The Clinical Neuropsychologist
2000, Vol. 14, No. 4, pp. 535-545

1385-4046/00/1404-535$15.00

Myths of Neuropsychology: Intelligence, Neurometabolism, and Cognitive Ability*

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ABSTRACT

Recently, Dodrill (1999) revised a previously described ‘‘Myth of neuropsychology’’ (1997) to state: ‘‘Just as below average performances on neuropsychological tests are found when intelligence is below average, to that same degree above average performances on neuropsychological tests are expected when intellectual abilities are above average.’’ This study addresses the relationship between intellectual and neuropsychological performance in the context of Magnetic Resonance Spectroscopy (MRS) measurements of the neurometabolite N-acetylaspartate (NAA). When subjects were stratified by Full Scale IQ (Average, High Average, Superior) they differed significantly in terms of total neuropsychological performance [$F(2,47) = 17.63$; $p < .001$] and the neuronal marker NAA [$F(2,47) = 3.25$; $p < .05$]. Regression analysis across groups demonstrated that FSIQ and NAA were independently related to Total z-score [$F(1,47) = 29.43$; $p < .0001$] and accounted for over half the variance (r^2 of model = .56). The concurrent relationship of FSIQ and NAA to total neuropsychological performance suggests that the relationship between measures sensitive to intellectual ability and neuropsychological performance is real, and does not reflect arbitrary psychometric or scaling properties of the WAIS-III.

Dodrill (1997) has described six ‘‘myths’’, or common assumptions, of neuropsychology which invite careful reflection on clinical practice and challenge clinical neuropsychologists to re-evaluate some long-held assumptions. Myth 4 states that ‘‘above average performances on neuropsychological tests are expected when intellectual abilities are above average’’. This is an important clinical issue, central to the determination of neuropsychological deficit and/or disability in half of the population. To test this assumption, Dodrill presented data from 181 control cases, stratifying intellectual performance against the Impairment Index from the Halstead-Reitan neuropsychological battery (HRB). Dodrill found that, in this young cohort, the relationship between IQ and HRB Impairment Index is linear in IQs below 100, but the relationship asymptotes as ‘‘Full Scale IQ rises above 100 or 105.’’ His main explanation for this finding relies upon the purported nature of neuropsychological tests; that is, that they measure brain *dysfunction.* Consequently, brains of normal subjects (particularly those with above-average IQs) would not be expected to perform above ‘‘normal’’ function levels as assessed by the HRB.

Subsequently, other researchers have presented data suggesting that IQ is related to neuropsychological performance above the average range (Bell & Roper, 1998; Horton, 1999; Tremont, Hoffman, Scott, & Adams, 1998). A

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* This study was supported by NIH Grant NS35708 and the National Foundation for Functional Brain Imaging #99ER62764.

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Accepted for publication: August 5, 2000.

review of published norms revealed that, in addition to the HRB, certain measures of performance, including the Paced Auditory Serial Addition Test, Symbol Digit Modalities, Rey Complex Figure – Delayed Recall, and the Rey Auditory Verbal Learning Test, were related linearly to Full Scale Intelligence quotient (FSIQ), even when IQ scores were greater than 100 (Bell & Roper, 1998). A second set of archival data revealed that ‘‘subjects who earned above average FSIQ scores performed better (on several neuropsychological tests) than those who earned average FSIQ scores who in turn performed better than individual(s) performing in the below average range on FSIQ’’ (Tremont et al., 1998). Finally, Horton (1999) reanalyzed performance of 363 controls on the HRB and WAIS and found that higher IQ was associated with better neuropsychological performance on all measures except Finger Tapping with the dominant hand.

Recently, Dodrill (1999) revised Myth 4 to clarify the distinction he intended to make between the relative strength of the relationship between FSIQ and neuropsychological performance in below average versus above average individuals. Thus, Myth 4 would be restated as: ‘‘Just as below average performances on neuropsychological tests are found when intelligence is below average, to that same degree above average performances on neuropsychological tests are expected when intellectual abilities are above average.’’ He presents reanalyzed data of the original 181 subjects stratified by FSIQ performance (Below Average, Average, Above Average FSIQ), and demonstrates that the Above Average group was significantly better than the Average group on just 7 of 23 variables explored. Finally, he states that his intention to test Myth 4 was in application to (1) neurologically normal controls, to which (2) a broad battery of neuropsychological measures is administered, in situations under which (3) tests are administered according to their originally intended purpose.

To date, the discussion of the potential relationship between FSIQ and neuropsychological performance has not included any measures of the biological underpinnings of intellectual or neuropsychological performance. A different way to approach this issue is to determine whether FSIQ and neuropsychological status are empirically related to the underlying construct of brain metabolic function. Several in vivo metabolic markers of brain function have emerged from Magnetic Resonance Spectroscopy (MRS) studies which provide a quantitative measurement of the neurochemical component of neuronal-axonal variation in disease and health. Proton MRS (^{1}H-MRS) detects signals from metabolites, including N-acetylaspartate (NAA), creatine (Cre), and choline-containing compounds (Cho) (Fig. 1). NAA is synthesized in neuronal mitochondria (Bates et al., 1996), is predominantly localized in neurons (Urenjak, Williams, Gadian, & Noble, 1992), and does not cross the blood–brain barrier (Berlinguet & Laliberte, 1966). In disease, reduced NAA has been well associated with neuronal-axonal injury or death (Ross & Michaelis, 1994) and impaired cognition (Brooks, Jung, Ford, Grenel, & Sibbitt, 1999a; Brooks, Wesley, Kodituwakku, Garry, & Rosenberg, 1997; Friedman, Brooks, Jung, Hart, & Yeo, 1998; Friedman et al., 1999).

We recently reported that NAA concentrations assessed within a voxel of occipital-parietal white matter predicted both intellectual (Jung et al., 1999a) and neuropsychological (Jung et al., 1999b) performance in a cohort of neurologically normal college-aged students. Specifically, NAA predicted performance on timed or speeded neuropsychological tests, but not untimed tests, suggesting that NAA might tap ‘‘speed of processing’’. Given that our assay of NAA was conducted in white matter, it is possible that higher levels of NAA facilitates axonal functioning, perhaps conferring more rapid neural transmission through its putative role as an acetyl group donor for myelination (D’Adamo & Yatsu, 1996; Tallan, 1957). Indeed, two known predictors of neural transmission speed are myelin thickness and axonal diameter (Aboitiz, Scheibel, Fisher, & Zaidel, 1992). We hypothesized that, when subjects were stratified by FSIQ (Average, High Average, Superior), they would differ both in their total neuropsychological performance and in levels of NAA, a biological marker of cognition.

METHODS

Participants

Fifty-four participants (26 female, 28 male) were recruited from the local college community. Informed consent was obtained from all participants prior to study, under a protocol approved by the Institutional Review Board. We over-selected for increased levels of education (and thus older subjects) within this college community to increase the intellectual range of our sample. Participants were screened to exclude obvious organic or medical disease known to affect neurochemistry and neuropsychological performance: prior traumatic brain injury, disorders of attention, learning disability, neurological disease, psychiatric diagnosis, and use of psychoactive medications. Two participants were found not to meet experimental criteria after completion of testing (psychiatric diagnosis, drug abuse) and were excluded. Spectroscopic data were available on 50 of the remaining 52 subjects, as data for 2 participants was lost due to technical issues related to spectral acquisition. Thus, the final sample was comprised of 24 females and 26 males on which neuropsychological, intellectual, and spectroscopic data were complete. Forty-five of the current study participants were reported previously in a study of biochemical markers of cognition (Jung et al., 1999b).

Intellectual measurement

Intellectual examination was undertaken with the Wechsler Adult Intelligence Scale-3rd edition (WAIS-III), a reliable, valid, and standardized measure of IQ. Three subtests were not administered (Comprehension, Object Assembly, and Picture Arrangement). Prorated summary scores were generated for Verbal IQ (VIQ) and Performance IQ (PIQ), from which the Full Scale Intelligence Quotient (FSIQ) was calculated. Each intelligence quotient (VIQ, PIQ, and FSIQ) has a mean of 100 and a standard deviation of 15. Subjects were stratified for group comparisons by Average (90–109), High Average (110–119), and Superior (≥ 120) FSIQ scores (Wechsler, 1997).

Neuropsychological measurement

Neuropsychological examination was undertaken utilizing standard testing procedures, and was conducted during the same session as intelligence testing. This battery tested a broad range of domains commonly used to assess brain functioning, including attention (Paced Auditory Serial Addition Test: PASAT), memory [(Rey-Osterrieth Complex Figure Test: RCFT; California Verbal Learning Test (CVLT)], language [(Boston Naming Test: BNT; Controlled Oral Word Association (FAS)], visual (Facial Recognition Test: FACE), motor (Grip Strength: GRIP; Grooved Pegboard (PEG)], and frontal ''executive'' functioning (Trail Making Test: TMT; Stroop Interference Test (STR; Lezak, 1995)].

A composite measure of overall neuropsychological performance was calculated as follows. A representative variable was selected from each test to maximize the assessment of overall functional capacity: PASAT (number correct on 2-s trial); RCFT (total copy [RCFT-C] and 30-min delay score [RCFT-D]); CVLT (total recall over trials 1–5 [CVLT-T] and 20-min recall [CVLT–D]); BNT (total spontaneous and semantic cued correct); FAS (total production over three trials); FACE (total correct: short form); GRIP (kg average over three dominant [GRIP-D] and nondominant hand trials [GRIP-ND]); Grooved Pegboard (speed for both dominant [PEG-D] and nondominant hands [PEG-ND]); TMT (time on Trails A [TMT-A] and B [TMT-B]); STR (number correct for word [STR-W], color [STR-C] and interference trials [STR-I]). Representative variable *z*-scores were calculated by comparison to normative samples commonly utilized in research and clinical settings (Spreen & Strauss, 1998). The mean *z*-score (Total *z*-score) was then calculated and used in further analysis.

Magnetic resonance imaging and spectroscopy

All MR acquisitions were carried out on a 1.5 Tesla clinical MR scanner using standard software (GE Medical Systems, Waukesha, WI). Imaging included sagittal T_1- and axial T_1- and T_2-weighted series. A STEAM pulse sequence, including water suppression, was employed to sample one (12.6 cm^3) voxel location (TE = 30 ms, TR = 2000 ms, 128 averages) primarily within left occipito-parietal white matter. Specific voxel locations were prescribed from the T_1-weighted axial imaging series, and were localized to maximize white-matter and minimize gray-matter contribution. Quantification issues and techniques have been described previously by our group (Brooks et al., 1999b).

Voxel correction for partial volume

Images were segmented from the T_1-weighted series using a k-means clustering approach developed in our laboratory. Spatial information is automatically classified into clusters based on statistical properties of each image pixel (Petropoulos, Sibbitt, & Brooks, 1999). Each output cluster represents a different tissue type (e.g., white matter, gray matter, and cerebrospinal fluid [CSF]), as

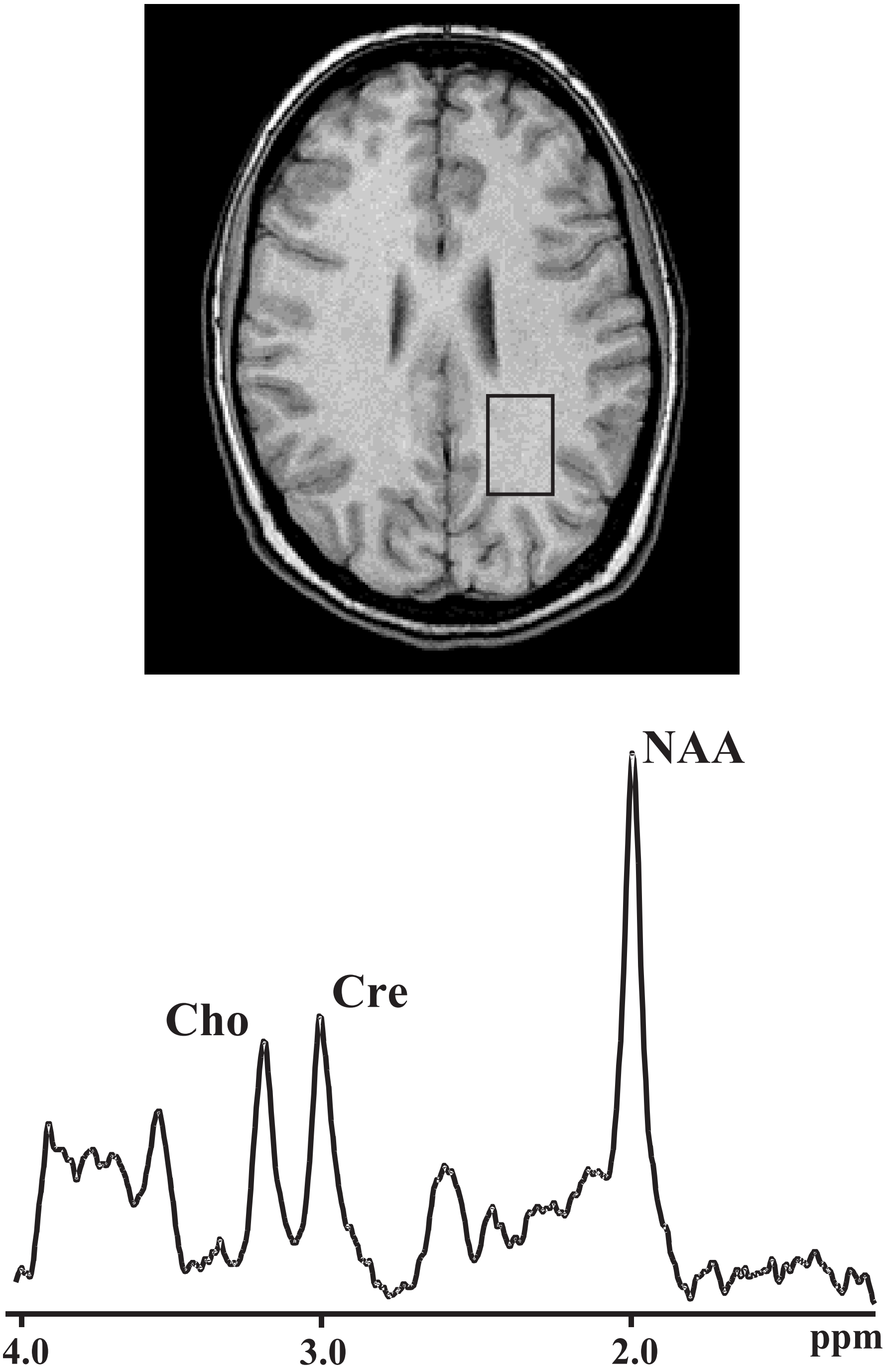

Fig. 1. Representative axial T_1 image, voxel location and resulting spectrum with Choline (Cho), Creatine (Cre) and N-acetylaspartate (NAA) peaks. Voxels were localized to maximize white-matter and minimize gray-matter contribution.

well as a small number of "partial volume" pixels comprised of both CSF and gray matter. The partial volume cluster was divided evenly between CSF and brain parenchyma. The total number of brain parenchyma pixels was divided by the total pixels within each voxel. This value was used to correct MRS values based upon the percent tissue within the voxel of acquisition.

Statistical analysis

Analysis of Variance (ANOVA) was used to assess the differences between Average, High Average, and Superior FSIQ groups. Post hoc group comparisons (*t* tests) were used to determine the source of group differences. Linear regression models were used to assess potential predictors of neuropsychological performance, the dependent variable. Independent variables were neurochemical concentrations of NAA and FSIQ. Two-tailed Pearson correlation coefficients were used to assess the relationships between FSIQ and neuropsychological subtest *z*-scores. Statistical analysis was conducted in SPSS for Macintosh (SPSS Inc., 1995).

RESULTS

Table 1 summarizes mean and standard deviation values for age, metabolic concentrations of NAA, FSIQ, and neuropsychological variables across the three FSIQ levels (Average, High Average, Superior). Because our subjects were recruited in a university setting, older subjects tended to have higher levels of education (i.e., post-bachelors) as well as higher FSIQ. Multivariate analysis of variance (MANOVA) revealed significant group differences for NAA ($F(2,47) = 3.25$; $p < .05$), and Total *z*-score ($F(2,47) = 17.63$; $p < .001$) across the three intellectual levels (Average, High Average, Superior). Post hoc group comparisons (*t* tests) revealed that the Average and Superior FSIQ group differed significantly in terms of age, NAA, and Total *z*-score, whereas the High Average and Superior FSIQ groups differed on Total *z*-score (Table 1). Group comparisons on specific neuropsychological tests are also summarized in Table 1. Of interest to this discussion, on nearly all tests of neuropsychological performance (except GRIP-D, GRIP-ND, STR-C, and STR-W), subjects in the average range of FSIQ performed at lower levels than subjects in the High Average FSIQ range, who in turn performed at lower levels than subjects in the Superior FSIQ range.

To determine the linear association of NAA and FSIQ to neuropsychological performance, each of these measures were regressed in a stepwise manner against Total *z*-score, the dependent variable. Regression analysis demonstrated that FSIQ ($t = 5.90$; $p < .0001$) and NAA ($t = 3.62$; $p < .001$) were independently related to Total *z*-score ($F(1,47) = 29.43$; $p < .0001$, r^2 of model = .56). Figure 2 shows the linear relationship of FSIQ to neuropsychological performance across the entire sample. Post hoc Pearson correlation coefficients revealed that 7 of 17 neuropsychological tests were significantly correlated with FSIQ (Table 2). No consistent relationship was found between FSIQ and motor tests (GRIP, PEG), the Trail Making Test, or the Stroop Test.

To identify the specific aspects of intellectual functioning that were most related to neuropsychological performance, we conducted a multiple regression analysis with all subtests of the WAIS-III as predictor variables of Total *z*-score. Stepwise regression revealed that two subtests of the WAIS-III best predicted total neuropsychological performance: Vocabulary ($t = 5.66$; $p < .0001$), and Block Design ($t = 3.08$; $p < .01$). These two variables accounted for more than half of the variance in Total *z*-score ($F(2,47) = 32.37$; $p < .0001$; r^2 of regression model = .58). Post hoc correlation analyses with Bonferroni correction for number of comparisons made (.05/34 = .001) revealed that the Vocabulary subtest was significantly related to verbal tests (BNT [$r = .81$; $p < .001$], FAS [$r = .45$; $p < .001$], CVLT-T [$r = .52$; $p < .001$], CVLT-D [$r = .56$; $p < .001$]), and the Block Design was related to measures of verbal fluency (FAS [$r = .47$; $p < .001$]) and visual memory (RCFT-D [$r = .62$; $p < .001$]).

DISCUSSION

We found that subjects stratified by FSIQ (Average, High Average, Superior) differed in aggregate neuropsychological performance (Total *z*-

Table 1. Demographic, Metabolic, Intellectual, and Neuropsychological Performance for the Sample at Three Levels of IQ (Average, High Average, Superior) and Analysis of Variance (ANOVA) Statistics for the Sample.

	Average FSIQ (90–109) *n* = 22		High Average FSIQ (110–119) *n* = 16		Superior FSIQ (120–145) *n* = 12		ANOVA	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	Overall *F*/	(*p*)
Age (years)	21.77^{c*}	(4.53)	23.69	(5.94)	26.42	(5.78)	2.98/	(.061)
NAA	12.92^{c*}	(.60)	12.95	(.76)	13.47	(.51)	3.25/	(.048)
WAIS-III FSIQ	101.2^{a***,c***}	(6.2)	112.8^{b***}	(2.7)	130.6	(7.6)	100.4/	(.000)
Total z-score	–.28^{a***,c***}	(.35)	.08^{b**}	(.34)	.42	(.30)	17.63/	(.000)
Paced Auditory Serial Addition Test	35.2^{c*}	7.0	36.0	9.1	40.7	8.0	1.99/	(.147)
Rey Complex Figure Test – Total	34.2	2.1	34.7	1.8	35.2	.8	1.08/	(.347)
Rey Complex Figure Test – Delay	19.3^{c**}	7.6	22.8	4.6	25.2	3.2	3.17/	(.051)
California Verbal Learning Test – Total	61.6^{c*}	8.1	64.6	5.2	68.7	6.1	4.24/	(.020)
California Verbal Learning Test – Delay	13.8^{c**}	2.1	14.5^{b*}	1.2	15.6	.9	4.73/	(.013)
Boston Naming Test	49.2^{a***,c***}	4.8	54.4	4.0	56.9	2.8	15.35/	(.000)
Verbal Fluency Test	33.1^{a**,c***}	9.6	41.3^{b*}	8.8	48.8	9.5	11.44/	(.000)
Facial Recognition Test	22.9	1.7	23.9	1.2	24.3	1.9	2.65/	(.082)
Grip Strength – Dominant Hand	42.6	12.8	43.6	15.3	43.6	10.9	.03/	(.966)
Grip Strength – Nondominant Hand	40.7	12.6	41.0	13.7	40.6	11.6	.01/	(.997)
Grooved Pegboard – Dominant Hand	63.4	7.8	60.5	8.8	59.0	5.4	1.47/	(.239)
Grooved Pegboard – Nondominant Hand	68.6	9.7	68.2	12.3	63.7	7.5	1.01/	(.372)
Stroop Test – Word Reading (45'')	107.3	15.7	104.6	19.2	108.1	10.1	.20/	(.816)
Stroop Test – Color Naming (45'')	76.2	11.2	73.6^{b*}	13.5	83.6	9.1	2.71/	(.077)
Stroop Test – Interference (45'')	45.0	5.8	45.6	5.1	46.6	5.7	.31/	(.732)
Trail Making Test – Part A	21.1^{c*}	5.4	19.2	4.9	17.5	3.6	2.20/	(.122)
Trail Making Test – Part B	53.9^{c**}	15.3	45.6	13.1	40.5	10.0	4.26/	(.020)

Group difference between Average and High Average (a), High Average and Superior (b), or Average and Superior (c) subjects.
$*p < .05$; $**p < .01$; $***p < .001$.

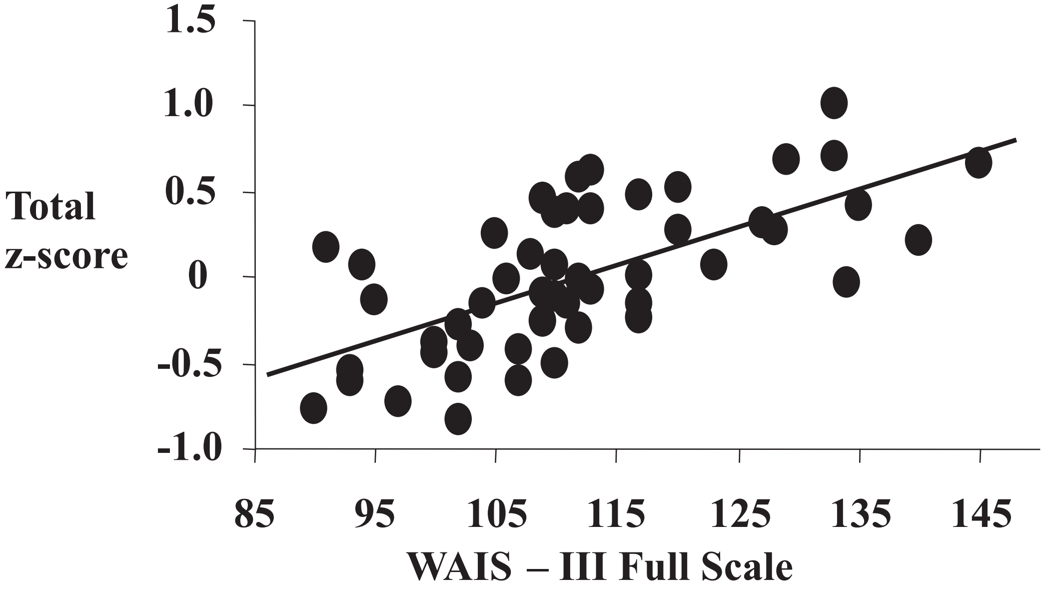

Fig. 2. Scatterplot of Total neuropsychological *z*-score and WAIS-III Full Scale IQ across the entire sample.

score). Our experimental cohort was extensively screened to exclude brain and psychological abnormalities and was recruited for the purpose of measuring the neuronal underpinnings of cognition in the normal brain. Moreover, this sample conformed to Dodrill's (1999) reasonable limitations to confine tests of the myth to neurologically normal young controls, tested with a broad neuropsychological battery, in situations where tests are administered under originally intended conditions. We also found that NAA, a biological marker of neuronal functioning, independently shows a relationship to neuropsychological performance, as does IQ. Because NAA provides a ratio-level measurement scale, this suggests that the relationship between tests sensitive to intellectual ability and neuropsychological performance is based on a common underlying biological factor, and does not reflect arbitrary psychometric or scaling properties of the WAIS-III.

Our results support previous associations between age, education, and overall neuropsychological performance reported in normal subjects (Heaton, Grant, & Mathews, 1991). Indeed, they confirm the suggestion that ''an adjustment of expectation in performance on neuropsychological tests should be made with relation to IQ'' (Reitan, 1985). Similarly, these results add to the increasing body of literature supporting an association between IQ and specific neuropsychological tests including the Rey Complex Figure (Boone, Lesser, Hill-Gutierrez, Berman, & D'Elia, 1993) the PASAT (Brittain, La Marche, Reeder, Roth, & Boll, 1991), Symbol Digit Modalities Test (Uchiyama et al., 1994), Rey Auditory Verbal Learning Test (Wiens, McMinn, & Crossen, 1988), California Verbal Learning Test (Wiens, Tindall, & Crossen, 1994), and subtests from the Halstead-Reitan Battery (Kane, Parsons, & Goldstein, 1985; Sherer, Scott, Parsons, & Adams, 1994). Although only 7 of 17 neuropsychological tests that we administered were significantly correlated with FSIQ, our observations highlight the benefit of aggregating various neuropsychological tests into a composite *z*-score, thus enabling a more direct comparison between the constructs of neuropsychological

Table 2. Pearson Correlation Coefficients for Wechsler Adult Intelligence Scale – III Full Scale Intelligence Quotient (FSIQ), Total *z*-Score, and Specific Neuropsychological Tests for All Cases, Average, High Average, and Superior Subject Groups.

	All Cases FSIQ (90–145) $n = 50$	Average FSIQ (90–109) $n = 22$	High Average FSIQ (110–119) $n = 16$	Superior FSIQ (120–145) $n = 12$
Total *z*-score	.66***	.32	.02	.22
Paced Auditory Serial Addition Test	.34*	.42*	.25	.06
Rey Complex Figure Test – Copy	.24	.23	–.16	.08
Rey Complex Figure Test – Delay	.42**	.32	.25	.40
California Verbal Learning Test – Total	.38**	–.22	.07	.62*
California Verbal Learning Test – Delay	.40**	.06	–.15	.29
Boston Naming Test	.63***	.20	.21	.58*
Verbal Fluency Test	.54***	.08	–.15	.22
Facial Recognition Test	.33*	–.01	.18	.46
Grip Strength – Dominant Hand	.21	.64***	.12	.40
Grip Strength – Non-dominant Hand	.20	.68***	.06	.46
Grooved Pegboard – Dominant Hand	–.14	.41	–.39	.17
Grooved Pegboard – Non-dominant Hand	–.08	.22	–.09	.53
Stroop Test – Word Reading (45”)	.04	.03	.19	.07
Stroop Test – Color Naming (45”)	.17	–.04	–.08	–.32
Stroop Test – Interference (45”)	.08	.03	.16	–.24
Trail Making Test – Part A	–.25	–.19	.04	.50
Trail Making Test – Part B	–.27	.10	.44	.22

Two-tailed Pearson correlation coefficients $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

performance and intellectual ability in future studies.

Although the exact mechanism by which NAA is related to neuronal functioning, and hence cognition, is unknown, it has been demonstrated that NAA contributes to lipid synthesis for myelination (D'Adamo & Yatsu, 1966; Tallan, 1957), is a metabolic precursor of N-acetyl-aspartyl-glutamate, an excitatory dipeptide (Blakely & Coyle, 1988), is a marker of neuronal oxidative phosphorylation (Bates et al., 1996), and may protect neurons from osmotic stress (Taylor et al., 1995). Considering only normal neuronal functioning, our current observation may reflect individual differences in the extent and efficiency of myelination occurring early in development, or myelin turnover associated with repair. Indeed, mitochondrial synthesis and distribution of NAA into the neuronal cytosol increases significantly during critical periods of brain development (Tallan, 1957). Similarly, because myelin is under continuous repair throughout the life span, even in normal subjects, lower concentrations of NAA may indicate more active myelin turnover, resulting in less efficient white matter functioning. Regardless of the precise mechanism, individual variation in NAA appears to have important consequences for myelination, and is consistent with the demonstrated importance of cerebral white matter connectivity in nerve cell conduction and cognition, both in health and across numerous neuropsychological disorders (Filley, 1998).

An important question for future research emerges from our use of a single, posterior white-matter voxel. We do not know how NAA assessed in other regions would relate to FSIQ or neuropsychological performance. Nonetheless, there is reason to believe that this particular region is important for diverse higher cognitive functions. Recent theories of brain-behavior relationships in normal subjects have stressed the central importance of white-matter interconnections in multiple neuronal networks (Mesalum, 1990). Indeed, recent fMRI results highlight the contribution of subcortical networks to conceptual reasoning skills in normal controls (Rao et al., 1997). The main association pathways sampled by our experimental voxel included axonal fibers from the posterior aspects of the superior and inferior longitudinal, occipitofrontal, and arcuate fasciculi, as well as those traversing the splenium of the corpus callosum. Consequently, this voxel location sampled association pathways connecting very disparate regions of brain, and underlying critically important association cortices. Moreover, the white-matter voxel lies within the cortico-subcortical and subcortico-cortical pathways central in regulating cortical tone. Thus, white matter NAA may reflect the quality of the interconnections between association cortices critical to neuropsychological performance.

The neural substrates of reasoning are being imaged with increasing sensitivity, and have demonstrated widely distributed regional activations analogous to the "working memory" circuitry proposed by Baddeley (1992). Indeed, the Raven's Progressive Matrices test (RPM), a measure known to predict performance on numerous reasoning tasks, was found to activate several widely distributed brain regions (including bilateral frontal cortex) in the normal brain (Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997). Similarly, Duncan et al. (2000), found extensive activation occurring in bilateral prefrontal cortex during performance of "high g" tasks, and argues for the specificity of frontal activation during tasks with high cognitive demand (Duncan et al., 2000). Thus, a possible explanation for why certain neuropsychological tests are related to IQ may be the wide distribution of brain regions used in problem-solving. Neuropsychological tasks with some cognitive complexity (i.e., distributed cognitive tasks relying heavily upon white-matter interconnections between the frontal and more posterior cortices) are well correlated with measures of intellectual performance, whereas more focal tasks (i.e., sensory-motor) are poorly related to intellectual ability.

Neuropsychologists in clinical and forensic settings often utilize premorbid estimates of IQ to establish functional decline after brain injury (Spreen & Strauss, 1998). Taken together with Bell and Roper (1998), Tremont et al. (1998), and Horton (1999), our results help to elucidate the appropriate use of IQ scores in the interpretation of neuropsychological results. Obviously, there are differences among neuropsychological tests in their relationship to IQ in individuals within the average range or higher. Thus, certain tests may be very appropriate for assessing neuropsychological decline following brain injury, but will be more weakly related to premorbid measures of IQ (above 100) than other neuropsychological tests, due to ceiling effects, reliance upon sensory-motor tests, and discrete localization of many subtests. On the other hand, more complex neuropsychological tests, including composite measures of verbal and visual memory, complex attention, working memory, and ''executive'' functioning, should be expected to roughly correspond to premorbid levels of IQ up to and including the superior range of performance. A priority within the field of clinical neuropsychology must be to establish a clear understanding of the specific associations between commonly used neuropsychological instruments and measures of intellectual functioning in health, injury, and disease.

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