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Neurocognitive Predictors of Academic Outcomes among Childhood Leukemia Survivors

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Abstract

Background—Acute lymphoblastic leukemia (ALL) is the most common pediatric cancer and survival approaches 90%. ALL survivors are more likely than healthy peers or siblings to experience academic underachievement yet little is known about neurocognitive predictors of academic outcomes.

Objective—Objectives were to compare neurocognitive abilities to age-adjusted standardized norms; to examine change over time in neurocognitive abilities; and to establish neurocognitive predictors of academic outcomes.

Methods—Seventy-one children were followed over the course of therapy. Cognitive abilities were assessed during Induction when the child was in remission (Baseline) and annually for 3 years (Year 1, Year 2, Year 3). Reading and mathematics abilities were assessed at Year 3.

Results—Fine motor dexterity was significantly below age-adjusted norms at all data points, but showed improvement over time. Baseline visual-motor integration was within the normal range but significantly declined by Year 3, and mean scores at Years 2 and 3 were significantly below age-adjusted norms. Verbal short-term memory was significantly below age-adjusted norms at all assessments. Visual-motor integration predicted reading and mathematics abilities. Verbal short-term memory predicted reading abilities, and visual short-term memory predicted mathematics abilities.

Conclusions—CNS-directed therapy is associated with specific neurocognitive problems. Visual spatial skills, verbal and visual short term memory predict academic outcomes.

Implications for practice—Early assessment of visual spatial perception and short-term memory can identify children at risk for academic problems. Children who are at risk for academic problems could benefit from a school based Individual Educational Program and/or educational intervention.

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Introduction

Acute lymphoblastic leukemia (ALL) is the most common pediatric cancer and because of advances in therapy, event free survival approaches 90%^{1–3}. Central nervous system (CNS)-directed therapy is needed to prevent recurrence in the brain that is a sanctuary site for sub-clinical disease^{4–6}. Most CNS-directed treatment regimens include intrathecal (IT) and escalating or high doses of intravenous methotrexate (IV MTX); cranial radiation is used for children who have or are at risk for CNS disease. Despite the necessity of CNS-directed treatment for event free survival, approximately 40% of pediatric ALL survivors experience neurotoxicity most commonly manifested as diminished cognitive abilities^{7–15}. These same survivors are more likely than healthy peers or siblings to experience academic underachievement and repeat a grade^{16–23}. Although there is evidence that children with ALL are at risk for school-related problems, little is known about the potential impact of diminished cognitive abilities on academic outcomes. Yet, identifying children who are at risk for academic problems is essential for knowing who is in need of and most likely to benefit from early intervention. In a sample of children receiving therapy for ALL, the specific aims were to:

1. Compare performance on selected domains of neurocognitive abilities frequently compromised by CNS-directed therapy to age-adjusted standardized normative data;
2. Examine change over time in these domains of neurocognitive abilities;
3. Identify neurocognitive abilities that predict academic outcomes.

Background

There is consistent evidence for significant neurocognitive impairment in children treated for ALL with radiation,²⁴ however, these effects are also reported in those patients treated with chemotherapy alone¹⁷. In one meta-analysis evaluating studies where children were treated with chemotherapy only, ALL survivors scored lower on the Purdue Pegboard test, a neuropsychological assessment of fine motor dexterity and coordination, when compared to normative data¹⁷. Additionally, in a recent assessment of ALL survivors who were at least five years post-diagnosis, children who received standard or high-risk therapy scored lower compared to normative expectation on neuropsychological measures evaluating verbal working memory and processing of complex visual information, as well as parent ratings of metacognitive skills²⁵. While neuropsychological deficits have been well documented in these children, there is also growing evidence of decreased academic achievement among ALL survivors.

Deficits in academic performance among children treated for ALL are seen in measures of both mathematics and reading. Findings from a meta-analysis of five studies evaluating outcomes in chemotherapy-only patients showed that ALL survivors performed significantly lower than average on mathematic and reading achievement¹⁷. In a population-based assessment using data from the Iowa Cancer Registry and the Iowa Testing Program, ALL survivors scored significantly lower than the 50th percentile on multiple domains, with the most marked deficits in mathematics performance¹⁶. Notably, when compared to their

healthy counterparts, childhood cancer survivors also have deficits in other academic domains including science, foreign languages, art, and music²³. Childhood cancer survivors are also more likely to experience greater anxiety²³, social introversion²³, frequent absences¹⁸, and have poor adjustment as rated by parents²⁶. Finally, at least 25% of ALL survivors require special education services^{25, 27}.

In spite of the cognitive and academic deficits seen among ALL survivors, much work remains in developing and applying successful interventions. Childhood cancer survivors who participated in a Cognitive Remediation Program (CRP) showed improved academic achievement as rated by seven measures including the Woodcock-Johnson Test of Achievement. However, there were no significant improvements in individual neurocognitive measures²⁸. Other researchers have suggested that preventing neurocognitive late effects requires reliable prediction of risk²⁹. Among medulloblastoma survivors, younger age at diagnosis and high-risk disease were associated with declines in academic outcomes over time. Reading ability among ALL survivors was predicted by sluggish cognitive tempo, which is characterized by symptoms including confusion, daydreaming, overtiredness, and blank staring³⁰. Because of this growing body of work related to improved risk prediction, Peterson and colleagues have suggested that “baseline testing of all young ALL patients is needed to track neuropsychological and academic skills over time to facilitate early intervention and prevent academic failure¹⁷.” The analyses described in this paper provide new information on some of the neurocognitive domains that predict later academic achievement in ALL survivors.

Materials and Methods

Eligible subjects were recruited from two pediatric oncology treatment centers in the southwestern United States. Eligibility included a recent diagnosis of pre-B or pre-T cell ALL and receiving treatment according to Children’s Oncology Group (COG) protocols for low, standard, high, or very high risk disease. CNS-directed treatment for these children included high- or intermediate-dose IV MTX and IT MTX administered at specific intervals over the 2 ½ to 3 years of ALL therapy. Children with a history of other causes of neurologic injury (i.e. seizures, traumatic brain injury), developmental disabilities (i.e. Down Syndrome or attention deficit disorder), CNS disease, or who were undergoing a bone marrow transplant were excluded. Approval was obtained from the respective Human Subjects Protection Committee; consent was obtained from parents and assent from children 7 years of age or older at the time of ALL diagnosis.

A within-subjects repeated measures design was used to assess cognitive abilities as soon as the child was in remission and medically stable (Baseline) and then annually for 3 years (Year 1, Year 2, and Year 3). Cognitive assessments included measures of fine motor dexterity, visual-motor integration, and short-term verbal and visual memory. Academic abilities were assessed at Year 3, and were assessed by standardized measures of reading and mathematics.

Cognitive Assessments

Fine motor dexterity was assessed by the Purdue Pegboard test which measures the child's ability to quickly place small pegs into round holes using first only the dominant hand, then the non-dominant hand, then both hands simultaneously. Results are reported as Z scores ($M = 0$; $SD = 1$). Test-retest reliabilities range from 0.63 to 0.82³¹. Visual-motor integration was assessed by the Beery Test of Visual Motor Integration (VMI). The VMI measures the child's ability to copy designs of increasing difficulty and requires coordination of visual perception and finger and hand movements, and has been found to be a good predictor of academic achievement³². Results are reported as standard scores based on a mean of 100 and SD of 15. Short-term visual and verbal memory were assessed by the Stanford Binet Intelligence Scale – 4th Edition (SB-IV) Bead Memory and Memory for Sentences subtests³¹. Bead Memory is a short-term visual memory task that requires immediate reproduction of bead sequences. Task difficulty increases as children continue to provide correct responses. Memory for Sentences is a short-term verbal memory task that requires repeating brief phrases or sentences that increase in length and complexity. These measures are moderately correlated with general intelligence ($r = 0.67$). Results are reported as standard age scores based on a mean of 50 and a standard deviation of 8.

Academic Assessments

Academic abilities were assessed by the Woodcock-Johnson Tests of Achievement-III (WJ-III) Calculation and Letter-Word Identification subtests³³. The Calculation subtest measures written mathematical computation skills. Items on this test are arranged in increasing difficulty. Early items require writing single numbers; whereas later items progress to addition, subtraction, multiplication, division and some geometric, trigonometric and calculus operations. Children complete as many mathematic problems as they are able to until 6 consecutive incorrect responses are made. Median reliability coefficients for each subtest are equal to or greater than 0.86³³. The Letter-Word Identification subtest measures the ability to identify letters and read single words. Responses are scored based on correct letter identification and ability to pronounce a word. Children are not asked about the meaning of words. Results are reported as standard scores with a mean of 100 and standard deviation of 15. Median cluster reliabilities range from 0.92 to 0.98³³.

Data were analyzed using SPSS version 20. Descriptive statistics were used to summarize sample characteristics and performance on cognitive measures. Mean scores on neurocognitive measures were compared to age-adjusted standardized norms using one sample T-tests. General linear model (GLM) one-way ANOVA was used to test for change over time in performance on the neurocognitive measures. Associations between neurocognitive measures and academic abilities were tested using Pearson Correlation. Finally, four stepwise multiple linear regression analyses, one for each measurement occasion, were used to identify neurocognitive measures at Baseline, Year 1, Year 2, and Year 3 that predicted academic outcomes at Year 3. Statistical significance was set at $\alpha = .05$.

Results

The sample included 71 children with ALL who completed all neurocognitive and academic assessments. Fourteen children were from a smaller treatment center (Center 1) and 57 children were from a second larger treatment center (Center 2), both in the Southwestern United States. Demographic and clinical characteristics of the sample of the 71 participants are summarized in Table 1. Patients were an average of 6.8 years old at diagnosis and 55% were female. Of those that did report ethnicity and/or race, 25.4% attributed their race as Caucasian, 1.4% as Native American, and 1.4% as African American, (71.8% did not report race). Thirty-four percent attributed their ethnicity to Hispanic and 2.8% as other. These categories are not inclusive. For this study we only included children who were sufficiently fluent in English to complete the cognitive measures. Four children were not enrolled into the cognitive study due to a language barrier.

There were no significant differences in demographic or ethnicity/race characteristics of subjects by treatment center. With the exception of fine motor dexterity at Baseline, there were no significant differences in mean scores on the measures of neurocognitive and academic abilities. Children at both treatment Centers performed significantly below age-adjusted norms on the measure of fine motor dexterity at the Baseline assessment. However, children treated at Center 1 performed lower than those at Center 2 for dominant hand ($t = -2.53$; $p = 0.014$), non-dominant hand ($t = 2.49$; $p = 0.015$), and both hands ($t = -2.47$; $p = 0.016$).

Fine motor dexterity at Baseline was significantly below standardized age-adjusted norms ($P < .001$) for dominant hand ($t = -6.149$), non-dominant hand ($t = -5.342$) and both hands ($t = -5.715$). As shown in Figure 1, motor dexterity improved over time but performance remained significantly below age-adjusted norms ($P < .01$) at Year 1. Fine motor dexterity also improved at Year 2 but declined at Year 3. At Year 3, performance was below standardized scores for dominant hand ($t = -4.098$; $P = .01$), non-dominant hand ($t = -2.537$; $P = .014$) and both hands ($t = -2.443$; $P = .017$).

Visual-motor integration at Baseline was within the normal range. However, as shown in Figure 2 performance on this neurocognitive measure declined over time such that scores were significantly below age-adjusted norms at Year 2 ($t = -2.683$; $P = .009$) and Year 3 ($t = -5.220$; $P < .01$).

Mean scores on the short-term memory measures at each assessment are shown in Figure 3. Visual short-term memory mean scores were within the normal range at all assessments, however, verbal short-term memory mean scores were significantly below age-adjusted norms at Baseline ($t = -2.487$; $P = .015$), Year 1 ($t = -2.146$; $P = .035$), and Year 3 ($t = -2.703$; $P = .009$).

Results from the GLM for repeated measures ANOVA and within-subjects contrasts are shown in Table 2. There was a significant decline over time in scores on the Beery VMI ($F = 3.75$, $P = .012$), and the mean score at Year 3 was significantly below that at Baseline. In contrast to visual-motor integration, fine motor dexterity actually improved over time for the dominant, non-dominant, and both hands. For the dominant and both hands trials, mean

scores at Years 1, 2 and Year 3 were significantly higher than at Baseline ($P < .05$), and for the non-dominant hand mean scores at Years 2 and 3 were significantly higher than at Baseline. There was no significant change over time in verbal or visual working memory.

At Year 3 scores on reading abilities ranged from 52 to 132 ($M = 100.70$; $SD = 14.66$); and scores on calculation ranged from 61 to 124 ($M = 100.45$; $SD = 14.35$). Based on normative data, approximately 16% of children would be expected to fall above and 16% would be expected to fall below the mean standard score of 100. For reading abilities, 10 children in our sample (14%) performed at least one standard deviation below and three children (4.2%) performed at least one standard deviation above the standardized mean score. For mathematics abilities, 14 children (19.7%) performed one standard deviation or more below and 13 children (18.3%) performed one standard deviation or more above the standardized mean score.

Table 3 summarizes correlations between neurocognitive measures at each assessment with academic abilities at Year 3. At all four measurement occasions visual-motor integration, verbal short-term memory, and visual short-term memory were significantly correlated with reading and mathematics abilities at Year 3. With the exception of dominant hand at Year 1 and Year 3, fine motor dexterity was significantly correlated with reading scores. However, fine motor dexterity was not associated with math abilities.

Results from the four step-wise multiple linear regression analyses are shown in Table 4. Reading abilities at Year 3 were predicted by performance on measures of visual-motor integration (Beery VMI) and verbal short-term memory (SB-IV Memory for Sentences) at Baseline, Year 1, and Year 3 ($P < .05$). Visual-motor integration and fine motor dexterity of the dominant hand at Year 2 also predicted reading abilities at Year 3. Visual-motor integration at all assessments significantly predicted math abilities ($P < .05$). Math abilities were also predicted by visual working memory at Baseline and Year 1 and verbal working memory at Year 3.

Discussion

In one of the most comprehensive studies of its kind, our results suggest that fine motor dexterity, visual motor integration and verbal short term memory are impacted by ALL treatment such that performance was below age and gender matched norms. Fine motor dexterity improved at Year 2 and then declined at Year 3. This could be due in part to vincristine treatment, which is most intense during induction and post-induction and subsequently related to the persistent effect of methotrexate which is administered throughout the duration of therapy. In contrast to fine motor dexterity, visual motor integration and verbal short term memory continued to decline over the Year 1, Year 2, and Year 3 assessments. Since children in this study received treatment according to the same COG protocols, differences in baseline fine motor dexterity abilities between children at the 2 Centers could be due to the smaller sample size at Center 1.

Findings also suggest that cognitive assessments during ALL treatment may predict academic outcomes at the end of treatment. Specifically, visual-motor integration at

Baseline, Year 1, Year 2, and Year 3 was associated with both verbal academic abilities and mathematic academic abilities. Other cognitive domains that predicted verbal academic performance in Year 3 were verbal short-term at Baseline, Year 1, and Year 3 and fine motor dexterity at Year 2. Additionally, visual short-term memory at Baseline, Year 1, and Year 3 predicted mathematic academic performance.

Visual-motor/visual-spatial abilities are implicated in mathematical ability among children with neurodevelopmental disorders including children treated for cancer (for a review see³⁴). Possible explanations include that for some math tasks including estimation and operations (e.g., subtraction) children use a mental number line dependent on visual spatial processing. Additional visual aids could be a useful strategy when working on mathematical concepts, rather than relying on mental images. Further, fine motor and finger abilities, such as those measured with the Purdue Pegboard Test, are linked to math achievement in early grades³⁴. Visual-motor/visual-spatial and fine motor skills uniquely predicted object-based quantity manipulation related to adding and subtracting³⁵. The extent to which visual-spatial skills and finger dexterity contribute to math achievement is unknown, but each appears to offer unique contributions.

Verbal short-term memory was also associated with poorer academic achievement as assessed by Letter-Word Identification and Calculation. The ability to recall what has just been said (including the sequence of information) is important for remembering instructions about assignments. Distinctions are made between short-term memory and working memory^{36–38}. In children ages 4 to 11 years of age, there are 4 components in the cognitive processes underlying working memory. The four components are verbal short term memory, visuospatial short term memory, verbal working memory and visuospatial working memory. Literature suggests that verbal and visuospatial working memory capture common underlying cognitive skills.³⁷ Hence, the relationships between verbal short-term memory and academic achievement may reflect a deficit in the ability to recall direct instructions rather than the more complex task of recalling and manipulating information as in working memory. The additional information can be used to inform interventions such as making sure the child understands and remembers instructions.

Parents and older children who participated in our study frequently reported problems with fine motor skills. These problems were most pronounced at the Baseline assessment and presumably due to systemic treatment with vincristine. While fine motor dexterity improved over time, at Year 3 fine motor dexterity remained below age-adjusted standardized norms. Very young children (toddlers and preschoolers) rely on sensorimotor skills to explore and learn about their environment. Interruption or compromise in the development of these skills can have adverse impact on the development of higher-order abilities. Although systemic and CNS-directed therapies appear to adversely impact fine motor dexterity and coordination, these skills were not the most consistent or strongest predictors of academic reading and calculation abilities. However, interventions to improve fine motor dexterity in children with ALL that could be implemented by parents or caregivers are an important area for future research.

Our findings are in keeping with previous investigations; specifically, both cognitive impairment and academic deficits have been reported among children being actively treated for ALL and for ALL survivors. For instance, according to a recent meta-analysis¹⁷, children with ALL treated with chemotherapy alone scored lower on several neurocognitive domains including general intelligence, the Purdue Pegboard, and some aspects of executive function. Additionally, among childhood cancer survivors, there are deficits among many academic domains including mathematic performance and reading achievement as well as science, foreign languages, art, and music²³. Furthermore, our results support the work of Reeves et al, which indicated reading ability among ALL survivors was predicted by sluggish cognitive tempo³⁰. However, it is important to note that although our subjects' scores on the cognitive and fine motor measures were significantly lower than normative data, the overall level of performance did not fall into the impaired range.

Findings from the study reported here show that early assessment of visual-motor integration, fine motor dexterity, verbal short-term memory, and visual short term memory can be used to identify children at risk for academic problems. These findings corroborate other research showing the importance of these various domains for academic success³², and early assessment could be used to screen for "at risk" children in order to identify those children who could benefit from a school based Individual Educational Program (IEP) and/or cognitive remediation, such as our Mathematics Intervention Program³⁹. Early intervention may alter the trajectory of deficient reading and mathematical ability and change the course of school achievement, and subsequently lead to impact on level and quality of functional abilities in adulthood.

Our findings have several clinical implications. First, problems in visual motor integration, verbal and visual working memory were predictive of later academic difficulties, which continue to persist in a subset of children with ALL. Therefore, assessing these specific cognitive abilities during ALL treatment may be useful in identifying children in greatest need of early academic intervention. Second, assessment of visual motor integration and working memory can be completed in a relatively short period of time. More extensive neurocognitive evaluations can be quite time consuming and costly, and perhaps could be completed at less frequent intervals.

Limitations

Although we were able to longitudinally follow a sample of 71 children over the duration of ALL treatment, our sample size did not allow us to determine more subtle cognitive changes that may predict academic outcomes. Larger sample sizes are needed to determine those modest effects. Additionally, we were not able to evaluate academic performance beyond Year 3. It will be important to determine if these neurocognitive measures can predict long-term academic performance. Finally, we were not able to incorporate biological correlates of academic performance (e.g., genetic predictors).

Summary

In response to recent work suggesting the importance of tracking cognitive abilities during treatment to predict academic outcomes, we conducted an investigation to validate the utility of these measurements among ALL patients. While this study demonstrates the importance of cognitive changes during therapy on academic outcomes, future assessments should incorporate measures of other domains to improve risk prediction, which may aid the prevention of adverse outcomes among those treated for ALL.

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Figure 1.
Purdue Pegboard Performance Over Time
Abbreviation: M, mean.

Figure 2.
Beery VMI Performance Over Time
Abbreviations: VMI, Visual Motor Integration; M, mean.

Figure 3.
Stanford-Binet Performance Over Time
Abbreviation: M, mean.

Table 1

Participant Demographic and Clinical Characteristics

	N	%	
Gender			
Male	39	45.1	
Female	42	54.9	
Treatment Risk Stratum			
B-precursor Low	8	11.3	
B-precursor or B cell Standard	41	57.7	
B-precursor or B cell High	12	16.9	
B cell Very High	2	2.8	
T cell ALL	8	11.3	
	M (SD)	Min	Max
Age at diagnosis	6.8 (3.3)	2.9	14.7
Age at Baseline evaluation	6.9 (3.3)	3.1	15.2
Age at Year 1 evaluation	8.0 (3.3)	4.5	16.3
Age at Year 2 evaluation	9.1 (3.3)	5.5	17.0
Age at Year 3 evaluation	10.1 (3.3)	6.4	17.9
Maternal education (years)	13.3 (2.6)	5	20
Paternal education (years)	13.1 (2.8)	5	20

Table 2
Change in Neurocognitive Measures over Time: GLM for One-Way Repeated Measures ANOVA

Neurocognitive Measure	df	F	P	Within-subjects Contrasts		
				Level	F	P
Purdue Pegboard dominant hand	3	7.930	<.001	Baseline vs Year 1	7.616	.007
				Baseline vs Year 2	25.076	<.001
				Baseline vs Year 3	5.729	.020
Purdue Pegboard non-dominant hand	3	5.858	.001	Baseline vs Year 1	2.915	NS
				Baseline vs Year 2	12.044	.001
				Baseline vs Year 3	5.391	.023
Purdue Pegboard both hands	3	8.886	<.001	Baseline vs Year 1	6.566	.013
				Baseline vs Year 2	18.425	<.001
				Baseline vs Year 3	14.327	<.001
Beery VMI	3	3.750	.012	Baseline vs Year 1	0.580	NS
				Baseline vs Year 2	1.502	NS
				Baseline vs Year 3	8.870	.004
SB IV Memory for Sentences	3	0.345	NS	NR		
SB IV Bead Memory	3	1.075	NS	NR		

Abbreviations: NS, not significant; NR, not relevant; VMI, Visual Motor Integration; SB, Stanford-Binet

Table 3

Associations Between Cognitive Measures and Academic Outcomes

Cognitive Measure by Assessment	Letter-Word Identification		Calculation	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
Baseline				
Berry VMI	0.477	< .001	0.428	< .001
SB Bead Memory	0.247	.020	0.547	< .001
SB Memory for Sentences	0.539	< .001	0.443	< .001
Purdue Pegboard dominant hand	0.363	.001	0.080	NS
Purdue Pegboard non-dominant hand	0.220	.033	0.088	NS
Purdue Pegboard both hands	0.278	.010	0.038	NS
Year 1				
Berry VMI	0.583	< .001	0.357	.001
SB Bead Memory	0.380	.001	0.453	< .001
SB Memory for Sentences	0.537	< .001	0.305	.005
Purdue Pegboard dominant hand	0.092	NS	0.084	NS
Purdue Pegboard non-dominant hand	0.217	.038	0.183	NS
Purdue Pegboard both hands	0.208	.044	0.014	NS
Year 2				
Berry VMI	0.559	< .001	0.479	< .001
SB Bead Memory	0.488	< .001	0.395	< .001
SB Memory for Sentences	0.468	< .001	0.368	.001
Purdue Pegboard dominant hand	0.372	.001	0.193	NS
Purdue Pegboard non-dominant hand	0.235	.027	0.125	NS
Purdue Pegboard both hands	0.285	.009	0.216	.040
Year 3				
Berry VMI	0.464	< .001	0.472	< .001
SB Bead Memory	0.388	.001	0.380	.001
SB Memory for Sentences	0.591	< .001	0.386	.001
Purdue Pegboard dominant hand	0.166	NS	0.079	NS
Purdue Pegboard non-dominant hand	0.209	.043	0.148	NS
Purdue Pegboard both hands	0.245	.022	0.161	NS

Abbreviations: VMI, Visual Motor Integration; SB, Stanford-Binet; NS, not significant.

Table 4Neurocognitive Predictors of Academic Outcomes^a

Letter-Word Identification	R	R²	R² change	β
SB Sentence Memory Baseline	.517	.267	.267	.385
Beery VMI Baseline	.582	.338	.071	.298
Beery VMI Year 1	.542	.294	.295	.427
SB Sentence Memory Year 1	.605	.367	.073	.293
Beery VMI Year 2	.766	.586	.586	.714
Purdue Dominant Hand Year 2	.795	.633	.047	.222
SB Sentence Memory Year 3	.607	.368	.368	.547
Beery VMI Year 3	.664	.440	.072	.275
Calculation	R	R²	R² change	β
SB Bead Memory Baseline	.557	.310	.310	.457
Beery VMI Baseline	.627	.393	.083	.305
SB Bead Memory Year 1	.455	.207	.207	.381
Beery VMI Year 1	.514	.263	.057	.249
Beery VMI Year 2	.573	.328	.328	.573
SB Sentence Memory Year 3	.607	.368	.368	.531
Beery VMI Year 3	.673	.453	.080	.301

Abbreviations: VMI, Visual Motor Integration; SB, Stanford-Binet;

^aResults from stepwise regression; neurocognitive measures are independent variables; Letter-Word Identification and Calculation at Year 3 are dependent variables; statistical significance .05