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A nonparametric study of the performance of cortical lesion patients on the Cognitive Assessment System

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Abstract

Cortical lesion patients were tested on the Cognitive Assessment System (CAS) in the post-acute phase (median ≥ 1 month) to determine the degree of sensitivity and specificity of the CAS subtests to neuropsychological impairment. Nonparametric ANOVA and subsequent Mann–Whitney statistics were used. Demographic variables of age, education, handedness, sex were controlled for Matching Numbers was sensitive to right-hemisphere lesions while Verbal–Spatial Relations was sensitive to anterior lesions. Receptive Attention and Figure Memory were sensitive to posterior lesions. Number Detection was sensitive to right anterior lesions. Nonverbal Matrices was sensitive right anterior lesions and the inclusion of a disproportionate number of left-handers within this specific group appeared to be partly moderating this effect. The magnitudes of the performance decrement for these subtests were substantial with Figure Memory demonstrating the largest effect. The results suggest that select CAS subtests could be useful for the multiple baseline assessment of neuropsychological functioning.

Keywords: Ischemic stroke; Hemorrhagic stroke; Planning; Attention; Executive functions; Language functions; Laterality; Specificity

The Cognitive Assessment System or CAS is based on the PASS model of planning, attention, simultaneous and successive cognitive processes developed by Das, Naglieri and Kirby (1994). The model is based on Luria's tripartite synthetic view of the three functional units of the brain, that being a hierarchical control or executive system; a tonic arousal/attention system; as well as two coding/representational units: simultaneous synthesis and successive/sequential processing units. These units correspond, respectively, to the prefrontal convexity; the reticular formation and parts of the mesencephalon; as well as the posterior association cortices within the vicinity of the occitoparietotemporal junction (Luria, 1966). The CAS has proven to be a useful mean of assessing cognitive processes directly implicated in learning processes and in understanding exceptional learners and as such provides a theoretical and practical link between assessment and learning that other models often do not provide (e.g., see Das, 2002 for a review).

Recently, the CAS has begun to be used in neuropsychological contexts. Gutentag, Naglieri, and Yeates (1998) demonstrated that subtests within the Cognitive Assessment System (CAS) reliably discriminated between adolescents with traumatic brain injury. Wysocki et al. (2003) used the CAS in a large multiple baseline clinical neuropharmacological study and provided evidence that its subtests and scales demonstrated good test–retest characteristics. In a response

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to criticisms Haddad (2004) showed that select CAS planning subtests are not merely measuring speed of processing and point to definitive utilization of strategies by subjects. Ryan, Atkinson, and Dunham's (2004) study of 262 adults (mean age = 20 years) found that CAS subtests were useful for characterizing executive function impairments in college students.

Recently, Perez-Alvarez, Timoneda-Gallart, and Baus-Rosell (2006) found that epilepsy patients responding to topiramate scored better on the planning scale after 6 months on the medication suggesting that this composite scale could be useful as a global indicator of improvement in executive function. Mack et al. (2006) found that surgically restoring blood flow to children with hepatic thrombosis resulted in better performance on the attention composite scale 1 year after surgery. Thus, the test–retest characteristics of the CAS could potentially be of interest in baseline assessments of global cognitive functioning across a variety of domains in the neuropsychological setting. The purpose of this study was to examine the neuropsychological specificity of the CAS subtests in a heterogeneous sample of focal brain lesion patients using *t*-scores in the post-acute injury phase of recovery.

1. Method

The median delay between brain injury and assessment with the CAS was 1 month. Participants with diffuse subcortical or cortical involvement, severely incapacitating strokes or receptive aphasia, significant post-stroke depression, extensive occipital damage and co-morbid neurodegenerative diseases were excluded. A consecutive sample consisting

Table 1
A or ant.: anterior lesion, P or pos.: posterior lesion, Lat.: laterality of lesion, c.: centrum, C: control group, M: male, F: female, LT: left and RT: right, Hand: handedness, Educ. level: educational level in years of formal education (1: ≤8, 2: 9–12, 3: 13–14, 4: ≥15 years, respectively); age group (1: ≤25, 2: 26–40, 3: 41–50, 4: 51–60, 5: ≥61 years, respectively)

Case	Lesion	Lat.	A/P	Sex	Age group	Hand	Educ. level
1	Posterior left frontal lobe	Left	Ant.	M	4	Right	4
2	Left frontal horn and LT basal ganglia	Left	Ant.	F	3	Left	2
3	Anterior left frontal lobe	Left	Ant.	F	4	Left	2
4	LT frontal lobe	Left	Ant.	M	3	Right	2
5	LT inferior frontal and cingulate gyrus	Left	Ant.	M	5	Right	2
6	LT temporal lobe lesion	Left	Pos.	M	3	Right	2
8	LT occipitotemporal lesion	Left	Pos.	M	4	Right	2
9	LT parieto-occipital craniotomy	Left	Pos.	M	5	Right	2
10	LT parietal arteriovenous mal	Left	Pos.	M	2	Right	1
11	LT paracentral lobule	Left	Pos.	M	2	Right	2
12	RT posterior frontal operculum	Right	Ant.	F	4	Left	2
13	RT frontal lobe and basal ganglia	Right	Ant.	F	5	Left	2
14	RT frontal lobe lesion	Right	Ant.	M	4	Left	3
15	RT posterior frontal lobe	Right	Ant.	F	3	Right	2
16	RT frontal lobe and frontal operculum	Right	Ant.	M	3	Right	2
17	RT frontal lobe and RT basal ganglia	Right	Ant.	M	4	Right	4
18	RT frontal lobe and internal capsule	Right	Ant.	M	4	Right	2
19	RT c. semiovale and paracentral sulcus	Right	Pos.	M	4	Right	3
20	RT c. semiovale and paracentral sulcus	Right	Pos.	M	2	Right	3
21	RT frontoparietal lobe	Right	Pos.	M	5	Right	1
22	RT temporoparietal region	Right	Pos.	F	3	Right	2
23	RT frontoparietal region	Right	Pos.	M	4	Left	2
24	Bilateral frontal lobe lesions	C	C	M	1	Left	2
25	LT frontotemporal lobar region tumor	C	C	F	2	Right	4
26	Bilateral frontal atrophy	C	C	M	3	Right	2
27	Bilateral frontal atrophy	C	C	F	2	Right	2
28	Bilateral medial frontal lesions	C	C	M	1	Right	3
29	RT cerebellar lesion	C	C	F	2	Right	2
30	RT posterior cerebellar hemisphere	C	C	M	5	Right	2
31	Superior right cerebellar hemisphere	C	C	M	3	Right	2
32	Postero-central midbrain-pons lesion	C	C	M	4	Right	3
33	Unspecified	C	C	M	1	Right	2

of single infarct in-patients who met these criteria were screened by neurologists over a 9-month period. Neurologist's were instructed to screen for patients in the post-acute stable phase with a diversity of lesion localizations to be included so that a maximum amount of variation among subtest scores would be selected for.

All subjects were administered Annett's (1967) 12-point questionnaire to evaluate handedness after initial screening and informed consent for participation in the study was obtained by all subjects. At the same time that this preliminary assessment was completed demographic information was also gathered. Documentation regarding lesion locus, severity, lateralization, clinical neurological, radiological and neuroradiological findings was collated by participating neurologists (see Table 1).

2. Results

The anterior-lesioned group consisted of subjects for whom the center of mass of the lesion was anterior to the central sulcus and for whom at least 75% of the lesion extended exclusively within the frontal lobes. In contrast the posterior lesion group consisted of subjects for whom the center of mass of the lesion was posterior to the central sulcus and for whom at least 75% of the lesion extended within the parietal–temporal–occipital lobes. All subjects lesions were corroborated by neuroradiological report, a neuroradiologist's qualitative ratings of the images, and with visual inspection with lesion visualization software (MEDisplay, http://www.medisplay.com/html). The 10 subjects that did not fit exclusively into either the: (i) laterality or the (ii) rostral–caudal variable groupings were used as the control comparison subjects for nonparametric comparisons.

A chi-square analysis of the variables of sex, handedness, age, and education demonstrated that there were no significant differences in the frequencies of these demographics across the two groupings of anterior/posterior/control and left-hemisphere/right-hemisphere/control subjects (all p's > 0.15). An exception to this was found in frequencies of handedness among the anterior/posterior/control groups [$\chi^2(2) = 6$, $p < 0.05$]. Mann–Whitney U-test isolated the source of this effect to the fact that there were 1.5 times as many left-handers than expected on the basis of chance in the anterior-lesioned group alone. There were four left-handed women and two left-handed men in this group however this sex difference was found to not be significant.

Kruskal–Wallis H-tests statistically corrected for 12 nonparametric ANOVA demonstrated that for the laterality of the lesion (e.g., left-hemisphere, right-hemisphere and control subjects) there were significant main effects for Matching Numbers [$\chi^2(2) = 11$, $p < 0.004$]; Number Detection [$\chi^2(2) = 7$, $p < 0.03$]; and Nonverbal Matrices [$\chi^2(2) = 10$, $p < 0.007$]. These nonparametric ANOVA were followed by subsequent Mann–Whitney U-test multiple comparisons (Table 2).

Similarly Kruskal–Wallis H-tests corrected for 12 nonparametric ANOVA demonstrated that the for the rostral–caudal lesion variable (e.g., anterior, posterior and control subjects) there were significant main effects for Number Detection [$\chi^2(2) = 7$, $p < 0.03$]; Receptive Attention [$\chi^2(2) = 8$, $p < 0.01$]; Nonverbal Matrices [$\chi^2(2) = 9$, $p < 0.01$]; Verbal–Spatial Relations [$\chi^2(2) = 7$, $p < 0.03$]; and Figure Memory [$\chi^2(2) = 10$, $p < 0.008$]. Again nonparametric ANOVA were succeeded by subsequent Mann–Whitney tests (see Table 3).

For the anterior/posterior/control groups and for the subtests of Number Detection, Nonverbal Matrices and Verbal–Spatial Relations predicted t-scores were calculated using handedness as a covariate since there were a dispro-

Table 2
Sex, handedness, age and educational level of subjects

Lesion group	M	F	Handedness		Age		Education	
			LT	RT	Mean	S.D.	Mean	S.D.
LT lesion	9	2	3	8	49	13	11	3
RT lesion	8	4	4	8	50	9	12	3
Control	7	3	1	9	39	15	12	2
Anterior	7	5	6	6	52	7	12	3
Posterior	10	1	1	10	46	13	11	3
Control	7	3	1	9	39	15	11	2
Total	24	9	8	25	46	13	12	3

Table 3
Nonparametric analysis of CAS subtest *t*-scores across brain lesion groupings

CAS subtests	LT lesion *t*-score (S.D.) ($n = 11$)	RT lesion *t*-score (S.D.) ($n = 12$)	Control *t*-score (S.D.) ($n = 10$)	Mann–Whitney MC's	Estimate of ES
Matching Numbers	50 (9)	**44** (**8**)	**57** (**8**)	$p < 0.002$	1.3σ
Number Detection	49 (7)	**45** (**11**)	**57** (**8**)	$p < 0.02$	1.2σ
Nonverbal Matrices	51 (9)	**44** (**9**)	**57** (**6**)	$p < 0.004$	1.3σ

CAS subtests	Anterior *t*-score (S.D.) ($n = 12$)	Posterior *t*-score (S.D.) ($n = 11$)	Control *t*-score (S.D.) ($n = 10$)	Mann–Whitney MC's	Estimate of ES
Number Detection	**45** (**7**)	49 (12)	**57** (**8**)	$p < 0.02, 0.05$	1.2σ
Receptive Attention	48 (10)	**44** (**9**)	**57** (**7**)	$p < 0.008$	1.3σ
Nonverbal Matrices	**45** (**9**)	49 (11)	**57** (**6**)	$p < 0.002, 0.05$	1.2σ
Verbal–Spatial Relation	**46** (**7**)	49 (11)	**57** (**8**)	$p < 0.01, 0.05$	1.1σ
Figure Memory	49 (7)	**42** (**7**)	**59** (**9**)	$p < 0.004$	1.7σ

Bold values indicate exact statistical significance levels with Bonferroni correction for multiple comparisons.

portionate number of left-handers within the anterior-lesioned group. Kruskal–Wallis *H*-tests corrected for multiple nonparametric ANOVA demonstrated that the main effects for Number Detection [$\chi^2(2) = 7$, $p < 0.03$]; Nonverbal Matrices [$\chi^2(2) = 7$, $p < 0.03$]; and Verbal–Spatial Relations [$\chi^2(2) = 7$, $p < 0.03$] were all still significant. Nonparametric ANOVA were succeeded by Mann–Whitney multiple comparisons. This second set of comparisons using the covariate of handedness are depicted in the second column of probability values depicted in Table 3. However, on the Nonverbal Matrices subtest there was a large decrement in critical α between the *t*-score and the predicted *t*-score using handedness as a covariate—and the magnitude of this difference approached significance [$z = -1.25$, $p = < 0.10$]. Collectively then for these three subtests then only for Nonverbal Matrices was there statistical evidence that the left-handed variable was in part significantly moderating the effects of the lesion for the anterior group.

3. Discussion

All of the effects for the six subtests demonstrating dissociations were large (Cohen, 1988) despite the relatively modest sample size. The exception to this fact was on the Figure Memory subtest where the magnitude of the effect was very large. Stringent controls for multiple Bonferroni nonparametric ANOVA's as well as multiple comparisons suggests that the effects are not artifactual. Lesions were well characterized and demographics were matched as closely as possible. The exception to this last point was the disproportionate number of left-handers displaying impaired performance on the Nonverbal Matrices where it appeared that this variable was partly moderating this effect.

The sample as a whole consisted of a third women and this difference was significant [$\chi^2(1) = 6$, $p = 0.01$]. The reason for the disproportionate sampling of the sexes was likely three-fold. Men have an elevated risk of cerebrovascular accident at all ages (Braun et al., 2001). Moreover, at the relatively younger ages of stroke subjects recruited into this study testable stroke patients are often male since younger women that do happen to have a stroke tend to have poor prognosis due a selection effect of stroke severity and etiology (Roquer, Campello, & Gomis, 2003).

Finally, the apparent effect of left-handedness on Nonverbal Matrices performance could be explained on the basis of an increased frequency of the bilateral representation of language functions in sinistrals. In this context right-anterior lesions would be expected to exert a twofold effect on this group. We could expect linguistic mediation of the higher level analogical reasoning ceiling items of this group to be impaired. In addition impairment in nonverbal working memory, visuoperceptual and visuoattentional functions could be expected as consequence of right-hemisphere damages adverse effects on basal level items on the Nonverbal Matrices (Heilman & Valenstein, 2003).

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References

Annett, M. (1967). The binomial distribution of right, mixed and left-handedness. *Quarterly Journal of Experimental Psychology*, *19*, 327–333.

Braun, C. M., Montour-Proulx, I., Daigneault, S., Rouleau, I., Kuehn, S., Piskopos, M., et al. (2001). Prevalence, and intellectual outcome of unilateral focal cortical brain damage as a function of age, sex and aetiology. *Behavioral Neurology*, *13*, 105–116.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York: Academic Press.

Das, J. P. (2002). A better look at intelligence. *Current Directions in Psychological Science*, *11*, 28–33.

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994). *Assessment of cognitive processes: The PASS theory of intelligence*. Boston: Allyn & Bacon.

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

Haddad, F. A. (2004). Planning versus speed: An experimental examination of what Planned Codes of the Cognitive Assessment System measures. *Archives of Clinical Neuropsychology*, *19*, 313–317.

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

Luria, A. R. (1966). *Human brain and psychological processes*. New York: Basic Books.

Mack, C. L., Zelko, F. A., Lokar, J., Superina, R., Alonso, E. M., Blei, A. T., et al. (2006). Surgically restoring portal blood flow to the liver in children with primary extrahepatic portal vein thrombosis improves fluid neurocognitive ability. *Pediatrics*, *117*, 405–412.

Perez-Alvarez, F., Timoneda-Gallart, C., & Baus-Rosell, J. (2006). Topiramate and epilepsy in the light of Das–Naglieri Cognitive Assessment System. *Revista de Neurología*, *42*, 3–7.

Roquer, J., Campello, A. R., & Gomis, M. (2003). Sex differences in first-ever acute stroke. *Stroke*, *34*, 1581–1585.

Ryan, J. P., Atkinson, T. M., & Dunham, K. T. (2004). Sports-related and gender differences on neuropsychological measures of frontal lobe functioning. *Clinical Journal of Sport Medicine*, *14*, 18–24.

Wysocki, T., Harris, M. A., Mauras, N., Fox, L., Taylor, A., Jackson, S. C., et al. (2003). Absence of adverse effects of severe hypoglycemia on cognitive function in school-aged children with diabetes over 18 months. *Diabetes Care*, *26*, 1100–1105.