Evaluation of Visual-Motor Integration Skills in Preschool and Elementary School-Aged Chinese Children

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Abstract

Background: *Visual-motor integration is the ability to coordinate visual perceptual and motor skills. The Beery Developmental Test of Visual-Motor Integration (VMI) is a standardized copy forms-type test that is frequently used to assess visual-motor integration. In China, there are few effective methods to assess visual-motor integration skill in children. The intention of this study was to determine whether Chinese children exhibit VMI performance comparable to established U.S. norms.*

Methods: *Three hundred fifty-six children, aged three to 12 years old from six public schools in Shanghai and Ningbo, were administered the VMI. The students were arranged in groups of four to ten for each test administrator. Participants were allowed as much time as needed to complete the VMI.*

Results: *Standard scores for each age group and the entire group were statistically compared to the corresponding mean value for United States children. Except for two groups (3.0 to 3.11 ($p = 0.45$) and 10.0 to 10.11 ($p = 0.09$)), the mean standard score for Chinese children was significantly higher than the normative mean for U.S. children ($p<0.005$). Actual values were shifted upward relative to that expected at each age. The following equation was derived to allow comparison to U.S. norms (Adjusted score = 0.956 (Chinese VMI raw score) – 1.098).*

Conclusion: *Differences related to gender and place of residence were observed within the Chinese population sampled. The equations and tabular guidelines derived from this study allow practitioners in China to administer the VMI and apply a correction factor to raw scores, such that these scores can be more closely compared to published U.S. normative data. This study underscores the need to use customized scoring criteria for the VMI with children in China.*

Key Words

Beery Developmental Test of Visual-Motor Integration (VMI), children, China, visual-motor integration

Introduction

Visual-motor integration is the ability to coordinate visual perceptual and motor skills.[1] The *Beery Developmental Test of Visual-Motor Integration (VMI)* is a standardized copy forms-type test that is frequently used to assess visual-motor integration.[2] The patient is presented 24 geometric shapes of increasing complexity and is asked to draw an exact copy of each in a space provided below each shape. Simultaneous processing skills are necessary to execute the VMI correctly. Adequate fine motor control, the ability to integrate sub-skills into a whole, and visual conceptualization skills are requisites to reproduce the geometric forms.[3] Previous studies have shown that early childhood VMI performance is correlated with later academic performance.[4,5] Hence, the VMI can serve as a valuable tool for monitoring childhood perceptual and fine-motor development and help guide intervention decisions. Current VMI norms encompass ages two through 99 years,[6] but are most specific and discriminative for individuals between two and 19 years old.

In China, there are few effective methods to assess a child's visual-motor integration skills.[7] It is conceivable that the VMI may prove to be an appropriate test to assist in identifying Chinese children at risk for later learning difficulties, thus allowing for appropriate intervention at an earlier age. Although the VMI utilizes geometric forms and therefore is relatively culture independent, cross-cultural factors have been reported to yield differences between U.S. and Asian children.[8-14] While Chinese stroke characters are similar to the geometric symbols used in the VMI, they are distinct from the alphanumeric characters learned by English-speaking children. Indeed, Chinese children typically are required to learn and copy simple and complex characters at an early age (e.g., age three when starting kindergarten for most city children).[15] It is not unreasonable to expect that this earlier symbol emphasis in China may lead to significant differences in performance on the VMI, as compared to English speaking children in the U.S. If this is indeed the case, then normative values established for U.S. children may not be directly applicable to Chinese children. For example, Saeki reported enhanced performance in Japanese children on visual motor tests comparable to the VMI.[12] Sanghavi documented that Indian children, aged 10 to 14, performed better than American children in her study.[8] Liu[10] and Shi[7] measured higher-level performance for young Chinese children on the VMI. In contrast, Hsu found no difference between the performance of Taiwanese children and US norms.[9] These conflicting results point to the need for additional research. Three speculative hypotheses have been proposed to explain this difference: genetic influence, right hemispheric superiority of Chinese children, and cultural factors, such as early use of chopsticks. Sakei's study suggests that cultural practices may have more impact on eye-hand coordination scores than do genetic factors.[12] Our intention was to determine whether Chinese children exhibit VMI performance comparable to established U.S. norms.

Methods

Subjects

In this study, the first author randomly contacted ten preschools and primary schools (identified in the public phone book) and received affirmative responses to participate from six schools. All participants were recruited from two cities in east China, Shanghai and Ningbo, and subjects were randomly selected by student number from each kindergarten and elementary school. These two cities represent average-size, metropolitan areas in east China, a region known for advanced economic development compared to inner China. Although the existing VMI norms were gathered from a diverse demographic representation of the U.S. population, only two cities in China were chosen for the purposes of this comparison study. The intent was to minimize potential demographic differences between subjects included in this initial study. In other words, had we recruited subjects from the rural areas in China, interpreting our results would have been more problematic because of the large demographic differences in terms of economic development, school quality, and arguably, educational expectation.

In most Chinese cities, children first go to preschool at age three. Most parents choose to send their children to kindergarten for one year at age six for the purpose of familiarizing with school mates, and getting them used to the future study environment, etc. At age seven to eight children enroll in elementary school as required by Chinese compulsory education policy.

Three hundred fifty-six children, aged three to 12 years old, from six public schools in Shanghai and Ningbo agreed to participate in this study. This group included 169 children from Shanghai and 187 children from Ningbo. In China, there is a lack of standardized tests for assessing the children with learning difficulties. Tests to rule out learning difficulties were not administered to participants, so presumably children in this study are representative of normal classrooms in Shanghai and Ningbo. Data from subjects were coded according to age, gender, school, and city.

Procedure

This study received approval from the Pacific University Institutional Review Board. The head of each school granted permission for data collection after receipt of the IRB approved protocol and informed consent documents. Parental consent was obtained for each student participant, and the Ethics Committee for the Shanghai Ministry of Education approved the study.

The VMI 4th edition was administered in standard classrooms under normal room illumination according to test instructions. The eight test administrators were teachers from participating schools and faculty from the Optometry Department, Health Technology College, and Jiaotong University, China. All were trained in proper administration of the VMI test and were required to demonstrate accuracy and proficiency prior to testing. The students were arranged in groups of four to ten for each test administrator (at least one administrator was allotted to each group of four children aged five or younger). Participants were allowed as much time as needed to complete the VMI. To maintain test validity and reliability, administration and scoring instructions were adapted directly from the test manual. All test results and data were analyzed at Pacific University College of Optometry.

The principal investigator scored VMI results for each subject. This approach was validated with random samples of VMI data sheets (20% from each age group) that were scored by three different optometrists with expertise in VMI scoring. There was high agreement between the experts and the principal investigator (Pearson Correlation=0.99), validating the VMI scoring methodology used in this study.

Results

Age and gender distributions for the 356 children who participated in this study are shown in Table 1. Mean and standard deviation (SD) of the raw scores for each age group are shown in Table 2. All raw scores were converted to standard scores, based on the VMI tabular norms from 2,614 United States school-age children.[1] The mean and standard deviation of standard scores for our sample also are shown in Table 2.

The standard scores in the VMI are standardized relative to a mean value of 100 (SD = 15), such that the standard score normative mean for each age group is 100, and the SD is 15. It is clear from Table 2 that the mean standard scores for our sample consistently exceed the standardized mean of 100, suggesting that overall performance of Chinese children in our sample exceeds normative values for the VMI. Our mean standard score across all ages for the 356 Chinese students was 110.20 (SD 14.73). With the exception of age three, the SD is comparable to 15 in each group, suggesting an overall enhancement in performance with minimal change in variability. Figure 1 illustrates the mean (±SD) standard scores of Chinese children in our sample plotted for each age group.

To explore these findings in greater detail, standard scores for our sample in each age group were statistically compared to the corresponding mean value for U.S. children (standard score mean=100). Table 3 shows Student's t-test results and probability levels for each age group. In most cases, except

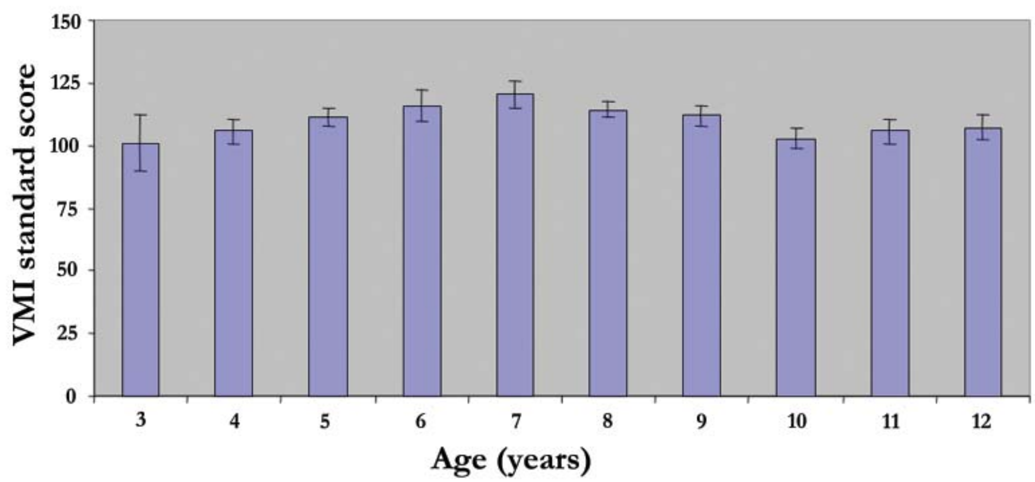
Table 1. Age and gender distributions

Age	Male	Female	Sum
3.0 – 3.11	13	6	19
4.0 – 4.11	25	14	39
5.0 – 5.11	38	27	65
6.0 – 6.11	7	5	12
7.0 – 7.11	15	14	29
8.0 – 8.11	32	33	65
9.0 – 9.11	21	25	46
10.0 – 10.11	15	19	34
11.0 – 11.11	7	13	20
12.0 – 12.11	14	13	27
Total	187	169	356

Table 2. Mean and standard deviation (SD) of the raw scores for each age group

Age (years. months)	Mean Raw Score	Standard Deviation	Mean Standard Score	Standard Deviation
3.0 – 3.11	5.58	2.71	100.74	24.41
4.0 – 4.11	9.88	2.99	105.65	14.71
5.0 – 5.11	14.16	2.96	111.35	13.40
6.0 – 6.11	17.33	2.87	116.08	10.87
7.0 – 7.11	20.69	2.88	120.10	14.14
8.0 – 8.11	21.22	2.36	114.38	12.67
9.0 – 9.11	21.96	2.45	112.15	14.10
10.0 – 10.11	21.15	2.44	102.71	11.51
11.0 – 11.11	22.90	2.45	105.71	11.44
12.0 – 12.11	23.74	2.23	107.19	12.13
Overall	17.86	2.63	110.20	14.73

Figure 1. VMI Standard Scores in Chinese Children (mean and 2SD)



for two groups (3.0 to 3.11 and 10.0 to 10.11), the mean standard score for Chinese children in our sample is significantly higher than the normative mean for U.S. children (Table 3).

In order to assess the dependency of the VMI score on age, the expected value, derived from the mean U.S. raw score, was determined for each Chinese subject, based on the subject's age (to the nearest month) and normative values in the Beery VMI Administration, Scoring, and Teaching Manual (4th Edition, Revised; pages 146-175). Expected VMI scores and actual scores are plotted against age in Figure 2. As shown, both expected and actual scores increase linearly with the logarithm of age. However, actual values are generally shifted upward relative to that expected at each age, indicating that, on average, urban Chinese children perform at an enhanced level compared to U.S. norms.

Although the relationship for urban Chinese children is based on a much smaller sample (n=356) than that describing U.S. norms (n=2,614); it may be useful to preliminarily derive a quantitative expression to estimate an adjusted standard score that would account for the difference between performance of U.S. children and those tested in our sample.

Table 3. Student t-test and probablility levels by age group

Age (years. months)	Mean Standard Score	Student's t-test comparison to U.S. mean of 100 (degrees of freedom in parenthesis)	Probability that Chinese sample derived from a population with a mean of "100" (*p<0.005; significant after adjustment for multiple t-tests)
3.0 – 3.11	100.74	t = 0.13; (df = 18)	p = 0.45
4.0 – 4.11	105.65	t = 2.43; (df = 39)	p = 0.01
5.0 – 5.11	111.35	t = 6.72; (df = 62)	p < 0.0001*
6.0 – 6.11	116.08	t = 5.12; (df = 11)	p < 0.0001*
7.0 – 7.11	120.10	t = 7.66; (df = 28)	p < 0.0001*
8.0 – 8.11	114.38	t = 9.16; (df = 64)	p < 0.0001*
9.0 – 9.11	112.15	t = 5.84; (df = 45)	p < 0.0001*
10.0 – 10.11	102.71	t = 1.37; (df = 33)	p = 0.09
11.0 – 11.11	105.71	t = 2.29; (df = 20)	p = 0.02
12.0 – 12.11	107.19	t = 3.08; (df = 26	p = 0.002*

Figure 2. Comparison of Raw Score

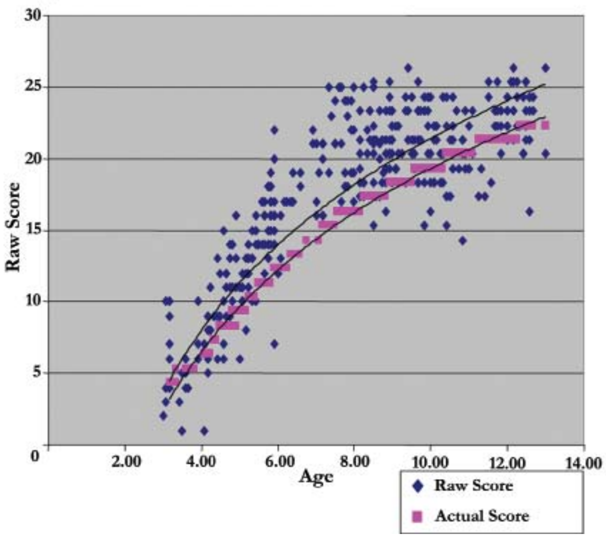


Figure 3. VMI and Age

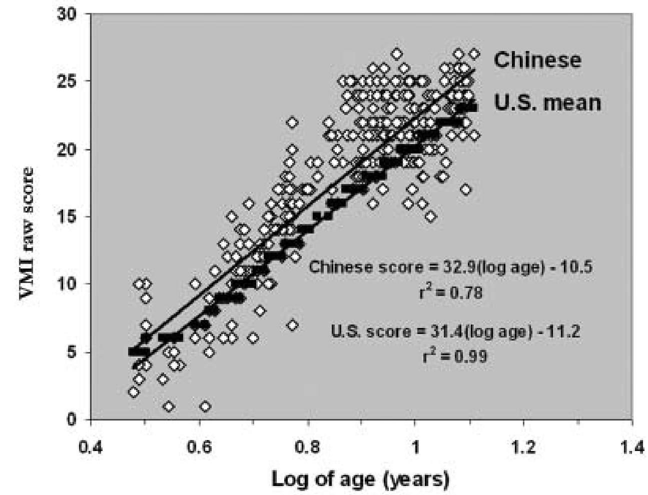


Figure 4. Residence Difference in VMI

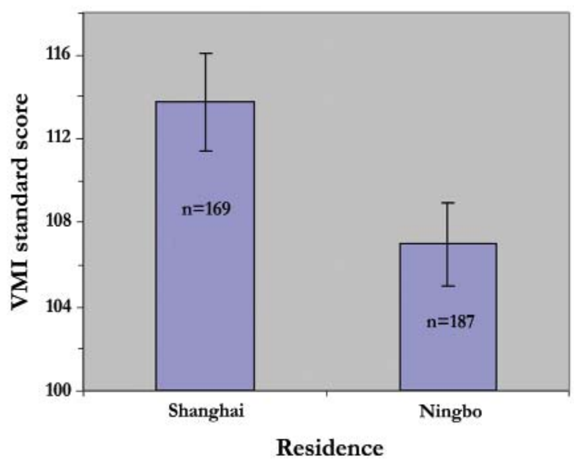
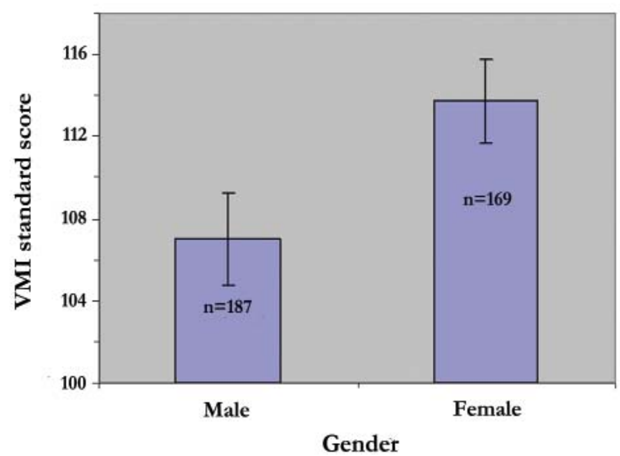


Figure 5. Gender Difference in VMI



The adjusted score then can be used to determine the corresponding standard score and percentile score. By setting each linear equation in Figure 3 equal to log AGE, and solving for U.S. score, the following equation was derived:

Adjusted score = 0.956(Chinese VMI raw score) – 1.098

This equation provides a score, adjusted for the difference between our sample and U.S. children, which can be used to tentatively determine whether a specific Chinese raw score is within normal limits. For example, assume that a Chinese child, age 7 years and one month, achieves a VMI raw score of 13. With no adjustment, a score of 13 indicates a standard score of 87 (page 154, 4th Edition VMI Scoring Manual), and a percentile rank of 19 (page 176, 4th Edition VMI Scoring Manual); both scores are low but within normal limits. However, the adjusted score, which is 0.956(13)-1.098-11.33, indicates a standard score of 77, and ranking in the 6th percentile. The adjusted score suggests performance well below normal values, and possibly an increased risk for a potential learning problem. This approach provides an initial estimate of the student's academic potential.

An alternative approach, which yields comparable results, is an adjustment to the standard score based on the difference between mean values for Chinese and U.S. children. The simplicity of this equation does make it a bit more "clinician-friendly," a definite advantage. The mean standard score for U.S. children is 100, regardless of age.

The adjustment to Chinese scores is specified as the difference between mean Chinese standard score and 100, as shown in Table 4. Thus, the definitive evaluation of Chinese VMI skills could be based on the adjusted standard score, a useful rule-of-thumb for the clinician in China.

The results of this study also revealed differences in VMI scores across residence ($t = 4.43$, $p < 0.01$; Figure 4) and gender ($t=4.42$, $p <0.01$, Figure 5). Mean values (±2 SD; across all ages) are shown plotted as a function of city in Figure 4, and as function gender in Figure 5.

Discussion

The Beery VMI Administration, Scoring, and Teaching Manual (4th Edition, Revised; pages 122) states, "At early ages, Chinese children have performed somewhat better than U.S. children, but the norms were very similar from age nine

Table 4. Mean Chinese standard score and rredicted score

Age	Mean Chinese Standard Score (S)	The Predicted Score is the standard score (from VMI tabular values*) minus the value shown below for each year group.
3.0 – 3.11	S = 100.74	No correction; Predicted = Standard.
4.0 – 4.11	S = 105.65	Predicted = Standard - 5
5.0 – 5.11	S =111.35	Predicted = Standard - 11
6.0 – 6.11	S =116.08	Predicted = Standard - 16
7.0 – 7.11	S =120.10	Predicted = Standard - 20
8.0 – 8.11	S = 114.38	Predicted = Standard - 14
9.0 – 9.11	S = 112.15	Predicted = Standard - 12
10.0 – 10.11	S = 102.71	No correction; Predicted = Standard.
11.0 – 11.11	S = 105.71	Predicted = Standard - 5
12.0 – 12.11	S = 107.19	Predicted = Standard - 7

to 17."[1] However, we found statistically significant differences between the Chinese children that we tested and the norms based on the performance of U.S. children. As was mentioned in the results section, the mean standard score across all ages for the 356 Chinese students in this study was 110.20 (SD 14.73). Our results suggest that children from different cultures and educational backgrounds may show performance differences on the VMI. Other investigators have previously reported similar findings, notably Liu[10], Shi[7], Sanghavi[8], and also by Mao (1995) as reported by Hsu[9]. However, not all past research results are consistent with this finding[9], so further research is needed to clarify and identify the key factors responsible for the conflicting results in previously mentioned studies.

In China, many children are highly motivated by teachers and parents to learn to write Chinese characters at an early age. This likely influences their performance on the VMI. Indeed, a significant relationship has been demonstrated between child performance on the VMI and the ability to copy letters legibly.[16,17] It also is important to note that an increasing number of Chinese kindergartens, as well as early childhood classes, emphasize handwriting lessons in the curriculum. Typically, Chinese children in elementary school participate in 30-60 minutes of handwriting lessons daily. This early intensive handwriting training could conceivably contribute to superior performance on the VMI. Or put another way, visual-perceptual development and early childhood "penmanship practice" or visual-motor development may be bidirectional, where either can have an effect on the other. We suspect that the relative enhanced VMI performance of Chinese children observed in this study may in part, relate to the detailed geometric shapes and complex graphical nature of Chinese characters. Accurate reproduction with paper and pencil requires fairly precise visual-motor control and drawing skills. Further, it seems consistent with our finding that Chinese female children show better VMI performance than males at early ages, since Goetz reported that motor skills of females develop more rapidly than those of males.[18] Aylward & Schmidt also found gender differences in VMI.[19] These studies taken in aggregate, suggest that early childhood experience, culture, gender, and social-economic factors all contribute to VMI performance.

The difference between the standard from our sample and U.S. VMI norms shows a gradual increase from age three to a peak at age seven. We suggest that this difference in VMI performance derives from differences in educational emphasis, pedagogical practices, and academic rigor between China and the U.S. In Shanghai and Ningbo, students in primary school are subjected to many more hours of lecture and homework than in the U.S. Given the greater number of hours in school and increased homework demand, it is not unreasonable that visual-motor integration skills might differ between groups.

Shi reported that there were significant differences in children's VMI scores from small towns versus those from larger cities.[7] We found a difference in mean VMI performance between Shanghai and Ningbo children. Although Shanghai and Ningbo are both in the prosperous Eastern area in Mainland China, Shanghai is more developed in terms of economics, education, and heath care than Ningbo. We suspect these factors may contribute to better VMI performance at an earlier age. Future studies should explore the effect of social economic status and early educational experience on VMI performance.

Although there is no reported difference between group and individual administration,[1] it is possible that our method of administration could have affected our results. Even though younger children were tested in smaller groups, it was difficult for the administrators to monitor each child continuously; the result being that some subjects probably did not attend to the test optimally. This trend was more prevalent among males, which may have contributed to the gender specific performance differences observed herein. In addition, review of the raw data for younger subjects (ages 3.0 - 4.11), suggested that some subjects performed the tasks out of proper sequence, and were not included in the initial scoring. Secondly, although erasures are not permitted on the VMI, several cases were observed for ages 10.0-10.11. Those items were scored as incorrect responses. These all stemmed from the one class, and are likely due to instructions that were misinterpreted by one administrator with that class, or simply the carelessness of individual children. Interestingly, if erasures are counted, then the difference between Chinese scores and U.S. norms at age 10, originally non-significant ($p=0.09$), is in fact significant ($p=0.017$), consistent with our finding for most other age groups. Finally, the number and gender distribution of subjects was not the same within each age group, and sample sizes were much smaller than those used to determine U.S. normative values, making definitive generalizations from these limited data somewhat problematic. Despite these limitations, the results reported provide initial, basic data for Chinese children in the age range 3-12 years, encompassing six different schools in two separate cities.

Conclusion

This study uncovered differences between Chinese and U.S. children in performance on the VMI. Differences related to gender and place of residence were observed within the Chinese population sampled. The equations and tabular guidelines derived from this study allow the practitioner in China to administer the VMI, and apply a correction factor to raw scores, such that these scores can be more meaningfully compared to U.S. normative data published in the VMI scoring manual. This study underscores the need to use customized scoring criteria for the VMI with urban children in China. Although the sample size of this study was not extensive enough to establish normative values for Chinese children, the tentative adjusted scores from this study could prove useful in the interim. Further investigation with a larger and more diverse sample of Chinese and Asian children will be necessary to confirm and perhaps refine current normative values.

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