letter-matching in children aged six to eight using a tachistoscopic presentation paradigm. These researchers found a constant left hemisphere advantage in reaction time for verbal stimuli in grades 1 and 2 and a small right hemisphere advantage for kindergartener's accuracy of letter matching. These findings provide definitive evidence for a developmental hierarchy in the changes in visual field advantages associated with single-letter and whole-word presentations. Such changes are suggestive of neuropsychological patterns of differential hemispheric advantages underlying reading subskills, most likely through mechanisms of (i) maturation of commissural fibers and (ii) differential hemispheric and age-specific callosal excitation and inhibitory processes (Kinsbourne, 1970).

Eviatar and Zaidel (1994) studied three commissurotomy patients performing these dual matching tasks, such that pairs of letters were presented either unilaterally or bilaterally. All patients could perform physical matches when presented unilaterally even when visual field and response hand were crossed. Cross hemisphere comparisons of letter identities was not possible for any patients and only one patient could cross hemisphere compare physical identities. McCrea (2006) found that Receptive Attention was sensitive to posterior lesions. Such studies imply that Receptive Attention could be useful in identifying neurodevelopmental disorders where there is a presumed to be abnormalities of the corpus callosum (Fischer, Ryan, & Dobyns, 1992). Pollman, Zaidel, and von Cramon (2003) found that physical and lexical match resulted in activation of: posterior superior temporal gyrus, superior frontal gyrus, left frontopolar cortex versus left fusiform gyrus, intraparietal sulcus, bilateral inferior frontal gyrus, and right frontopolar cortex; respectively, in an event-related fMRI study of Posner's classic task.

NONVERBAL MATRICES

Nonverbal Matrices is designed similarly to the Ravens Colored Progressive Matrices (Raven, 1965) on which basis Naglieri (1985) developed the Matrix Analogies Test with characteristic low floor and high ceiling level items across a broad range of difficulty. Like the Raven, Nonverbal Matrices progresses through groups of items involving: (i) gestalt completion of geometric patterns, (ii) spatial visualization, and (iii) reasoning by means of analogy. The Raven's tests were originally designed to be "culture-free" measures of intelligence and it is generally characterized as the quintessential test of fluid intelligence available (Spreen & Strauss, 1998). The first neuropsychological studies of this instrument found that Matrices were highly sensitive to neglect in the early stages of recovery after right hemisphere stroke and that such transitory deficits rapidly resolve within the first 6 months postinfarct (Campbell & Oxbury, 1976). Perhaps prophetic of current efforts to understand the integration of the dorsal and ventral streams in complex cognition (Kanwisher & Duncan, 2004; Robertson, 2004) early investigators attempted successfully to remediate deficiencies by placing Raven items along the vertical midline (Caltagirone, Gainotti, & Micelli, 1977).

Denes, Semeza, Stoppa, and Gradenigo (1978) compared the improvement of left hemisphere (LH) and right hemisphere (RH) stroke patients that were tested within a week of admission and 2 months after. The greatest single improvement was observed in the RH patients in Set B, while for the LH group greater improvement was found in Set A. The authors concluded that the Raven is a nonhomogenous test and that improvement in these cases is chiefly due to residual, perceptual, and cognitive capacities of the intact hemisphere. Villardita (1985) classified items as involving principles of sameness, symmetry, and analogy and group performance was compared on Set I (completion or sameness), Set II (symmetry or visualization), or Set III (analogical reasoning). RH patients performed poorer than LH nonaphasics on Set I; while LH aphasics scored significantly worse than LH non-aphasics and RH patients on Set II. On Set III RH patients performed significantly better on LH aphasics and nonaphasics.

This elegant and small sample-size study demonstrated that Set I is dependent on perceptual organization modules within the RH and that subjects appear to rely on linguistic mediation to solve items from Set II, since aphasics performed poorest on this set. Finally Set III was only sensitive to left-hemisphere damage suggesting a left hemisphere dominance in solving the most complex problems. These results are entirely compatible with Zaidel, Zaidel, and Sperry's (1981) assertion that only the left hemisphere is capable of benefiting from the opportunity for error correction via verbal mediation as witnessed in the performance of both comissurotomy and hemispherectomy patients on the Raven. Recently Prabhakaran, Smith, Desmond, Glover, and Gabrieli (1997) found bilateral frontal, left parietal, occipital, and temporal activation in response to solving analogical items. McCrea (2006) found that Nonverbal Matrices was especially sensitive to right anterior lesions in congruence with recent event-related fMRI studies showing that analogical items requires robust and selective activation of right rostral dorsolateral prefrontal cortex (Christoff et al., 2001; Kroger et al., 2002).

VERBAL-SPATIAL RELATIONS

Verbal-Spatial Relations is composed of 27 items that require the comprehension of grammatical description of spatial relationships depicted in accompanying sets of pictures and stimulus sentences. Verbal-Spatial Relations earliest predecessor would be the Token Test (De Renzi & Vignolo, 1962). Poeck and Hartje (1979) described a version of the Token Test administered in both the standard auditory presentation as well as using visual depiction of the cue sentence. Neuroanatomical studies of performance on the Token Tests have been conducted in stroke patients in conjunction with psycholinguistic correlates of syntactic comprehension yielding significant relationships (Naessar et al., 1987). In one such study patients with nine different forms of aphasia and heterogeneous lesions were tested on the Boston Diagnostic Aphasia Exam (Goodglass & Kaplan, 1972); Token Test and the Palo Alto Syntax Test (PAST) of Peraino (1976) involving 10 common types of syntactic classes of contrast. The types of pictures available for response to each PAST cue include: (i) the correct picture, (ii) opposite of the syntactic contrast sentence, and (iii) two semantically related foils.

Verbal-Spatial Relations is similarly constructed although it is more psychometrically sound in that it provides six alternatives: the target, the opposite syntactic contrast, as well as four semantically related foils ranging from close to far in meaning. Incidentally these task-item response differences are more characteristic of many CAS subtests and use of derivations of such techniques such as latent semantic analysis could be useful in further understanding the nature of this battery (e.g., see Landauer & Dumais, 1997; Lautenschlager, Dunn, Bonney, Flicker, & Almeida, 2006). Naessar et al. (1981, 1987) found that severe syntactic comprehension deficits were to be found in extensive temporal lesion patients. Less severe deficits associated with pointing to the correct depiction were found with lesions of the inferior parietal and frontal lobes. Finally, another test that is similar to Verbal-Spatial Relations is the Test for the Reception of Grammar (Bishop, 1989) although the lesion-localizing nature of this test is unknown.

An fMRI study by Dapretto and Bookheimer (1999) found that it was the *pars opercularis* of Broca's area (BA 44) that was critically implicated in the syntactic processing involved in Verbal-Spatial Relations like tests. Whereas the anterior aspect of the inferior frontal gyrus (BA 47) was selectively activated in processing the semantic aspects of the same sentences. Recently a "ventral semantic stream" in the left hemisphere that originates within the left posterior perisylvian region and then approaches the temporal pole and then traverses to the orbital regions within the frontal lobe (Mandonnet, Nouet, Gatignol, Capelle, & Duffau, 2007) has been discovered. Stimulation of this pathway in vivo in alert humans has elicited robust semantic paraphasias (Duffau et al., 2005). In the Dapretto and Bookheimer study there was greater activation in the syntactic-only condition within portions of the middle temporal gyrus, temporal pole, and the left parietal lobe with greater activation in LH. In agreement with the fMRI studies McCrea (2006) found that anterior lesions were the most detrimental to performance on Verbal-Spatial Relations and RH homologues might be expected to be involved with more difficult items (Just, Carpenter, Keller, Eddy, & Thulborn, 1996).

FIGURE MEMORY

In Figure Memory examinees are shown geometric figures for 5 s and then the examinee is presented subsequently with a response page that contains the original design embedded in a larger design. The red-pencil traced responses within the full item context or free form on a blank sheet of paper make this test amenable to a number of qualitative analysis of errors. Figure Memory is modeled on a number of copying tests such as the Benton Visual Retention Test (Sivan, 1992) and the Embedded Figures Test (Witkin, Oltham, Raskin, & Karp, 1971). These copying tests derive from Poppelreuter's overlapping figures tests developed in the 1920s (e.g., see Spreen & Strauss, 1998, pp. 500–501).

De Renzi & Spinnler (1966) suggested a right hemisphere bias for the Embedded Figures Test (EFT) as well as a greater sensitivity to anterior as opposed to posterior lesions (Egelko et al., 1988).Russo and Vignolo (1967) found that left hemisphere patients with aphasia also performed poorly on EFT whereas left hemisphere patients without aphasia performed like normal controls. Ryan, Clark, Klonoff, Li, and Patty (1996) found that MS patients with callosal lesions performed particularly poorly on the Benton Visual Retention Test and Corkin (1979) suggested that the laterality of lesion was not definitive. If the Figure-Memory subtest is analyzed in terms of components requiring coordination of the overall gestalt configural outline of the figure as well as the local line elements then it can be conceived of as a global-local task.

Such studies point toward the importance of interhemispheric coordination of bilateral parietal regions via the posterior corpus callosum as being critically involved (Berlucchi & Aglioti, 1999, p. 636) in such global/local tasks. An fMRI study using the EFT resulted in activation in bilateral parietal, right dorsolateral prefrontal cortex, and bilateral association occipital cortices consonant with activation of the dorsal stream in the normal control group (Ring et al., 1999). Other lesion studies using global-local tasks such as Navon figures (Navon, 1977) have found that subjects with stroke lesions centered on the left and right temporoparietal junction had difficulties in perceiving local and global elements; respectively (Robertson, Lamb, & Knight, 1988). In the Visual Patterns Tests or VPT (Della Sala, Gray, Baddeley, & Wilson, 1997) the subject is presented with a mixture of black and white squares in grids of varying size, such that the patterns are impossible to encode verbally and as such could be a purer test of visual STM than Corsi blocks.

Riddoch, Humphreys, Blott, Hardy, and Smith (2003) tested an integrative agnosic with bilateral occipitotemporal lesions on the VPT and found normal performance suggesting that it is the bilateral medial parietal lobe that could be the main source of activations for holding a memory of a previously viewed image. McCrea (2006) found that Figure Memory was the subtest most sensitive to posterior lesions congruent with other studies noting the involvement of bilateral occipitoparietal and right dorsolateral prefrontal cortex dorsal stream network functions in coordinating performance on the Figure Memory like subtests (Goodale & Milner, 1992). From college students' performance on the VPT it was inferred that patients with LH damage might have difficulty using verbal codes for visual stimuli whereas those with RH damage may have difficulties with the converse (Silverberg & Buchanan, 2005).

WORD SERIES

Word Series requires the examinee to repeat words in the same order as stated by the examiner and the task consists of the following single-syllable high-frequency words: *book, car, cow, dog, girl, key, man, shoe,* and *wall*. This task is built like Talland's (1965) Word Span Tasks and is similar to other span tasks such as the Wechsler Digit Span Tasks. Talland found that there was remarkable consistency of an average of five such words recalled across the five decades between 20 and 70. Miller (1973) used this task in comparing age-matched control and Alzheimer's patients and found that the mean span in demented patients dipped to only four words recalled.

Supraspan verbal tasks using words have shown to be superior to Digit Span tasks (Trahan, Goethe, & Larrabee, 1989, p. 82) in detecting brain damage. These authors found that 46% of LH patients scored below the cut-off whereas only 33% of RH patients did. Moreover a moderate correlation of ($r = 0.35$) between digit span forward and word span suggests that these two tasks are measuring similar processes. The nine words that comprise Word Series are concrete, familiar, and high in imagery and it is probable that dual coding mechanisms involving verbal/visuospatial representations and strategies could be utilized (Das, Kirby, & Jarman, 1975, 1979; Paivio, 1995). A dual-coding account arguing for a greater right hemispheric role in the processing of the verbal span task compared with the digit span forward would be consistent with the spatial visualization account (Kaplan, Fein, Morris, & Delis, 1991) as well as Jessen et al. (2000) finding of greater activation within the right inferior parietal lobe for concrete versus abstract word encoding strategies. On Digit Span Forward Black and Strub (1978) found that left posterior lesioned patients scored worst ($x = 4.9$) while right posterior lesioned patients ($x = 6.2$) were not significantly different than controls ($x = 7.0$). In the left hemisphere there was a 0.9 score spread between anterior ($x = 5.8$) and posterior lesions ($x = 4.9$); whereas in the right hemisphere there was a reversal in this pattern, such that anterior patients ($x = 5.5$) scored 0.7 points lower than posterior patients ($x = 6.2$). These trends are congruent with Kaplan et al. (1991) assertion that performance on Digit Span is reliant on immediate auditory memory and sustained attention.

Immediate auditory recall is sensitive to lesions encompassing Heschyl's gyrus, the middle and superior temporal gyrus, and the inferior parietal lobule (Gordon, 1983) whereas sustained attention is sensitive to right anterior lesions (Rueckert & Grafman, 1996). Word Series was the most sensitive of all of the twelve CAS subtests in two demographically matched patients one of whom had strategic infarct dementia (McCrea & Scott, 2002) with an aneurysmal infarct in the left frontotemporal region. Collectively these results indicate a dominant left posterior perisylvian language network for performance on Word Series with undetermined but not insubstantial influence of right hemisphere homologues. Finally, Damasio, Tranel, Grabowski, Adolphs, and Damasio (2004) used the lesion method and functional neuroimaging to arrive at a model of the naming of concrete objects depends on partially segregated regions in the higher-order cortex of the left temporal lobe whereas retrieval of conceptual knowledge pertaining to the same entities was located predominately in the right hemisphere (e.g., cow = animal; dog = animal).

SENTENCE REPETITION

Sentence Repetition is composed of color words (e.g., The blue is yellowing). Color content words are utilized, so that the sentences contain no meaning, to help reduce the influence of semantic cues and to accentuate the demands upon syntactic processing related to the sentence. Lezak (1995, p. 364) notes that length, meaningfulness, familiarity, and speed at which the examiner speaks sentences are all important factors determining their repeatability. Sentence Repetition is designed along Botwinick and Storandt's (1974) Silly Paragraphs emphasizing syntactic processing.

This emphasis on syntactic processing is synonymous with Luria's (1974) observations that anterior brain damage may cause deterioration in the smooth flow from subject to verb, which he termed a failure of *syntagmatic organization*, with a deficit in internal speech and eventually resulting in a telegraphic style (Stuss & Benson, 1990, p. 31). These Silly Sentences involved the recall of nonsensical information, which the subjects were then asked to repeat verbatim as soon as the examiner had finished reading the sentence. In Silly Paragraphs, the sentences are lengthened and recognition but not verbal comprehension is emphasized. Analysis of subjects between the ages of 20 and 70 revealed that age accounted for more variance in performance on Silly Paragraphs than comparison of meaningful sentences. Also, education has a differential positive effect on recall of Silly Paragraphs as opposed to meaningful information.

In the CAS version access to semantic representations will not provide any additional useful information insofar as performance is concerned. Thus one could expect Sentence Repetition to be a (i) much more difficult task than more conventional meaningful sentence repetition tasks used in the detection of conduction aphasia. Moreover, the CAS version could be useful with elderly populations given its sensitivity to aging effects. Selnes, Knopman, Niccum, and Rubens (1985) large study of an unselected sample of aphasic stroke patients underscored the importance of the integrity of Wernicke's area in sentence repetition type tasks. These researchers tested aphasics at 1 month and 6 months poststroke on the Sentence Repetition and other tasks included within the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983) and Wernicke's area was defined as including the posterior superior temporal lobe and the infrasylvian supramarginal gyrus.

A strong correlation between the size of the lesion within Wernicke's area and the severity of the repetition deficit was found ($r = -0.63$). It was also found that lesions within supramarginal gyrus without extension into the posterior superior temporal lobe did not result in a persistent deficit of the ability to repeat at 6 months. Lesions elsewhere within the LH, including posterior insula, supramarginal gyrus, and parietal operculum were only associated with transitory repetition deficits. McCrea and Scott (2002) found that Sentence Repetition was moderately discriminating between the dementia patient with an aneurysmal infarct in the left frontal lobe compared to the demographically matched control patient. Taken together these studies show that lesions within left posterior perisylvian region are critically involved (Nadeau, 2003) in the etiology and performance patterns of Sentence Repetition deficits normally associated with conduction aphasia.

SENTENCE QUESTIONS

During the Sentence Questions subtest examinees are read a cue sentence and then asked a question about the same sentence. For example, the examiner states that "The blue is yellowing" and then asks the following question: "Who is yellowing?" The correct answer is of course: "the blue." Sentence Questions is most similar to Collins and Quillan's (1969) false sentences test and requires a decision about meaningless sentences using exclusively syntactic analysis. False Sentences was originally a reaction time memory task, although Sentence Questions is untimed. In this earlier derivation subjects were presented with a series of statements that are obviously true (e.g., "A bird has wings?") or false (e.g., "Hockey is a race?") and were asked to answer accordingly in a yes or no format.

Sentence Questions has the decision component of False Sentences although the decision is not based on a choice reaction time paradigm. Rather the decision is based entirely upon the syntactical arrangement of subjects and verbs as opposed to semantic analysis of the stimulus sentences or understanding the categorical nature of various word classifications. Thus Sentence Questions involves recall of key elements of the semantically meaningless sentence based entirely on the sequence in which the words are presented. In future it might be useful to measure reaction times and errors such as (e.g., word substitutions and paraphasias) in the overall analysis of the subject's performance on this unique task. There is virtually no neuropsychological data on any similarly constructed types of tasks in the literature and therefore we refer to more general studies of syntactic comprehension.

Caplan, Hildebrandt, and Makris (1996) similarly conducted comprehension for sentences in such a way that "subjects structure the sentences syntactically and not simply rely on real world knowledge to determine the correct meaning of these sentences" (p. 935). Subjects were tested on a wide range of sentences with varying syntactic arrangements in patients with LH-RH-damaged and control subjects with tasks that had been used to test for comprehension. Lesions within the LH- rather than the RH-affected syntactic comprehension the most, although RH-lesioned patients also performed significantly poorer than controls on such tasks.

Specifically, lesions within the left perisylvian association cortex consisting of superior temporal gyrus, the inferior frontal gyrus, angular and supramarginal gyrus, and parietal operculum all demonstrated concordance with defects in syntax comprehension with a lesser role for right hemisphere homologues in the syntactically most complex linguistic constructions. There were no differences between anterior and posterior perisylvian damage, suggesting a widely distributed network as involved in performance on such tasks. A PET study found that judgments about the syntactic acceptability of sentences activated the pars opercularis of Broca's areas in normal subjects (Stromswold, Caplan, Alpert, & Rauch, 1996). Jointly, these results are tell-tale of a widely distributed perisylvian network comprising both anterior and posterior segments with undetermined influences of right hemisphere homologues in more complex working-memory dependent syntactic comprehension items of the Sentence Questions task.

Table 1. Neuropsychological description of cognitive assessment system subtests

CAS subtest	Task most similar to CAS subtest	Perceptual, cognitive and motor components of task	Neuropsychological correlates of CAS subtests based on tests in the literature	Major differences between CAS subtest and predecessor-tasks
Matching numbers	Visual search: Teuber et al., 1951; Digit Span Backwards: Wechsler, 1981	visual search, working memory, strategy, motor speed, dexterity, praxis	bilateral frontal eye fields, right posterior parietal cortex, bilateral dorsolateral prefrontal cortex	use of different strategies, requirement for working memory, mental tracking, praxis, unique
Planned codes	Symbol digit modalities test: Smith, 1991	visual search, working memory, strategy, motor speed, dexterity, praxis	basal ganglia, frontostriatal loops, dorsolateral prefrontal cortex	use of different strategies, lexical items, praxis, verbalization, unique
Planned connections	Trail-making test: Reitan, 1992	visual search, motor speed, dexterity, set-shifting, strategy, praxis	dorsolateral PFC, corticostriatal loops, caudate, dopaminergic projections from midbrain	strategy checklist, low floor items, graduated level of difficulty
Expressive attention	Stroop test: Stroop, 1935	response inhibition, sensitivity to color anomia	dorsolateral prefrontal cortex, right anterior cingulate	inclusion of a color naming and word naming accuracy/reaction time
Number detection	Letter-digit cancellation: Diller et al., 1974	sustained attention, visual scanning, motor speed, dexterity, visual neglect, praxis	right frontoparietal networks of dorsal stream	inclusion of symmetric L or R hemifields for quantification of both horizontal or altitudinal neglect, praxis, unique
Receptive attention	Physical-lexical identity match: Posner and Mitchell, 1967; Pollman et al., 2003	lexical categorization, perceptual identification, praxis, interhemispheric coordination, motor speed, dexterity	splenium for IHT; physical: pos. STG, s. frontal gyri, LT frontopolar; lexical: lateral occipital complex, fusiform g, LT intraparietal s., inferior frontal gyri, RT frontopolar	inclusion of symmetric left and right hemifield for quantification of both hemifield and altitudinal neglect, praxis, unique

Continued on next page

Table 1. Neuropsychological description of cognitive assessment system subtests (Continued)

CAS subtest	Task most similar to CAS subtest	Perceptual, cognitive and motor components of task	Neuropsychological correlates of CAS subtests based on tests in the literature	Major differences between CAS subtest and predecessor-tasks
Nonverbal matrices	Raven's colored progressive matrices: Raven, 1965	perceptual matching, analogical reasoning, fluid intelligence, Spearman's g, interhemispheric process	right rostral dorsolateral prefrontal cortex, bilateral parietal, dorsal/ventral stream, corpus callosum	low ceiling items and similarly high ceiling items, use of item response theory statistics, excellent range of items
Verbal-spatial relations	Palo alto syntax test: Peraino, 1976; Test for the Reception of Grammar: Bishop, 1989	syntax, verbal comprehension, pictorial matching with verbal/nonverbal material	Broca's area, left posterior superior temporal gyrus, Wernicke's area, left temporoparietal region	multiple graded levels of semantically-related foils, prepositional and item-level analysis potential, read vs. oral, unique
Figure memory	Visual patterns test: Della Sala et al., 1997	short-term visuospatial memory, praxis, global/local processing, interhemispheric	bilateral occipitoparietal and right dorsolateral prefrontal cortex, dorsal stream functions, corpus callosum	item analysis of global-local errors, differential susceptibility of items to verbalization, unique
Word series	Word span: Miller, 1973	immediate auditory memory, sustained attention, verbal span, concrete verbal imagery	Heschyl's gyrus, middle and superior temporal gyrus, bilateral inferior parietal lobule, right frontal lobe	comparison with non-semantically or strategically coded digit span forward, unique
Sentence repetition	Silly paragraphs: Botwinick and Storandt, 1974	verbal working memory, syntax	Left posterior perisylvian language, Broca's area	theoretical comparison with semantically meaningful sentence repetition tasks, unique
Sentence questions	False sentences: Collins and Quillian, 1969	verbal comprehension, syntax	distributed perisylvian language networks, right hemisphere homologues to a lesser extent	comparison with semantically meaningful sentence comprehension tasks, completely unique

RESULTS

Subject 1. AO: Syntactic Processing Impairment

AO was a 43-year-old right-handed male with 11 years of formal education who suffered a left frontotemporal opercular infarct as a result of a left middle-cerebral artery occlusion within the distal aspects of the anterior branches. AO was self-employed as a highly successful real estate agent before the onset of his cerebrovascular disease. AO presented with right-sided arm and leg weakness and expressive aphasia. AO was able to follow simple commands and thus comprehension was significantly preserved. He was hospitalized after it was found that he was unable to talk or move the right side and neurologists noted that he had some depression of affect. At admission AO had a mild right visual field defect, a right facial droop, and his tongue deviated to the right side. AO's right upper and lower extremity were completely paralyzed and mildly weakened, respectively. AO's sensory functions were all within normal limits and he was noted to be alert on presentation and he had no previous history of strokes.

Over the next 2 days after presentation at emergency AO had marked improvement of his lower extremities' strength and he started to have some movement in his fingers and he was also actively trying to vocalize words. Carotid dopplers revealed no evidence of any significant carotid artery disease.

Table 2. Cognitive assessment system subtest scores for AO

	(T-Scores)			
	T1	T2	*Z*-Score	Probability
Matching numbers	43	58		ns
Planned codes	40	55		ns
Planned connections	38	47		ns
Expressive attention	36	51		ns
Number detection	41	55		ns
Receptive attention	38	50		ns
Nonverbal matrices	45	54		ns
Verbal-spatial relations	38	45		ns
Figure memory	49	45		ns
Word series	43	52		ns
Sentence repetition	52	62		ns
Sentence questions	44	60	1.60	$p < 0.05$
Mean subtest score	42	53	1.10	ns

The patient was examined by speech therapists 2 days after admission and they found a moderate impairment in auditory comprehension and he answered 16/20 yes/no questions correctly. AO had a score of 50/60 on auditory word recognition and he was able to follow single-step commands. He had some difficulty following multistep commands and received a score of 12 out of 80 on the sequential commands measure, suggestive of some degree of transitory ideomotor apraxia. Further examination by the speech therapists at this time found that he had moderately severe problems with verbal expression except for verbal repetition, which was excellent with a score of 94 out of 100. On initial admission AO's motor speech was moderately severely involved and most of his spontaneous speech was actually unintelligible. However, AO was able to repeat heard short phrases moderately fluently.

Occupational therapists also assessed AO 1 week after admission and found him to be somewhat impulsive, such that his judgment was impaired and he would become argumentative when discussing discharge issues, suggestive of anosagnosia. At this time, postinfarct, AO still retained a marked expressive speech deficit and he was unable to write comprehensible sentences and also had some difficulties with verbal expressive speech, such that it was halting and telegraphic. Again, at this time AO demonstrated some degree of transitory agraphia, which is perhaps not unexpected given the proximity of his lesion to the foot of the second frontal convolution or Exner's area (Roeltgen, 2003, p. 126). These findings of transitory ideomotor apraxia and/or apractic agraphia are likely of a diaschisis nature since left posterior parietal and left inferior frontal gyral regions, respectively associated with these functions, were largely intact (De Renzi & Faglioni, 1999; Denes, Cipolotti, & Zorzi, 1999).

At 1 week postinfarct AO also demonstrated some residualized impairment in high-level receptive language skills along with a slight difficulty in mental calculations. The entire symptom profile was suggestive of a *transcortical motor aphasia* in which spontaneous speech is reduced but repetition is essentially intact. In this regard AO's problems with multistep commands could conceivably be secondary to planning deficiencies rather than actual problems with auditory comprehension since he did get 16/20 yes/no questions correct along with a score of 50/60 on the auditory word recognition tasks. Finally, despite his fluency and word-finding difficulties, which caused him considerable frustration, he was able to complete the CAS and he displayed excellent motivation and no evident problems in simple attention to tasks.

The only subtest that remained within normal limits on the first assessment was Sentence Repetition. This intact functioning on this subtest is consistent with previous studies reporting the adverse effects of posterior temporal gyrus

Figure 1. AO's CT scan**:** AO was administered a noncontrast enhanced CT scan 1 week prior to his assessment. On admission the CT scan primarily revealed hypointensity in the insular and opercular regions. There is distinct involvement of the left temporal pole and the inferior aspect of the left temporal lobe and also more subtle involvement of the inferolateral frontal lobe. However, the lesion is centered on the left temporal lobe. There was extension medially to involve most of the caudate nucleus and putamen on the left side as well as the lateral aspect of the caudate nucleus. There was also some involvement of the corona radiata anteriorly and medially. According to neuroradiological convention left is right and right is left.

lesions on repetition whereas more anterior lesions usually spare repetition (Selnes et al., 1985). Sentence Questions was highly significantly impaired at first test compared to retest consistent with studies suggesting that damage within the vicinity of Broca's area carries with it the potential for significant impairments in syntactic aspects of speech comprehension (Caplan et al., 1996). Some slowing of motor execution and performance was noted in the acute phase, perhaps not unexpectedly, given the involvement of the basal ganglia in generalized bradykinesia (Mattingley, Bradshaw, & Phillips, 1992). AO was able to competently read the cue sentences at the bottom of the Verbal-Spatial Relations subtests suggesting no evidence of acquired dyslexia or alexia without agraphia or letter-by-letter reading (Coslett, 2003, p. 112). These types of syndromes are most frequently associated with lesions of the ventral occipitotemporal cortex of the word-form area and AO's lesion was characteristically more temporal-polar than ventral-posterior in congruence with this observation (see Figure 1).

Subject 2. JL: Right Orbitofrontal Syndrome

JL was a 54-year-old left-handed male with 14 years of formal education who suffered a right anterior cerebral artery (ACA) infarct that essentially obliterated the right orbital frontal gyrus as well as damaging more superior right medial and lateral inferior prefrontal cortex. JL had been previously working as a licensed steam engineer who had 2 years of skilled technical postsecondary education and 1 year of on-the-job skilled journeyman training. JL had been dutifully employed at the same job for the past decade in a middle-management and supervisory capacity. His career required that he be able to oversee the work of his coworkers on an independent basis in a capacity that required a high degree of responsibility up until the time of his severe stroke.

JL was admitted the night after experiencing mild weakness on his left side and after exhibiting abnormal behavior such as urinating at his bedside without any obvious insight into his actions. This was accompanied by strange behaviors such as aimlessly wandering around, self-reports of visual hallucinations, dressing inappropriately, and evident confusion. His wife noted that JL suddenly became very quiet and did not initiate any communication compatible with akinetic mutism probably as a consequence to medial frontal cortex damage via the ACA (Chui & Willis, 1999, p. 382). His spouse was worried about him and initially suggested that they go to the hospital.

The next day JL started to develop nausea with no further progression in his motor weakness. When examined at the emergency room he was apathetic

Table 3. Cognitive assessment system subtest scores for JL

	(*T*-Scores)		Ipsative	
	*T*1	*T*2	*Z*-Scores	Probability
Matching numbers	34	49		ns
Planned codes	40	49		ns
Planned connections	38	53		ns
Expressive attention	33	60	2.70	$p < 0.01$
Number detection	34	47		ns
Receptive attention	32	-		ns
Nonverbal matrices	36	49		ns
Verbal-spatial relations	43	56		ns
Figure memory	39	49		ns
Word series	52	69	1.70	$p < 0.05$
Sentence repetition	62	58		ns
Sentence questions	60	58		ns
Mean subtest score	42	54	1.20	ns

and disorientated yet at the same time disconcertingly calm with some degree of flat affect. He would attempt to answer the neurologist's questions but was mistaken with many of his answers and appeared unalarmed about his present condition and situation. JL's cranial nerve exam was normal and motor exam revealed increased tone on his left side with mild weakness of his left arm. JL displayed some generalized left hemiparesis that rapidly resolved as well as a left facial droop. JL's reflexes were symmetrical and plantars were down going.

It was noted by neurologists that he often engaged in repetitive actions that did not have any evident meaning. His past history included myocardial infarction some 6 years before, alcohol abuse, and smoking; however, he had no history of diabetes, hypertension, or immediately prior cardiac problems. He was disorientated to both time and place and he displayed some degree of drowsiness and he was unsure as to why he was admitted to hospital.

When administered several of the manual CAS Planning subtests JL had to be reminded several times not to turn the page on his own, suggestive of disinhibition of automatic behaviors (Edwards-Lee & Saul, 1999). However JL did not demonstrate any apraxia or agraphia on any of the CAS manual subtests. Of clinical interest JL's right hand was often observed to sequentially and repetitively turn the page halfway through a testing on items of several of the subtests. It was noted that JL was strongly left-handed yet this repetitive and evidently serial behaviour occurred despite the fact that repeated verbal cues had been given by the examiner that he should not do this. Another peculiar behaviour that was routinely observed of this patient for the initial postacute phase when he was first tested with the CAS was his tendency to walk closely next to the walls and sidewall railings by grasping them when ambulating between different rooms of the stroke ward. This observation is entirely consistent with the hypothesis that right frontal lobe patients are overly dependent on either overt verbal or concrete environmental cues to guide their behaviour (Edwards-Lee & Saul, 1999).

Shortly after leaving the postacute stroke unit JL was admitted to a long-term care unit for elderly and neurodegenerative patients, despite his relatively young age, on a trial-by-trial basis. Although home care trials were tested for JL and his spouse it was found that JL was completely incapable of looking after himself and therefore he posed a large burden on his spouse who was responsible for looking after all his basic needs. JL remained at the long-term care unit when he was tested again at 6 months postinfarct and by this time he was no longer making any financial, major life decision or legal decisions for himself. Interestingly his wife reported that he had apathetically agreed to go to the long-term care home without any evident concern or argument. It is also reported that he displayed no regret at being away from his wife, which his spouse felt very distressing. His wife reported that he was previously dominant, reliable, and highly independent in their relationship and that now he was completely passive, which she referred to as an extremely marked and permanent change in his personality pattern. However, no formal assessment of personality changes occurring after JL's stroke was undertaken.

At the first assessment on the Planning subtests JL either did not use a strategy listed in the Strategy Assessment Checklist or used a strategy that was simple, not as efficient, and typical of developmentally younger age groups. Across assessments on the Planning subtests JL either: (i) continued not to use any strategy, (ii) used developmentally simpler and less elaborated strategies, or finally (iii) fluctuated in the use of a particular strategy from test session to test session. At the second assessment JL was subjected to testing of the limits with respect to his intrinsic capacity to implement a strategy on any of the three CAS Planning subtests (Lezak, 1995, p. 140). It was found that with experimenter instruction and sequential verbal cues JL was easily able to implement the most complex of strategies often used to solve the three Planning subtests. However, this apparent ability to utilize strategies was highly context- and examiner-dependent, sporadic, inconsistent, and generally not autonomous.

Other symptoms of JL's syndrome were that even at 6 months poststroke it took him 2 hours to get ready on his own in the morning and that he could

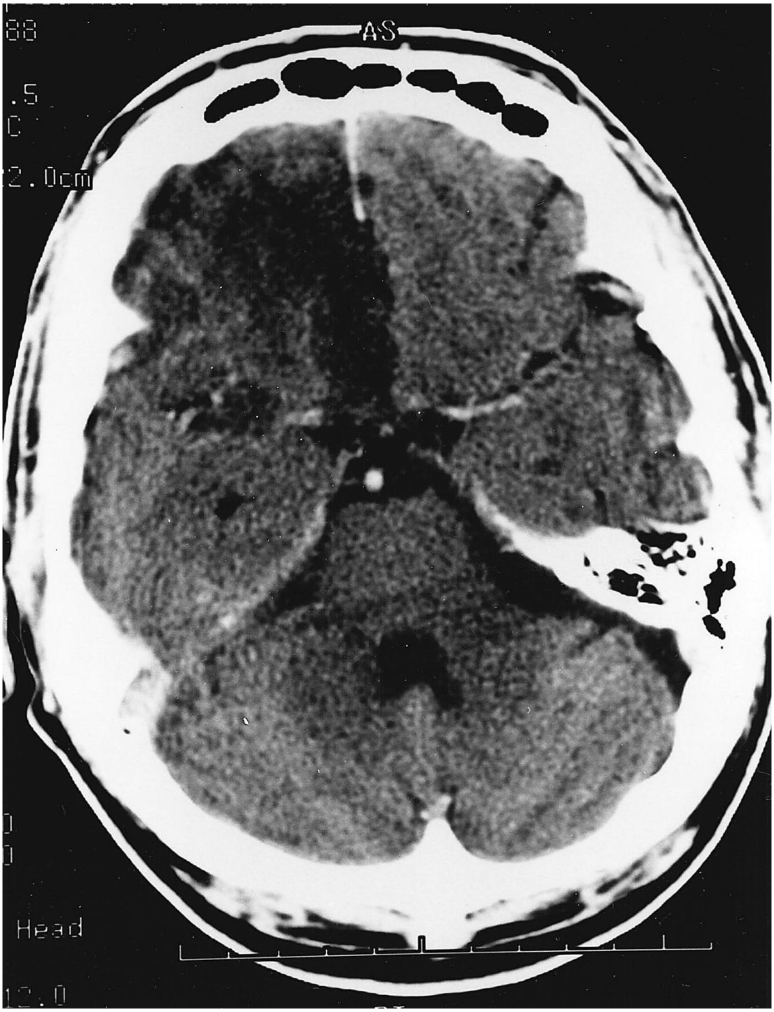

Figure 2. JL's CT scan: JL was administered a contrast-enhanced CT scan 1 week prior to the first assessment on the CAS. There is a roughly triangular large well-defined hypointensity involving the right frontal lobe extending from the genu of the corpus callosum to the inner table of the skull. The appearance is compatible with an acute infarct in the distribution of the right anterior cerebral artery possibly also including the recurrent artery of Heubner. The hypodensity extended from the orbitofrontal lobe, gyrus rectus, as well as the anterior aspect of the superior, middle and inferior frontal gyrus and the ischemia extends back to within 2 cm of the precentral gyrus on its posterior margin. There is less significant involvement of the dorsolateral frontal lobe. The right insular cortex is also involved and the basal ganglia are spared except perhaps for the lateral-most aspect of the putamen. The maximum dimensions of the infarct measure approximately 3.5 × 8.4 × 9 cm. According to neuroradiological convention left is right and right is left.

not remember being tested initially at 1-month poststroke, suggesting severely impaired episodic memory retrieval. JL also reported that he needed directions as to what was to be done next in the daily schedule of events. JL often reported that he "forgot what I was going to do next," suggesting some ability to at least retain the sequence of a prospective memory if not the actual content of that sequence. Interestingly, JL reported at the 6-month assessment that he could not remember the examiner's name; however, he was emphatic that he certainly remembered the examiner's face or he stated that the examiner's face at least was familiar. The latter finding is consistent with JL's entirely intact posterior occipitotemporal face-processing regions and anterior temporal face-processing zones involved in the construction of person-identity nodes (Farah, 2004).

JL's impairment in the retrieval of a person's name from a familiar face is consistent with his damage to retrieval mechanisms usually associated with the right frontal lobe. That is episodic retrieval of a name is usually associated with the maintenance of a retrieval mode within the right prefrontal cortex (Dobbins & Davachi, 2006, p. 244), a region that was severely damaged in JL. Again of note was that JL demonstrated a characteristic insensitivity to verbal commands and required considerable and repeated prompts and cues to implement strategies. Significant and not unexpected serious episodic memory problems were noted in that he could not remember his previous job, where he lived, nor could he remember the names of his children. Although by 6 months he was "aware" that he had suffered a stroke he often minimized the symptoms, and was completely unable to describe the specific deficits that he experienced cognitively, emotionally, or somatically. At 6 months these memory problems were still so severe that he couldn't remember who his friends were although he had an active and satisfying social life prior to his stroke and he could not remember what he ate for breakfast or what specific room he was located in.

Finally, there were two subtests on which JL demonstrated significant initial impairment on the basis of test and retest scores. Expressive Attention was significantly impaired, which is perhaps not unexpected since Vendrell et al. (1995) found that patients with lesions of the right frontal lobe particularly along the medial aspects involving the anterior cingulate were most impaired on the Stroop test. Similarly, Word Series was impaired congruent with Kaplan et al. (1991) hypothesis that performance on Digit Span forward was most sensitive to deficits in immediate auditory memory and sustained attention. Sustained attention has been found to be especially impaired as measured by several different tests after right anterior lesions (Rueckert & Grafman, 1996). The abnormally low score on Word Series (1st assessment raw score

= 12 items correct) versus (2nd assessment raw score = 18 items correct) suggests some type of problem in encoding. Since Word Series is a task where dual-coding mechanisms can be used to solve the problems is perhaps congruent with a visuospatial encoding deficit (Paivio, 1995). These results could point toward a greater right-hemispheric role in encoding these concrete words in complete agreement with the spatial visualization strategy account of dissociations in performance between tests of immediate auditory memory such as the Wechsler's digit span forward and backward (Kaplan et al., 1991).

Finally, what is of most interest for the purposes of the present discussion, JL demonstrated a peculiar pattern of performance on the Figure Memory test at 6 months postinjury, which will be elaborated upon later in the discussion (see Figure 2).

Subject 3. KH: Unilateral Spatial Neglect Syndrome

KH was a 41-year-old right-handed woman with 12 years of formal education who was employed as a secretary up until the time of her stroke. KH suffered a large right middle cerebral artery occlusion focalized within the right parietal lobe with subtler involvement of the right inferior frontal lobe. She was admitted with left hemiplegia, slurred dysarthric speech, and severe left visual field neglect. KH had a history of hypertension, hypercholesterolemia, and smoking, and presented with a right gaze preference suggestive of problems with eye movements and/or frontal eye field function. KH had some degree of hemianopia, some loss of movement of the left upper extremity, as well as substantially less loss of movement associated with the left lower extremity. KH had no evidence of carotid artery obstruction and instead it appears that her stroke could have been a function of comorbid vasculitis.

At the time of the first assessment on Matching Numbers KH uncharacteristically scanned from right to left instead of left to right suggestive of left visual neglect. On Planned Connections KH was able to use elementary strategies such as repeating alphabet-number series out loud and/or she tried to scan for the next number or letter. However, on Planned Connections KH displayed difficulties in moving her eyes into the bottom left visual field. For example, on Item 6 digit number 8 (which involved simple digit sequences and not set-shifting or complex strategies), KH was unable to move her eyes into this lower left field without verbal cues and pointing by the examiner. This pattern of impairment is suggestive of right frontal eye field (FEF) damage or damage to the FEF's source of afferent connectivity such as the right superior parietal lobule (Kastner, 2004, p. 314). Moreover, the slow or inefficient eye

Table 4. Cognitive assessment system subtest scores for KH

	(T-Scores)		Ipsative	
	$T1$	$T2$	Z-Scores	Probability
Matching numbers	34	51	1.70	$p < 0.05$
Planned codes	44	54		ns
Planned connections	38	43		ns
Expressive attention	44	53		ns
Number detection 36	55	1.90		$p < 0.05$
Receptive attention	36	59	2.30	$p < 0.01$
Nonverbal matrices	44	56		ns
Verbal-spatial relations	44	48		ns
Figure memory	39	51		ns
Word series	46	46		ns
Sentence repetition	45	48		ns
Sentence questions	42	44		ns
Mean subtest score	41	51	1.00	ns

movements into the lower left visual field implies that there might be damage to neurons within the dorsal bank of the calcarine sulcus or secondary visual cortical fields streaming from this area, such as the right occipitoparietal regions (Young & Young, 1997, p. 158).

KH demonstrated highly significant initial impairment in Receptive Attention compared to retest 6 months later and qualitative analysis revealed definitive left visual field neglect in the form of lexical omissions most likely as a result of a large right parietal infarct and consequent search asymmetries. This left visual field neglect was also visibly present on Matching Numbers and Number Detection; however, it is graphically depicted in Figure 5 in the Discussion only to illustrate how written praxis and early lexical processes could be studied with the unique and original Receptive Attention subtest. Thus Matching Numbers, Number Detection, and Receptive Attention all demonstrated significant impairment at the first testing session compared to retest 6 months later and this was attributed to left visual field neglect in all instances with Matching Numbers' scores additionally being lowered due to search assymetries and strategic attentional deployment disturbances.

Again Matching Numbers was severely impaired, originally compared to retest consistent with the finding that right parietal damage can cause visual neglect as well as defective serial search as a consequence perhaps of damage to afferents to the frontal eye fields. The same arguments would apply to the left

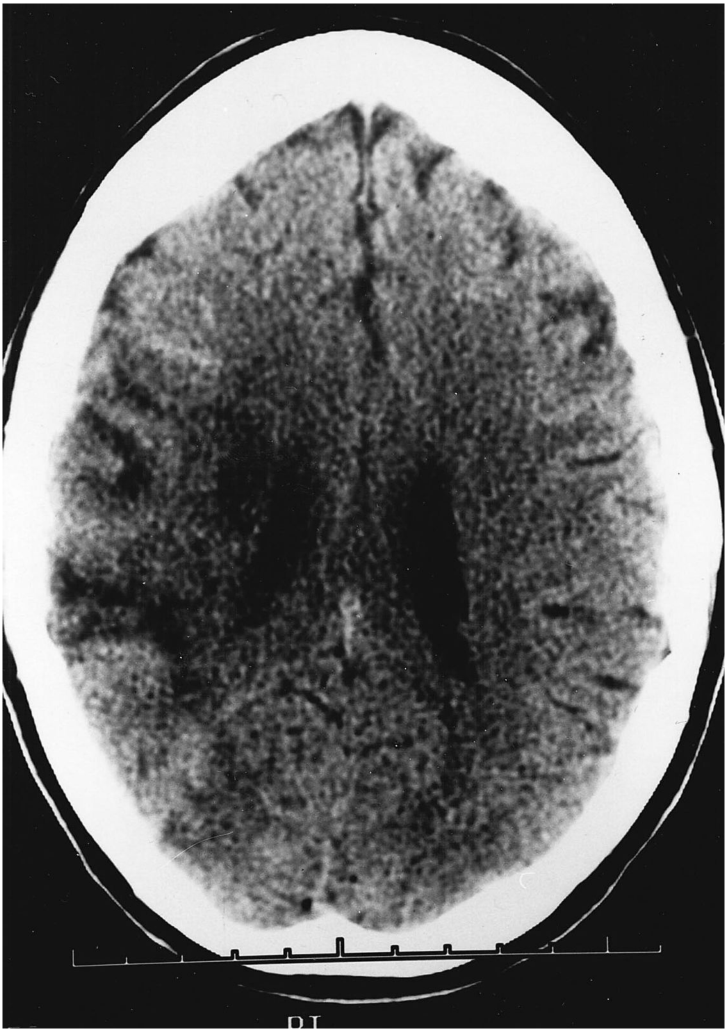

Figure 3. KH's CT scan: KH had a noncontrast enhanced CT scan 1 week before her first assessment with the CAS. A wedge-shaped remote cortical infarct which measures approximately 1.5 × 2 × 5 cm is centered in the anterior inferior right parietal region and extends to the border with the right temporal lobe. There is some effacement of the insular cortex in the right hemisphere as well as loss of gray-white matter differentiation up to the margins of the right inferior frontal lobe. The right operculum is involved and the sylvian fissure is obliterated on the right side. The CT scan accentuates the loss of gray-white matter differentiation within the right hemisphere. The occlusion is in the distribution of the middle cerebral artery in keeping with a distal middle cerebral artery infarct primarily affecting the right parietal lobe. Note the preservation of gray-white matter differentiation in the right-sided view of the left hemisphere and the mottled loss of gray-white in the left-sided right frontoparietal cortex According to neuroradiological convention left is right and right is left.

visual field neglect found for Number Detection. Recall that Binder et al. (1992) found that lesions within the right inferior frontal gyrus as in KH were the most deleterious to performance on visual search tasks. Husain and Kennard (1997) found that as the number of distracters increased so did the impairment in visual search selectively for a patient with a right frontal lesion compared to one with a right frontoparietal lesion. On Number Detection there was evidence in the transition from item 3 (three search targets) to Item 4 (six search targets) that as the number of distracters increased so did the impairment in visual search congruent with KH's right frontal lesion. However, on Matching Numbers it was more difficult to dissociate strategic impairment from search impairment as the two cognitive processes are linked (see Figure 3).

DISCUSSION

With regard to the first patient AO with the syntactic impairment Caplan (2003) has reviewed several studies suggesting that the left temporal pole is particularly involved in syntactic processing for which the primary dependent variable is usually comprehension. Characteristically, a broad range of perisylvian association cortex is involved including: pars triangularis, pars opecularis of the inferior frontal gyrus, the angular gyrus, supramarginal gyrus, and superior temporal gyrus of the left hemisphere. Such lesion-related deficits are present in all languages studied, ages, written or spoken input, as well as lesion etiology. Such regions of interest have also been demonstrated in PET, fMRI, and ERP studies. These ROI's have also been found in which sentences' content words have been replaced with semantically unrelated words as in Sentence Questions (Mazoyer et al., 1993) or when subjects read sentences (Bavelier, Corina, & Jezzard, 1997). In both of these two studies activation of anterior temporal cortex in syntactic processing was found. These findings have usually been interpreted in terms of strong modular models of deep structure account of syntactic comprehension (Chomsky, 1957; Luria, 1974).

In contrast Caplan notes that

> in *interactive model*s a wide range of types of information is used to create syntactic structures. Factors such as the plausibility of a noun playing a thematic role, the frequency with which particular words occur together in a language, and many other non-syntactic factors all interact with each other as well as with the syntactic category of a word to "constrain" the possible syntactic structures and sentence-level semantic representations that could be assigned as each new word is recognized (p. 65).

If we examine the first item (at the first assessment), which AO got wrong from the Sentence Questions subtest (Item 7), we find that

Cue Sentence: The red who blues yellow, browned on the green.
Question: Where did the red brown?
Answer: On (the) green.

It is not possible to use semantic associations or lexical aspects of the cue sentence to answer the question. The initial deficit in syntactic processing was associated with a characteristic perisylvian frontotemporal lesion. The involvement of the anterior temporal lobe is highly suggestive that the CAS's Sentence Questions is congruent with a strong modular account of syntactic processing. Since so few syntactic comprehension paradigms have been developed that have been well standardized and that have items with limited semantic confounds suggests that this interesting and unique task could conceivably be readily implemented in a functional neuroimaging environment.

Other studies have shown that right hemisphere homologues of perisylvian syntactic comprehension may become recruited with particularly difficult items typical of the ceiling items on the Sentence Questions subtest (Caplan et al., 1996; Just et al., 1996).

In a comprehensive review of the neuroimaging and lesion literature Friederici and Kotz (2003) showed that semantic and syntactic processes are supported by separable networks. Syntactic processes involved the left superior temporal gyrus, the left frontal operculum, and the basal ganglia. MEG and ERP data both supported the supposition that left anterior temporal and left inferior frontal lesions are particularly involved in early syntactic structure-building processes, whereas data from patients with basal ganglia dysfunction involved in rule-based processing in language is associated with late syntactic integrational processes.

One of the strengths of the case of AO is that he was assessed in the postacute phase and 6 months after infarct. Caplan (2003) has noted that sparing of syntactic comprehension after strokes in all parts of the perisylvian association cortex is difficult to reconcile with a *strongly localizationist* (Grodzinksy, 1990) or even *distributed net model* of syntactic comprehension (Mesulam, 1990). Caplan (2003) further hypothesizes that if patients are tested immediately after a stroke and with sensitive enough instruments then patients that did not have any syntactic comprehension deficits months after infarct could readily demonstrate such disorders initially (p. 69). This researcher's studies argue that this is evidence for his model that postulates enormous *individual variability* in the neural substrates for this function (Caplan et al., 1994). Therefore the significant initial performance deficit of AO shows that this simple, quick, and easily administered bedside CAS subtest of Sentence Questions could be just such a sensitive and specific task for such assessments of subtle syntactic comprehension deficits associated with individual variability perspectives based on contemporaneous cognitive neuropsychology models.

Patient 2, JL, who displayed impairment on Expressive Attention as a consequence of a right anterior cingulate lesion as well as an impairment on Word Series as a result of deficits in sustained attention and immediate auditory memory also displayed a heretofore undescribed phenomenon on Figure Memory at the second testing session.

JL demonstrated *figure-ground reversal* on Figure Memory test at the second assessment. We will hereafter refer this phenomenon as *Praxis-Based Figure-Ground Reversal*. This pattern was repeated on several of the items despite verbal cues to underline in red the figure and not the background. JL had no evident problems in understanding language or complex commands so the nature of this phenomenon is not likely to be related to linguistic problems per se.

A review of the published literature could not find any such description of such a motor-imbued spontaneous and uncued manifestation on such a task, although the piece-by-piece manner in which the surrounding was highlighted is reminiscent of integrative agnosia (Farah, 2004). Integrative agnosia is increasingly being understood as a deficiency in figure-ground organization, interpolation, and grouping of objects and scenes (Behrmann, 2003). Aviezer et al. (2007) have suggested that integrative agnosia is a disorder that is subject to the condition that compensatory top-down semantic links activate visual representations in a backward fashion (Peterson & Rhodes, 2003).

Recall that this test is motor and drawn and cue figures are first shown for 5 s and then removed. Without any prompts JL then drew in a piece-by-piece manner all of the elements around the figure in red pencil. Rubin (2001) has noted that such figure-ground reversal phenomenon is usually attributed to strictly visual gestalt phenomenon and not motor-sequencing or surround effects. The piece-by-piece manner in which these surrounding elements were filled in is suggestive of top-down modulation of the initial figure-ground distinction among edges and contours (Baylis & Driver, 2001) and could arise as a result of recently described long-range frontal-occipital connections involved in discriminating shape primitives (Bar et al., 2006). In this model low spatial frequencies facilitate visual object recognition by initiating top-down processes projected from orbitofrontal to visual cortex in the vicinity of the inferotemporal cortex (Baylis & Driver, 2001). Of interest was that JL only exhibited this Praxis-Based Figure-Ground Reversal when the items were verbalizable, such that all items that were verbalizable were reversed (see Figure 4).

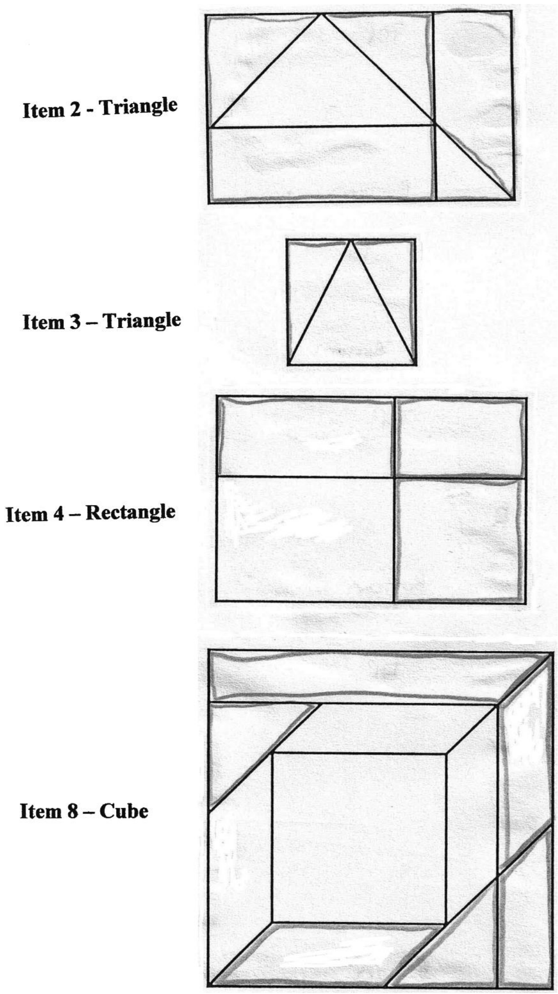

Figure 4. Depiction of JL's praxis-based figure-ground reversal on the figure memory subtest of the cognitive assessment system. The red marks in pencil denote JL's piece-by-piece attempt to pencil in the outline of the figure line by line. Note that it is the surrounded figure per se that should have been outlined in the template.

Patient 3, KH, demonstrated impairment on Matching Numbers and Number Detection due to a combination of left visual neglect in both instances as well as asymmetric search patterns in the former subtest. In addition to these visual neglect and parietal-based symptoms KH also demonstrated severe impairment on the Receptive Attention subtest. Pollman et al. (2003) examined the functional neuroanatomy of Posner and Mitchell's (1967) lexical/physical identity match task using a high temporal resolution event-related functional MRI design. This study's design most closely resembles the Receptive Attention subtest of the CAS however in the Pollman study targets are presented in pairs across the midline or within a visual field. In contrast, for Receptive Attention Item 5 involves physical matches and Item 6 involves lexical matches of letter pairs within the left and right visual fields. In these two subtasks both time for completion, number of errors, and false detections is tallied, which might be of use in examining the speed of lexical access across different hemifields given the wide-angle field of view within the Receptive Attention subtest. In Receptive Attention the manual praxis elements suggests that interactions between shape and lexical item coding might differentially interact with motor systems in unforeseen manners and likewise could provide useful information about linguistic-praxic lateralization processes (see Figure 5).

Unilateral presentation of shapes or letters as in Receptive Attention resulted in activation of unilateral lateral occipital and fusiform gyrus or bilateral activation of these areas, respectively (Pollman et al., 2003, p. 325). These investigators also examined the additional stepwise activation of letter name matches minus letter shape matches and found activations within: left lateral occipital complex, left fusiform gyrus, left intraparietal cortex, bilateral inferior frontal sulci, and right frontopolar cortex. The reverse contrast of letter shape minus letter name matches, similarly involved a distributed network including: bilateral posterior parts of the superior temporal gyri, bilateral superior frontal gyri, left frontopolar cortex, posterior cingulate, retrosplenial cortex, and bilateral cerebellum. These results suggest that hemispheres engage in resource sharing in letter name matching which does not occur in letter shape matching and finally that the resource sharing was restricted to these occipital regions. Thus it seems that name matching poses higher demands on visual letter processing beyond that predicted by additive factors compared with letter shape matching, and thus letter name information is most likely being transferred across the splenium (Berlucchi & Aglioti, 1999, p. 636); although the anterior and posterior cingulate may be involved in the coordination of such interhemispheric transfer processes.

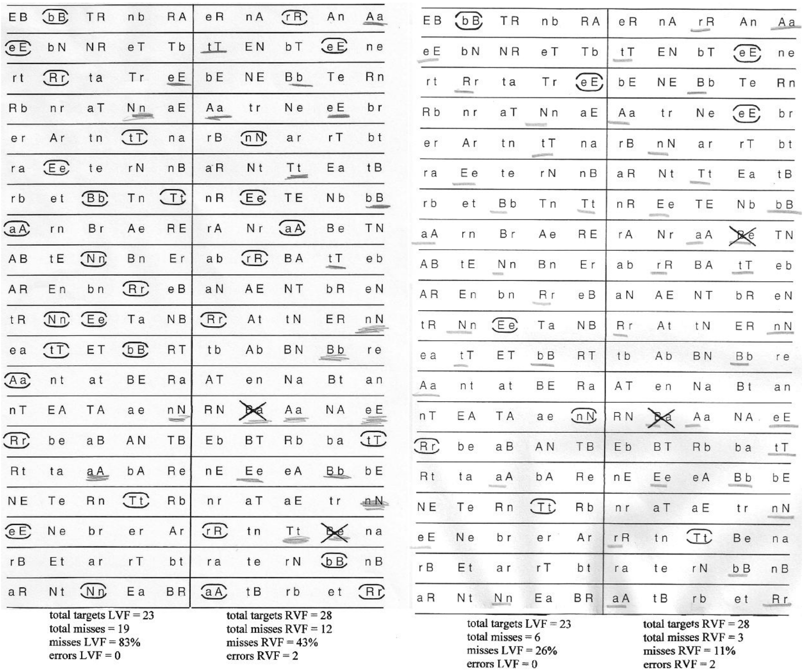

Figure 5. KH's first and second testing sessions took place 6 months apart. The illustration depicts Item 6 of the lexical match subtask of the receptive attention subtest. In the illustration red marks denote KH's answers, blue circles denote missed items, and blue x's through an item denote a false detection. The line down the middle of each Item 6 denotes an imaginary visual field midline depicted for sake of clarity of analysis.

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