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ORIGINAL ARTICLE

Are the Results of the Beery-Buktenica Developmental Test of Visual-Motor Integration and Its Subtests Related to Achievement Test Scores?

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ABSTRACT: *Purpose.* Although visual analysis, motor coordination, and visual-motor integration can each affect performance on a test of visual motor integration, previous studies have not reported the relative importance of these components to the relation between visual motor integration and learning readiness, reading, and math. This investigation relates academic achievement in reading and math to performance on the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) and its subtests, Visual Perception and Motor Coordination. *Methods.* The VMI was administered to 155 children in second through fourth grades (7 to 10 years of age; mean, 8.4 ± 1.0 years). The Otis-Lennon School Ability Test and Stanford Achievement Test were administered by the school. *Results.* A significant difference was found in performance on the VMI and Visual Perception and Motor Coordination subtests between children in the upper and lower quartiles in reading ($p = 0.020$, $p < 0.001$, and $p = 0.027$, respectively) and math achievement ($p = 0.004$, $p < 0.001$, and $p = 0.01$, respectively). The VMI standard score was significantly correlated with Stanford total math standard score ($p = 0.001$) and a trend toward significance was found for Stanford reading score ($p = 0.050$) while partially controlling for verbal school ability and age. In addition, Visual Perception and Motor Coordination standard scores were significantly related to Stanford math ($p < 0.001$ and $p = 0.005$, respectively) and reading score ($p = 0.008$ and $p = 0.027$, respectively) after partially controlling for verbal school ability and age. Multiple linear regressions controlling for performance on the VMI and each subtest, as well as age and verbal cognitive ability, showed a significant relation between the Visual Perception subtest score and math achievement. *Conclusion.* Visual perceptual ability should be assessed in children with poor math and/or reading achievement. (Optom Vis Sci 2003;80:758–763)

Key Words: academic achievement, children, motor coordination, visual-motor integration, visual analysis, reading, mathematics

Visual perception is the process of extracting and organizing visual information from the environment.[1] Visual-motor integration is the ability to coordinate visual perception and finger-hand movements.[2] Performance on a test of visual-motor integration can be affected by visual spatial/discrimination ability and motor skill as well as the ability to integrate the two. Although differences of opinion exist,[3, 4] a substantial body of work has shown a positive relationship between visual perceptual skill and academic measures such as learning readiness, reading, and math.[5–13] Feagans and Merriwether[9] studied the relation between poor visual discrimination ability and achievement (both reading and general) in 66 learning-disabled and 66 control children in a 6-year longitudinal study. They found that children with reduced visual discrimination ability at age 6 or 7 performed more poorly in reading and overall achievement throughout the elementary school years compared with controls and compared with learning-disabled children without reduced visual discrimination ability. Visual-motor integration is another visual perceptual skill that has been shown to be positively correlated with academic achievement. For example, Leton et al.[13] administered psychometric tests of sequencing, visual-spatial ability, auditory-verbal skill, and motoric ability to 100 severely learning-disabled students to determine different classifications of learning-disabled students. He found a large cluster of children (36%) with low scores on the visual-spatial and motor tests (visual-spatial subtests of the WISC-R [Picture Completion, Picture Arrangement, Block Design, and Object Assembly], the Benton Test of Visual Retention, the Bender-Gestalt, and the Purdue Perceptual Motor Survey) and better performance on verbal and auditory-perceptual tasks.[13]

In addition, a higher prevalence of visual motor skill dysfunction has been found among a learning-disabled population compared with a nonlearning-disabled control group from a clinic population. Rosner and Rosner[8] found reduced visual motor skill (as measured by the Beery Visual-Motor Integration Test, Rutgers Drawing Test, and the Test of Visual Analysis Skills) in 78% of learning-disabled students ($n = 261$) compared with only 25% of the nonlearning-disabled students in this clinic population ($n = 496$; $p < 0.001$).

A similar relation has also been demonstrated in normally achieving children. Keogh and Smith[11] administered the Bender-Gestalt, a test of visual-motor integration, to kindergartners ($n = 73$) and found that it was a good predictor of sixth grade reading performance ($r = 0.51$). In addition, Taylor Kulp[12] investigated the relation between academic achievement and visual-motor integration skill using the Beery Developmental Test of Visual-Motor Integration (VMI) in a group of 191 children in kindergarten through third grade. She found that visual-motor integration skill was significantly related to scores on standardized tests administered by the school and to the teachers' ratings in reading, math, writing, and spelling ($p < 0.0001$, $p < 0.0001$, $p < 0.0001$, and $p < 0.0118$, respectively). Furthermore, the significant correlations with teacher's ratings of math and writing ability were maintained after partially controlling for cognitive ability.[12]

Even authors who have expressed a difference of opinion have reported a difference in visual motor skill between good and poor readers (e.g., on a test that involved copying geometric figures, a "draw a bicycle" test ($p < 0.0001$), and the "draw a clock" test).[14] Finally, intervention with visual perceptual therapy in children with visual perceptual deficits has been found to improve visual perceptual skill as well as to increase the effectiveness of academic intervention,[15, 16] although this is controversial.

In summary, a large body of literature shows a relation between achievement in reading and math and performance on tests of visual motor integration. Visual analysis, motor coordination and visual-motor integration skill can each impact the performance on a test of visual motor integration and tests commonly used in optometric practice, such as the VMI, provide subtests to allow practitioners to differentiate between the various types of deficits. The question, therefore, arises as to the relative contribution of these components in the overall relation between visual-motor integration and academic achievement. Previously, Kavale[10] showed a somewhat stronger relation for visual discrimination (16%) than for visual motor integration (12%) with reading in a meta-analysis of 161 studies. However, many of the studies included in Kavale's meta-analysis did not include controls for intelligence/cognitive ability, and intelligence/cognitive ability has been identified as a potential confounder in studies examining the relation between achievement and visual perceptual skill. Furthermore, the relation between these subskills (visual analysis, motor coordination, and visual-motor integration) and math achievement has not been investigated previously. Thus, the purpose of this study was to determine the relation between reading and math achievement and visual motor integration, visual analysis, and motor coordination using a widely used test (the VMI and the VMI Supplemental Developmental Tests of Visual Perception [VP] and Motor Coordination [MC]). Partial controls for age and verbal cognitive ability were included.

METHODS

Subjects

All of the children in the second, third, and fourth grade classes from a primarily white, middle-class, suburban elementary school were invited to participate in this approved study. Thirty-five children were unable to participate; their standardized academic achievement scores were not available because they were new to the school in the fall and standardized testing was administered the previous spring. Additionally, 16 children did not participate due to lack of consent or absence during the time of the study.

Procedures

The elementary school independently selected and administered the Stanford Achievement Test Series (ninth edition, 1995, Harcourt Brace, San Antonio, TX) and the Otis-Lennon School Ability Test (seventh edition, 1996, Harcourt Brace) the previous spring to all enrolled first, second, and third graders. The resulting scores were used as measures of academic achievement and ability. The Otis-Lennon School Ability Test (OLSAT) is a group-administered standardized test that measures verbal and nonverbal cognitive abilities that relate to a student's ability to learn and do well in school. The OLSAT and Stanford Achievement Test are often administered together to obtain a comparison of ability and achievement. The OLSAT verbal ability scores were used to provide controls for cognitive ability because the failure to control for cognitive ability has been a criticism of previous investigations of visual perception and academic performance.[17] The Stanford total math and reading percentile scores were used as a measure of math and reading ability, respectively. These scores are each a composite measure of several component skills and reflect the overall ability in each area. There are a number of levels of the OLSAT and Stanford available to allow assessment of children in kindergarten through grade 12.

Visual perceptual skills were assessed using the VMI (fourth edition, revised), and the VMI Supplemental Developmental Tests, Visual Perception and Motor Coordination. The Beery VMI (fourth edition) is a copy forms test that is frequently administered during visual perceptual evaluations. It is a well-researched, commonly used, standardized test with an objective scoring system.[2, 18] The VMI supplemental tests contain the same forms, but were designed to identify visual analysis and motor coordination difficulties. Specifically, the Supplemental Developmental Test of Visual Perception assesses the child's visual analysis/visual spatial skills in a motor-reduced fashion by asking the child to identify each matching form. On the other hand, the Supplemental Developmental Test of Motor Coordination test focuses on the child's motor integration skill and minimizes the analysis requirement. In the Motor Coordination test, the child "traces" each form by connecting the dots within the provided paths.

The perceptual tests were individually administered according to the test directions by a clinician who was trained in the procedure. The VMI and its subtests were scored by the first author, who was masked to the results of the standardized test scores.

Statistical Analyses

A statistician was consulted for statistical analyses, and statistics were generated with SPSS Base 8.0 for Windows. Independent samples, two-tailed t-tests were used to compare the VMI performances of children in the upper vs. lower quartiles in reading and math achievement. Partial correlations were used to determine whether there were significant correlations between the standardized achievement test scores (Stanford Math and Reading Standard Scores) and the VMI and its subtests (Standard Scores) while controlling for age and verbal cognitive ability (Otis-Lennon verbal standard score). Multiple linear regressions were used to determine the relative contribution of each VMI area.

RESULTS

A total of 155 children (mean age, 8.4 ± 1.0 years) participated in this study. This group included 42 second graders, 55 third graders, and 58 fourth graders. All of the children in the sample population were able to complete the VMI and the Supplemental Developmental Tests of Visual Perception and Motor Coordination. Mean and standard deviation was determined for each visual perceptual test (Tables 1 to 3).

Independent samples, two-tailed t-tests showed a significant difference in performance on the VMI and Visual Perception and Motor Coordination subtests between children in the upper and lower quartiles in reading ($p = 0.020$, $p < 0.001$, and $p = 0.027$, respectively) and math achievement ($p = 0.004$, $p < 0.001$, and $p = 0.01$, respectively) (Tables 4 and 5).

Partial correlations controlling for age and verbal cognitive ability revealed that VMI standard score was significantly correlated with the Stanford total math score ($r = 0.274$, $r^2 = 8\%$, $p = 0.001$). A trend toward significance with total reading score was also found ($r = 0.163$, $r^2 = 3\%$, $p = 0.050$). The Visual Perception and Motor Coordination subtests were significantly correlated with both Stanford total reading (VP: $r = 0.233$, $r^2 = 5\%$, $p < 0.005$; MC: $r = 0.184$, $r^2 = 3\%$, $p < 0.027$) and total math (VP: $r = 0.346$, $r^2 = 12\%$, $p < 0.001$, MC: $r = 0.218$, $r^2 = 5\%$, $p = 0.008$) (Table 6).

Multiple linear regressions were performed to further examine the relation between the VMI and its subtests and math and reading ability. The VMI and Visual Perception and Motor Coordination subtest scores were all included in the model as well as controls for age and verbal cognitive ability. This analysis revealed no significant relations between the VMI or its subtests and reading achievement. In the analysis for math achievement, a significant relation was found for Visual Perception, however, the VMI and Motor Coordination subtests dropped out of the model (i.e., nonsignificant) (Table 7).

DISCUSSION

Children in this study population performed below what would be expected from the published norms. It was observed that a large proportion of the children in this group exhibited poor pencil grips while taking the VMI and its subtests. Thus, the lower scores for this population on the tests that are motor-involved could be attributed to the high percentage of children with poor pencil grips.[19] In addition, the school acknowledged that pencil grip and handwriting skills were not emphasized in their curriculum.

A significant difference on the VMI and its subtests was found between the children in the upper and lower quartiles in math and reading performance. Therefore, these results support previous studies showing a significant relation between visual perceptual/visual motor ability and math and reading achievement.[5–13] Furthermore, these significant correlations between visual perception and academic achievement appear to indicate that perceptual motor skills could contribute to several basic learning skills associated with normal educational development, such as (1) accurate visual perception of letters, phonemes, sight words, and numbers; (2) visual form constancy (such that variations in handwriting and font can be accurately interpreted); (3) visual discrimination of similar letters and numbers (so that similar letters such as "p" and "q" can be accurately distinguished; (4) visual memory of letters, phonemes, numbers, and irregular words; (5) visual spatial skill (to

TABLE 1.
Descriptive statistics for the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) scores.

	Mean Raw Score	Mean Standard Score (SS)[a]	Standard Deviation of SS[a]	95% Confidence Interval for SS
Grade				
Second, N = 42	15.17	92.19	11.19	88.70–95.68
Third, N = 55	17.20	94.71	10.37	91.91–97.51
Fourth, N = 58	18.14	93.17	12.87	89.79–96.56
Age[b]				
7, N = 38	15.45	94.08	9.77	90.87–97.29
8, N = 42	17.02	95.00	11.75	91.34–98.66
9, N = 56	17.70	92.98	11.89	89.80–96.17
10, N = 18	17.89	89.89	13.78	83.04–96.74
Total	17.00	93.45	11.55	91.62–95.28

[a] VMI published standard scores have a mean of 100 and a standard deviation of 15.
[b] One 11-year-old child is not included in the analysis by age.

TABLE 2.
Descriptive statistics for Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) Supplemental Developmental Test of Visual Perception.

	Mean Raw Score	Mean Standard Score (SS)[a]	Standard Deviation of SS[a]	95% Confidence Interval for SS
Grade				
Second, N = 42	17.86	98.26	14.58	93.72–102.81
Third, N = 55	20.25	101.58	13.52	97.93–105.24
Fourth, N = 58	21.26	101.40	16.76	96.99–105.80
Age[b]				
7, N = 38	18.18	100.66	12.76	96.47–104.85
8, N = 42	19.79	100.62	14.72	96.03–105.21
9, N = 56	20.63	99.93	17.71	95.19–104.67
10, N = 18	22.11	102.78	12.48	96.57–108.99
Total	19.98	100.61	15.06	98.22–103.00

[a] VMI published standard scores have a mean of 100 and a standard deviation of 15.
[b] One 11-year-old child is not included in the analysis by age.

TABLE 3.
Descriptive statistics for Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) Supplemental Developmental Test of Motor Coordination.

	Mean Raw Score	Mean Standard Score (SS)[a]	Standard Deviation of SS[a]	95% Confidence Interval for SS
Grade				
Second, N = 42	15.67	90.52	9.00	87.72–93.33
Third, N = 55	16.73	87.29	11.07	84.30–90.28
Fourth, N = 58	18.90	89.36	13.55	85.80–92.93
Age[b]				
7, N = 38	15.50	90.63	8.32	87.90–93.37
8, N = 42	16.52	88.05	11.62	84.43–91.67
9, N = 56	18.61	89.98	13.17	86.46–93.51
10, N = 18	18.44	84.94	11.84	79.05–90.83
Total	17.25	88.94	11.59	87.10–90.78

[a] VMI published standard scores have a mean of 100 and a standard deviation of 15.
[b] One 11-year-old child is not included in the analysis by age.

TABLE 4.
Comparison of Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) performance in children in the upper and lower quartiles in reading achievement.

Quartile	N	Mean	SD	p Value
VMI				
Lower	38	32.1	22.7	0.020
Upper	39	45.2	25.4	
Visual perception				
Lower	38	40.4	27.4	<0.001
Upper	39	67.5	26.4	
Motor coordination				
Lower	38	25.3	19.0	0.027
Upper	39	36.0	22.6	

TABLE 5.
Comparison of Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) performance in children in the upper and lower quartiles in math achievement.

Quartile	N	Mean	SD	p Value
VMI				
Lower	40	29.4	22.4	0.004
Upper	41	45.5	25.7	
Visual perception				
Lower	40	42.4	29.0	<0.001
Upper	41	70.6	23.6	
Motor coordination				
Lower	40	24.6	20.1	0.01
Upper	41	36.8	21.5	

maintain one's place on a page of text or in a column of numbers, for example); (6) visual fine motor skill (such that letters and words can be accurately reproduced within given boundaries); and (7) higher levels of visual conceptualization, visual attention, and visual memory.[3]

On the other hand, further analyses of the relation between

TABLE 6.
Partial correlations between achievement scores and the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) and its subtests controlling for age and verbal cognitive ability.[a]

	VMI Standard Score	Visual Perception Standard Score	Motor Coordination Standard Score
Stanford total math standard score	r = 0.274[b] p = 0.001 N = 144	r = 0.346[b] p < 0.001 N = 144	r = 0.218[b] p = .008 N = 144
Stanford total reading standard score	r = 0.163 p = 0.050 N = 144	r = 0.233[b] p = 0.005 N = 144	r = 0.184[b] p = 0.027 N = 144

[a] Decrease in sample size is the result of absences during portions of the standardized testing.
[b] Significant at the $\alpha = 0.05$ level.

TABLE 7.
Predictors of math achievement.

Dependent Variable	Predictors	β	p Value	Adjusted R^2
Stanford total math standard score	Visual Perception	0.133	0.035	0.393
	Verbal Cognitive Ability	0.592	<0.001	
	Age	0.310	0.858	

VMI scores and reading ability in this group were not consistently significant. In addition, it could be questioned whether the partial correlations (0.163 to 0.233), although statistically significant, are clinically meaningful. The correlations found in the current study were weaker than those previously reported.[5, 10–12, 19] This lower relation could be attributed to the lack of controls for cognitive ability/intelligence in some previous studies.[5, 10, 11] Conversely, the lower relation could be due to the fact that the children in this study were older (second through fourth grade) because it has been reported that perceptual skills have the greatest impact in the earlier school years.[5, 19]

A consistently significant relation was found between visual perceptual ability and math in this study. This study showed a significant statistical relation between math achievement and performance on tests of visual motor integration, visual perception (visual spatial/visual discrimination skill) and motor coordination. Therefore, these results support previous reports that visual perceptual skills are related to mathematics skills.[6, 12] In addition, although it has been argued that reports of a relation between visual perception and achievement are merely due to the confounding effects of cognitive ability/intelligence, this study supports previous research showing that these associations are maintained after controlling for verbal cognitive ability/intelligence.[12] Therefore, the significant relation between visual perception and achievement is not merely due to the fact that children who are more intelligent do better on tests in general.

Finally, regression analysis showed that, among the VMI and Visual Perception and Motor Coordination tests, performance on the Visual Perception test was most predictive of current achievement in math as measured by standardized testing. It could be argued, however, that the correlations found are influenced by the specific skills addressed in this study. The current study uses a global measure of math and reading achievement, yet one may expect higher correlations for the VMI and Motor Coordination subtests if a measure that incorporated writing/motor ability had been used or if handwriting skill had been studied.

In conclusion, visual perceptual skill should be regarded to be among the factors significantly related to math and reading achievement. This study suggests that children with poor achievement in math and reading should be tested for deficits in visual perceptual skill. Further research should also evaluate the efficacy of perceptual therapy on academic instruction in children with perceptual deficits.

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