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Evaluation of Visual-Motor Integration Functions in Children Between 6-15 Years of Age

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Abstract

Objective: *Visual-motor integration skills are considered an essential domain of clinical and psycho-educational assessment. The goal of the present investigation is to provide the Turkish norms for the Beery-Buktenica Developmental Visual-Motor Integration Test (VMI-4th) for children and adolescents between the ages of 6-15 years as part of a comprehensive neuropsychological test battery.*

Method: *A total of 1887 children from elementary and high schools in the city of Bursa were recruited for this study. From this sample 44 children were re-tested 3-4 weeks following the first administration for test-retest reliability.*

Results: *Findings showed clear developmental trajectories in visual-motor integration skills. Significant performance increments were observed in six month intervals for ages 6 and 7. Starting from age 8, norms were established for each age group separately. Girls and boys performed similarly on the VMI-4. Test- retest correlation was modest but within an acceptable range.*

Conclusion: *The age-based norms established for the VMI-4 in this study can be used to assess children between the ages of 6-15 years as part of a clinical neuropsychological and a psycho-educational assessment. The mean VMI scores presented in this study represent performance of children in middle and middle-upper socio-economic status and may not represent the normal performance range of children from lower SES.*

Key Words: *Visual-motor integration, development, children, neuropsychology*

Visual-motor integration is the ability to transform visually perceived objects to a motor output. This complex skill which requires intact visual perception, psychomotor speed and hand-eye coordination (Weil and Amundson 1994) is mediated by multiple brain regions and structures (see Schultz et al 1998). Comprehensive neuropsychological assessment involving different cognitive skills is an integral part of functional diagnosis. Evaluation of visual-motor integration abilities is essential for many types of neuropsychological testing. In general visual-motor integration is assessed by copying a visually presented figure, either by drawing or by constructing the figure in 3-D.

Although a comprehensive review of the clinical significance of cognitive impairments among children with psychiatric disorders is beyond the scope of this paper, it is important to note that the deficits in visual-perceptual and fine motor coordination have been well documented in various childhood neuropsychiatric disorders. Perceptual-motor skill deficits do not only create academic difficulties, but also have debilitating effects on children's ability to perform daily activities. Performance deficits on tests measuring these abilities are evident in some cases, especially when poor visual-motor performance leads to poor academic achievement (Klein 1978, Kulp 1999, Sortor and Kulp 2003), such as Learning Disorders (Leton et al 1987, Skeen et al 1982). However in other cases such as Attention Deficit Hyperactivity Disorder (ADHD), Tourette's Syndrome (TS), and Bipolar Disor-

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der (BP), the visual-motor integration problems can be ambiguous, complicated by comorbid psychopathologies and overshadowed by other cognitive difficulties (Olvera et al 2005, Piek and Dyck, 2004).

Compared to other childhood psychiatric problems, Tourette Syndrome has been consistently studied in terms of underlying visual-motor deficits most probably because of its adverse motor symptomatology. Schultz et al (1998) investigated neuropsychological performance on tests measuring visual-motor integration skills in children aged 8 -14 years with Tourette's Syndrome (TS). The findings of this study revealed that the TS group performed significantly lower on Beery-Buktenica Visual-Motor Integration Test (VMI) compared to healthy controls. In addition, the results of discriminant function analysis conducted with various neuropsychological performance measures showed that only VMI performance scores and commission errors on Continuous Performance Task discriminated TS groups from healthy controls. The authors (Schultz et al 1998) concluded that visual-motor integration and fine-motor skills are areas of significant weakness in children with TS and should be routinely assessed in neuropsychological assessments for this group. In a recent study Bloch et al (2006) supported the significant relationship between VMI performance and TS diagnosis however their results failed to show any predictive power of visual-motor integration performance of symptom severity in adulthood.

Children with Attention Deficit Hyperactivity Disorder also show performance decrements in several cognitive domains with varying severity. Yochman et al (2006) investigated the possibility of developmental delays within the domains of sensory- motor, language and intellectual functioning of a sample of preschool children with ADHD. The results of this study showed significant performance deficits in multiple cognitive and sensory-motor functioning in the ADHD group. Based on their findings the authors emphasized the importance of evaluating the sensory-motor functioning of preschool children with ADHD symptoms.

In general visual-motor integration problems are prominent in Learning Disorders (Leton et al 1987, Skeen et al 1982). Especially children with Non Verbal Learning Disorders present significant performance deficits in visual-spatial, visual-perceptual domain (Rourke, 1987).

Valid and reliable assessment of cognitive functions in neurodevelopmental disorders is an important component of diagnosis, intervention and prevention. The development of Turkish norms for the neuropsychological tests in the assessment of healthy and clinically diagnosed children is essential. Regarding the tests measuring visual-motor abilities, recently Ozer (2007) provided normative data on the Bender-Gestalt test for Turkish children ages from 5 year 5 months to 11 year 10 months. The results of this study revealed a developmental trend in visual-motor skills. Also the comparison between Turkish children and children in US sample at ages 5 and 6 years showed different performance patterns. This finding supports Ardilla and Roselli's (1994) argument against the concept of culture-free non-verbal tests and strengthens the need for appropriate norming of any cognitive measure developed in other cultures. Given the importance of neuropsychological assessment with appropriately normed, standardized tests, our purpose in this study is to establish normative values for Beery-Buktenica Developmental Test of Visual-Motor Integration Fourth Edition (VMI-4th) for Turkish children and adolescents between the ages of 6 to 15 years.

The Beery Buktenica Developmental Test of Visual Motor Integration (VMI) is a test of sensory-motor integration developed by Beery (1967). The VMI has an extensive age range (2-17) with developmental age norms. It has been frequently used in clinical neuropsychological and educational evaluations as well as occupational therapy assessments (Bonifacci 2004, Kleinman and Stalcup 1991, Knoff and Sperling 1986). The fourth version of VMI (VMI-4) was published in 1997 (Beery 1997). The psychometric properties of VMI-4 have been well documented. Overall test- retest and inter-rater reliabilities were reported as 0.87 and 0.94 respectively (Beery 1997). Concurrent validity studies revealed high correlations with other measures of visual-perceptual/motor abilities (see Bradley-Johnson 1998). In general, the VMI test is relatively independent from executive planning abilities and is considered to be a "purer" measure of visual-motor skills (Rhodes, D'Amatao and Rothlisberg 2009)

METHOD

Participants: A total of 1887 children and adolescents between the ages of 6.0-15.11 years (mean:9.9 sd: 2.65) were recruited from 8 different schools located in the middle-upper socio-economic districts of the city of Bursa. The sample consisted of 896 girls (47.5 %) and 991 boys (52.5 %).

Instrument:

Beery-Buktenica Developmental Test of Visual-Motor Integration-4th (VMI-4): The Developmental Test of Visual-Motor Integration was developed by Beery (1967)

to test visual motor abilities in children ages between 2-17 years for educational and clinical purposes. Over the years the test has been re-normed and standardized (Bradley-Johnson 1998). The VMI-4 consists of 3 practice, 15 (short form) and 24 (long form) increasingly complex geometrical shapes. The short form contains the first 15 stimuli of the long form and can be used with children ages 2.0 years through 7 years 11 months only. In this study, short form was administered to the children ages between 6 and 7 years, whereas the long form was administered to children ages 8 and older. For both of the forms the participants are required to copy a geometric figure without using an eraser. Only one attempt is permitted for each figure. The test is terminated after three consecutive incorrect copies. The VMI-4 can be administered either individually or in a group setting (Beery 1997). In addition to the main test, the VMI-4 has two separate supplementary tests to assess visual perception and motor coordination. These additional tests have been shown to provide valuable information regarding to specific perceptual and motor deficits in clinical practice (Kulp and Sortor, 2003). Supplementary tests were not included in the present study.

Procedure: The study was approved by the Turkish Ministry of Education Bursa Chamber's Ethical Committee. Separate permissions regarding school applications were also provided by each school principle. The research assistants were trained to administer the VMI-4. Individual administrations were done with 6 and 7 year olds. Group administrations were carried out for the older age groups during class hours. During the class administrations test booklets were distributed to the class. The participants were instructed to copy all the figures in the booklet and the termination criterion (three consecutive mistakes) was applied during the scoring. After the administration of the tests, the research assistants contacted school psychologists and/or counselors for information regarding possible learning disabilities, developmental delays and neurological problems within the participants. Documented cases were excluded from the data processing. The protocols which did not conform to the test instructions (such as drawing pictures and writing words on the test booklets) were also excluded from the study. The tests were scored by using the scoring criteria specified in the test manual (Beery 1997).

Statistical Analyses

Each age group (6 to 15 years) was divided into 4-three month developmental age groups (for example, age 6 was grouped as 6.0 months to 6.2 months, 6.3 months to 6.5 months, 6.6 months to 6.8 months, and 6.9 to 6.11 months). Descriptive statistics were presented in Table 1. Developmental age groups X gender ANOVAs were conducted to investigate age and gender differences on VMI-4 performance in each age group. None of the analyses yielded significant gender effects so the data were collapsed across gender. Within each age group one-way ANOVAs were conducted to investigate the group differences. Post-hoc analyses were done by Tukey HSD.

TABLE 1. Means and standard deviations of VMI raw scores for girls and boys within each 3 month age groups.

Age	Girls			Age	Boys		
	N	X	Sd		N	X	sd
6.0-6.2	21	11.38	2.52	6.0-6.2	13	10.54	3.18
6.3-6.5	33	12.24	2.61	6.3-6.5	24	11.42	2.53
6.6-6.8	44	13.14	2.92	6.6-6.8	44	12.95	2.96
6.9-6.11	45	13.73	2.90	6.9-6.11	44	12.57	2.54
7.0-7.2	22	14.41	2.72	7.0-7.2	18	13.22	2.58
7.3-7.5	25	15.64	2.88	7.3-7.5	25	15.48	2.36
7.6-7.8	21	13.81	2.44	7.6-7.8	35	15.03	3.62
7.9-7.11	31	15.58	2.62	7.9-7.11	27	15.30	2.45
8.0-8.2	30	17.53	2.84	8.0-8.2	27	17.92	3.36
8.3-8.5	24	17.58	2.16	8.3-8.5	17	16.94	1.98
8.6-8.8	17	16.76	2.22	8.6-8.8	13	17.38	3.12
8.9-8.11	26	16.77	1.61	8.9-8.11	18	17.28	1.64
9.0-9.2	24	18.87	2.25	9.0-9.2	23	18.13	2.47
9.3-9.5	16	18.00	2.63	9.3-9.5	28	17.93	1.88
9.6-9.8	21	18.67	2.29	9.6-9.8	20	18.95	2.50
9.9-9.11	28	18.78	3.05	9.9-9.11	23	18.56	3.12
10.0-10.2	34	19.23	2.55	10.0-10.2	24	19.42	2.75
10.3-10.5	25	19.60	2.89	10.3-10.5	39	19.49	2.94
10.6-10.8	29	20.10	2.48	10.6-10.8	35	19.77	3.07
10.9-10.11	24	19.41	2.65	10.9-10.11	24	19.71	3.34
11.0-11.2	26	20.50	2.98	11.0-11.2	24	20.29	2.68
11.3-11.5	35	20.46	2.75	11.3-11.5	40	19.97	2.99
11.6-11.8	29	19.48	3.49	11.6-11.8	29	20.59	3.20
11.9-11.11	19	20.10	3.43	11.9-11.11	16	19.81	2.97
12.0-12.2	28	21.21	3.15	12.0-12.2	18	20.67	2.63
12.3-12.5	26	21.77	3.68	12.3-12.5	37	21.62	2.56
12.6-12.8	31	21.71	2.84	12.6-12.8	29	22.27	2.27
12.9-12.11	27	20.44	3.09	12.9-12.11	40	21.90	2.54
13.0-13.2	22	21.91	2.60	13.0-13.2	21	21.09	2.43
13.3-13.5	24	21.46	2.90	13.3-13.5	38	21.31	2.63
13.6-13.8	21	21.28	3.24	13.6-13.8	27	22.33	2.46
13.9-13.11	23	22.26	3.09	13.9-13.11	37	21.22	2.66
14.0-14.2	10	23.30	2.31	14.0-14.2	12	23.00	2.33
14.3-14.5	4	24.75	2.87	14.3-14.5	12	23.00	3.07
14.6-14.8	7	24.14	2.73	14.6-14.8	16	24.50	2.31
14.9-14.11	11	25.00	1.41	14.9-14.11	19	23.79	1.65
15.0-15.2	6	24.83	1.94	15.0-15.2	26	24.69	1.35
15.3-15.5	4	24.75	3.30	15.3-15.5	20	24.45	1.19
15.6-15.8	1	25.00	------	15.6-15.8	4	24.25	.96
15.9-15.11	2	25.00	.71	15.9-15.11	5	24.20	1.30

RESULTS

The analyses yielded significant developmental age main effects for only the 6 (F(3,264)=6.61, p=0.00) and 7 (F(3,200)=3.71, p=.012) year old groups (Figure 1). Post-hoc comparisons for the 6 year olds showed that the children between the ages of 6.0-6.2 years performed significantly lower than the 6.6-6.8 (p=.002) and 6.9-6.11 year old groups (p=.001). The 6.3 to 6.5 year old group performed significantly lower than the children aged 6.9 and 6.11 years (p=.03).

Within 7 year old children, 7.0-7.2 year olds performed significantly lower than 7.3-7.5 (p=.023) and 7.9-7.11 (p=.032) year olds. No other significant differences were obtained for 7 year old children.

A one-way ANOVA revealed significant age effect (F (7,1406)=105.6, p=0.00) among 8 to 15 year old children. The VMI performance differences observed among children between the ages of 8 years to 15 years yielded a different pattern than age-related VMI performances that were observed in 6 and 7 year old children. The Tukey HSD post hoc comparisons showed that the 8 year olds had the lowest VMI performance (mean: 17.32 sd:2.46 , p<.001) whereas 14 and 15 year olds revealed the highest performance compared to the other age groups. Ten and 11 year old children were not significantly different than each other and both age groups had lower performance scores compared to the older groups in this study. The 12 year olds showed comparable performances with the 13 year old group, but their VMI scores were lower than the14 and 15 year olds (p=0.00). (Figure 2).

In summary the findings revealed a developmental pattern in visual-motor integration performance in children between the ages of 6 to 15 years. In younger children the significant performance differences were observed during three month intervals. From age 8 the significant performance increase was observed every two years. The highest performance level was reached at the age of 15.

Test-Retest Reliability: The VMI was administered to 44 randomly selected subjects (24 girls and 20 boys, mean age: 9.6 sd: 2.1, range: 6-13 years) 3 to 4 weeks following the first administration. A Pearson Correlation Coefficient was conducted between VMI time 1 and time 2 scores. Findings yielded a significant correlation between the two VMI performances (r= 0.68, p=0.01).

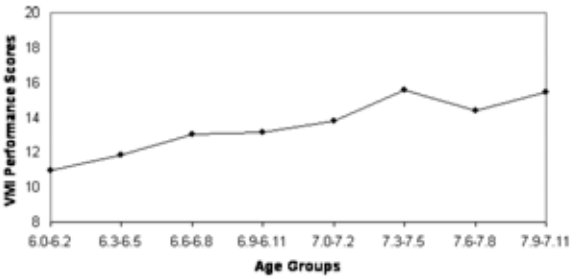

FIGURE 1. VMI Performance Differences (Raw Scores) Between 6 and 7 Year Old Children

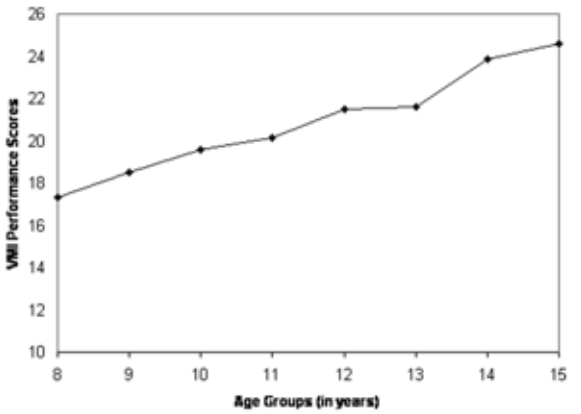

FIGURE 2. VMI Performance Differences (Raw Scores) Between Age Groups (8-15) year old children)

DISCUSSION

The goal of this study was to present Turkish norms for Beery-Buktenica Developmental Test of Visual Motor Integration-4, in children and adolescents ages 6-15 years. The VMI-4 has been shown to be sensitive to visual-motor problems in various neuropsychiatric disorders such as TS, ADHD and LD.

Overall results of this study showed age- related developmental progression of visual-motor skills in children between the ages of 6 to 15 years. These findings were in agreement with the developmental assumption and contributed to the construct validity of the VMI-4 (see Beery 1997).

Pattern of performance increments were different among younger (6 and 7) and older (8 and up) children. When the developmental trajectories were analyzed (see Figures 1 and 2), significant performance increases were obtained between developmental age groups within 6

and 7 year olds. In the 6 year old group, the lowest performance was observed in 6.0-6.2 year olds and 6.3-6.5 year olds. There was no significant performance difference between these two age groups. The VMI performance significantly improved in ages 6.6-6.8 and 6.9-6.11. Within the 7 year olds group, the lowest performance was observed in 7.0-7.2 year old children. There were no other significant differences among developmental age groups within this age group. Starting at age 8 the effect of developmental age (3 month periods) disappeared. This pattern suggests a faster development of visual-motor integration abilities during younger ages that requires separate norms based on monthly age groups. In this study the age norms for younger groups (6 and 7 years) were provided in 6 month developmental age groups in order to capture the significant performance differences. Also our results are in agreement with the findings that suggest the maturation of visual-motor skills beyond puberty (Shapiro and Simpson, 1995). Consistent with the previously reported results (Beery 1997, Schooler and Anderson 1979), our data did not reveal any sex differences for VMI-4 for any age groups.

The normative values provided by the results of this study were presented in Table 2. Furthermore percentile values (Table 3) were also provided. However, clinically sound interpretation should involve standard measures rather than using percentiles because of the distributional characteristics of the percentiles.

In summary, the present data revealed similar score ranges corresponding to each age level when compared to the original VMI-4 raw score age equivalents (Beery 1997 p.145). Preliminary psychometric analysis pertaining to the stability of the test performance over time, although moderate compared to the original test-retest reliability (r=0.84), was significant and within an acceptable range. The problem of moderate test- retest reliability might stem from the mixed age group used as the retest sample. Although, the retest sample was chosen among the children who were still in their "time 1" age groups, in the future it is desirable to conduct test-retest reliability analyses separately for each age group.

Regarding the validity of the instrument, we also showed the developmental characteristic of VMI-4 operating within our normative sample, thus satisfying one of the underlying assumptions regarding the construct validity. Future studies are needed to compare the performance on the VMI with a similar test (see Ozer, 2007). The clinical comparison studies will be important to increase the psychometric strength of this test in Turkish culture.

To the best of our knowledge this is the first normative study of visual-motor integration skills for Turkish children within an age range of 6-15 years. Although the sample size and the representation of both sexes in each age group are sufficient, the sample is biased towards middle-upper socio-economic status. There is a growing emphasis to report SES, race, and ethnic based norms (see Ardilla and Roselli 1994). Regarding performance on the VMI, the research related to the effects of socio-cultural background including race is scarce and not enough to draw any reliable conclusions. Future studies including low SES participants will be essential.

TABLE 2. VMI Performance Scores (Means and standard deviations)

Age	N	Mean	Standard deviation
6.0-6.5	91	11.58	2.67
6.6-6.11	177	13.10	2.84
7.0-7.5	90	14.81	2.76
7.6-7.11	114	15.01	2.93
8	172	17.32	2.53
9	183	18.49	2.53
10	234	19.59	2.81
11	218	20.16	3.03
12	236	21.52	2.86
13	213	21.58	2.73
14	91	23.87	2.30
15	68	24.60	1.44

TABLE 3. Percentiles in VMI by age

AGE	Percentile								
	10	20	30	40	50	60	70	80	90
6.0-6.5	9.0	9.0	10.0	10.0	11.0	12.0	13.0	14.0	15.0
6.6-6.11	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
7.0-7.5	12.0	13.0	13.0	14.0	15.0	15.0	16.0	17.0	19.0
7.6-7.11	12.0	12.0	14.0	14.0	15.0	16.0	17.0	17.0	19.0
8	14.0	15.0	16.0	17.0	17.0	18.0	18.0	19.0	20.0
9	15.4	16.0	17.0	18.0	18.0	19.0	20.0	21.0	22.0
10	16.0	17.0	18.0	19.0	19.0	20.0	21.0	22.0	24.0
11	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
12	17.7	19.0	20.0	21.0	22.0	23.0	23.0	24.0	25.0
13	18.0	19.0	20.0	21.0	22.0	22.0	23.0	24.0	25.0
14	21.0	22.0	23.0	23.0	24.0	25.0	25.0	26.0	27.0
15	23.0	23.0	24.0	24.0	25.0	25.0	25.0	26.0	27.0

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