

The relationship between visual–motor integration and handwriting skills in Arabic-speaking Egyptian children at the age of 4–6 years

Tamer Abou-El-Saad^a, Omayma Afsah^a, Hemmat Baz^a, Walaa Shaaban^b

^aPhoniatric Unit, ORL Department, Faculty of Medicine, Mansoura University, ^bPhoniatric Unit, ORL Department, Mansoura General Hospital, Mansoura, Egypt

Correspondence to Tamer Abou-El-Saad, MD, Phoniatric Unit, ORL Department, Faculty of Medicine, Mansoura University, Mansoura - 35516, Egypt Tel: +20 100 519 2300; fax: 002-0502373399; e-mail: taboelsaad@hotmail.com

Received 21 May 2017

Accepted 4 August 2017

The Egyptian Journal of Otolaryngology
2017, 33:663–669

Background

Handwriting is a complex perceptual-motor skill that is dependent on the maturation and integration of a number of cognitive, perceptual, and motor skills.

Aim

To examine the relationship between visual–motor skills and handwriting skills (HS) in Arabic-speaking Egyptian children at the age of 4–6 years.

Patients and methods

Overall, 200 typically developing kindergarten and primary school Arabic-speaking children, in the age range of 4–6 years, were tested using a constructed battery for assessment of both visual–motor integration (VMI) and HS.

Results and conclusion

Performance on both VMI and HS tasks improved with age. Moreover, the older the child was, the lesser the duration for completion of the tasks. Copying lines was found to be the best predictor of copying letters, copying words, and copying numbers. Reliability and validity of the designed VMI and HS assessment battery proved to be excellent. VMI is an important prerequisite for Arabic HS.

Keywords:

Arabic language, handwriting skills, learning disability, visual–motor integration

Egypt J Otolaryngol 33:663–669

© 2017 The Egyptian Journal of Otolaryngology

1012-5574

Introduction

Handwriting is a complex perceptual-motor skill that is dependent on the maturation and integration of a number of cognitive, perceptual, and motor skills and is developed through instruction. It is an academic skill that allows individuals to express their thoughts and feelings and communicate with others [1].

Handwriting development passes into steps. First the child scribbles spontaneously, then scribbles using direction (horizontal, vertical, circular), then imitates other's scribble (horizontal, vertical, and circular) and then imitates lines (horizontal line, vertical line, and circular line). This is followed by copying (previously drawn) lines: horizontal line, vertical line, circular line, and diagonal line [2]. A child begins to print letters by first imitating geometric shapes beginning with vertical strokes at age of 2 years, followed by horizontal strokes at age of 2 years and 6 months, and then circles at age of 3 years. Imitation and then copying of a cross occurs at 4 years, copying a square occurs at 5 years, and triangle at 5 years and 6 months. The ability to copy geometric shapes, especially oblique cross, is considered an indication of writing readiness in young child, as it requires crossing the body midline and has been implicated as the root of reversal problems [3].

Visual–motor integration (VMI) is the ability of the eyes and hand to work together in smooth, efficient patterns [4]. VMI consists of coordinating visual perceptual skills together with gross-motor movement and fine-motor movement. It is the ability to integrate visual input with motor output. This is how individuals plan, execute, and monitor motor tasks, such as threading a needle, tying shoe laces, and catching or hitting a ball. It is also essential in academic performance [5]. VMI is an important variable to the child's handwriting skills (HS), particularly when copying or transposing from printing material to cursive or manuscript writing [4]. It has been observed that as patient's ability to copy the forms on the VMI increases, a concomitant increase in ability to copy letters accurately is seen [6].

Handwriting involves the motor ability of holding and manipulating the writing instrument, specifically the pencil. It is important that hand muscles be matured and developmentally ready for handwriting. Otherwise the child will develop poor pencil gripping habits which will affect his or her mastery of the writing tool [7].

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work noncommercially, as long as the author is credited and the new creations are licensed under the identical terms.

Children who do not succeed in developing proficient handwriting are defined by some authors as poor hand writers and by others as dysgraphic [8]. Dysgraphia is characterized by difficulty in the production of legible writing, in maintaining the quantity and speed of writing demanded in class, or both. The number of typically developing children who struggle with handwriting varies, with reported prevalence worldwide ranging from 6 to 34% [9–11].

Words in Arabic are generally written from right to left in a cursive script where the shape of the letter or grapheme may be altered depending on its position in the word, in either initial, medial, or final position. Arabic letters also differ from each other depending on the number and position of the dots appearing above or below the letter. In the Arabic orthographic system, it is relatively simple to associate graphemes or letters to their corresponding phonemes (one-to-one correlation) compared with the more complicated orthographies such as those of English and German which lack that simple one-to-one correlation [12–14]. The Arabic script has been adopted for use in a wide variety of languages besides Arabic, including Persian, Malay, and Urdu, which are not Semitic [15]. Many studies were conducted to explore the relationship between VMI and HS in English speakers [6,16,17]. However, to the best of our knowledge, such relationship was not addressed in Arabic-speaking countries. Assessing Arabic-speaking children handwriting performance in relation to their visual-motor skills would highlight their writing readiness which is a fundamental academic skill.

The aim of this study was to examine the relationship between visual-motor skills and HS in Arabic-speaking Egyptian children at the age of 4–6 years to evaluate the role of VMI as one of the essential prewriting skills. Also the validity and reliability of the proposed assessment tool was examined.

Patients and methods

Patients

This prospective study was conducted on a sample of 200 typically developing kindergarten and primary school children (87 males and 113 females) in the age range of 4–6 years (mean: 5 ± 0.61 years). Children were selected from kindergarten and primary classrooms of governmental, experimental, and private schools in Mansoura City, Egypt, in which Arabic language is taught as the primary language. Children with visual impairments, cognitive impairments, language or

speech impairments, neurological, neuromuscular, or musculoskeletal disorders were excluded from the study.

The study sample was divided into three groups as follows:

- (1) Group I: it composed of 90 children at kindergarten level 1. Their ages ranged between 4 and 5 years. This group included 43 (47.8%) males and 47 (52.2%) females.
- (2) Group II: it composed of 90 children at kindergarten level 2. Their ages ranged between 5 years and 5 years nine months. This group included 36 (40%) males and 54 (60%) females.
- (3) Group III: it composed of 20 children at grade 1 primary school. Their ages ranged between 5 9/12 and 6 years. This group included eight (40%) males and 12 (60%) females.

Parents were asked to provide informed consent for their children to participate in the study. The study was approved by the ethics committee of the institution (MS/119).

Methods

All children were subjected to general examination and subjective evaluation for both language and speech to ensure their feasibility to participate in the study. Two formal assessment procedures were constructed for assessment of both VMI and HS based on Egyptian curriculum of kindergarten.

Assessment of visual-motor integration

The child was asked to copy 7 lines (including vertical, horizontal, oblique, zigzag, oblique cross, perpendicular, and diagonal lines), copy 7 two-dimensional geometric shapes (including triangle, circle, square, oval, rectangle, diamond, and pentagon), and color 6 geometric shapes (including triangle, circle, square, oval, rectangle, and star) using an unlined paper, a standard pencil, and crayons without an eraser.

Assessment of handwriting skills

The child was asked to copy 8 Arabic dissimilar letters, seven Arabic words varying in length (including monosyllabic, disyllabic, and multisyllabic words), and seven Arabic numbers (composed of 1, 2, and 3 digits) using a lined paper and a standard pencil without an eraser.

In all copying tasks, the child was first shown the task on the paper and asked to copy it without help. If failed, the examiner drew/wrote it in front of the child and the child was asked to imitate him. If failed, the child was

given the task as dots and asked to trace it by connecting the dots. The score of each of these copying tasks was based on four-point scale, ranging from 0 to 3, where 3 was given when the child could correctly copy the task without help, 2 was given for correct imitation, 1 was given for correct dot-to-dot tracing, and 0 if the child failed to perform the task. For coloring shapes, two-point scale was used, where 2 was given when the child could correctly color inside the shape and 1 was given when coloring extended outside the shape. Summation of scores of the 3 subscales of VMI assessment gave rise to a total score of 54, whereas summation of scores of the 3 subscales of HS assessment gave rise to a total score of 66. The total score for both VMI and HS assessments was 120 points. During both assessments, the child's pencil grip was observed, and the time for each task was calculated for every child.

Testing the validity and reliability of visual-motor integration-handwriting skills assessment battery

Validity of VMI-HS assessment battery: It was measured using content validity and internal consistency validity.

- (1) Content validity (judgments' validity): Three independent and experienced phoniatrists were asked to judge the all items of the VMI-HS assessment battery for its relevance to the purpose for which it was meant.
- (2) Internal consistency validity: It is a measure of assessment battery homogeneity measured by correlating each section subitems with the total section score.

Reliability of VMI and HS assessment battery: This was tested by the following:

- (1) Test-retest reliability: The children were asked to respond to the VMI-HS items twice with a 2-week interval.
- (2) Internal consistency reliability of VMI-HS assessment battery: This was analyzed using reliability coefficient α (Cronbach's α) test. Values of α are considered excellent when $\alpha \geq 0.9$, good $0.8 \leq \alpha < 0.9$, and acceptable when $0.7 \leq \alpha < 0.8$.

Statistical analysis

The results were collected, tabulated, and analyzed using SPSS package, version 15 (SPSS inc., Chicago, Illinois, USA). Qualitative data were presented as numbers and percentages. Comparison between groups was done by χ^2 -test. *F*-test (one-way analysis of variance) was used to compare between

more than two groups. Pearson's or Spearman's correlation coefficient was used to test correlation between variables. *P* value of less than 0.05 was considered to be statistically significant. Intraclass correlation coefficient was used for estimating test reliability. The reliability was scaled as follows: less than 0 to 0.25, weak reliability; 0.25 to 0.75, moderate reliability; 0.75 to less than 1, strong reliability; and 1, optimum. Linear regression is a statistical method that delineates the relationship between the independent variable (VMI items) and the dependent variable (HS). Based on the value of an independent variable, coefficient of determination (denoted by r^2) is a key output of regression analysis.

Results

Descriptive statistical analysis

Calculation of the duration of task completion

The duration taken for task completion was calculated for each task of each group:

- (1) Group I: the duration ranged from 1860 to 1985 s (mean: 1922.5 ± 14.72 s).
- (2) Group II: the duration ranged from 1465 to 1785 s (mean: 1625 ± 27.42 s).
- (3) Group III: the duration ranged from 1220 to 1425 s (mean: 1322.5 ± 34.33 s).

This means that the older the child, the lesser the duration taken for completion of the tasks.

Observation of the pencil grip

A total of 20 (10%) children in the age range 4 years to 4 years 3 months demonstrated quadripod (four fingers) pencil grip, 110 (55%) children in the age range 4 years – 5 years 9 months demonstrated static tripod pencil grip, 60 (30%) children in the age range 5 years – 6 years demonstrated dynamic tripod pencil grip, and 10 (5%) children at the age of 6 years demonstrated dynamic quadripod pencil grip.

Comparative analysis

Comparison between the studied groups in their performance in visual-motor integration assessment

Statistically significant differences were found among the three groups ($P < 0.05$) in their performance in VMI assessment (Table 1). Group III children showed the highest mean and SD, whereas group I children showed the lowest mean and SD in all subtotal as well as total scores. Regarding time taken for task completion, the group III children showed the lowest mean and SD whereas group I children showed the highest mean and SD.

Table 1 Comparison among the studied groups in their performance in visual-motor integration assessment

	Group I (n=90)	Group II (n=90)	Group III (n=20)	F	P
Copying line	19.03±1.43	20.86±0.35	20.90±0.31	84.289	<0.001**
Copying line time	137.16±3.04	121.49±3.55	101.25±8.25	767.479	<0.001**
Copying shapes	16.50±2.08	19.81±0.76	20.65±0.67	133.443	<0.001**
Copying shapes time	178.37±3.68	169.57±6.84	127.00±6.37	692.763	<0.001**
Coloring shapes	7.69±1.30	9.23±1.10	9.65±1.14	46.063	<0.001**
Coloring shapes time	780.59±13.56	691.10±78.38	513.00±35.67	210.373	<0.001**
Visual-motor integration total time	1099.22±14.72	982.16±87.16	741.25±34.33	306.104	<0.001**
Visual-motor integration total	43.18±3.20	49.90±1.37	51.20±1.01	217.808	<0.001**

F=analysis of variance test. ** $P \leq 0.001$.

Comparison between the studied groups in their performance in handwriting skills assessment

Statistically significant differences were found among the three groups ($P < 0.05$) in their performance in HS assessment (Table 2).

Correlative analysis

Using Pearson's correlation (r), significant positive correlations were found between total score of VMI and total score of HS ($P < 0.05$) in the three groups (Table 3).

Validity and reliability of visual-motor integration-handwriting skills assessment battery

Validity of visual-motor integration-handwriting skills assessment battery

- (1) Content validity (judgments' validity): The three independent and experienced phoniaticians judged all items of the VMI-HS assessment battery for being completely relevant to the purpose for which it was meant.
- (2) Internal consistency validity: It is a measure of assessment battery homogeneity measured by correlating each section subitems with the total section score. Statistically strong correlation values were found when $r = 0.5-1$, while medium correlation values were found when $r = 0.3-0.5$. There was a positive significant correlation of each item and its subtotal score (Tables 4 and 5).

Also, there were significant positive correlations between total score of VMI-HS and each of the total scores of VMI ($r = 0.841$, $P < 0.001$) and HS ($r = 0.938$, $P < 0.001$).

Reliability of visual-motor integration and handwriting skills assessment battery

- (1) Test-retest reliability: Test-retest of the copying lines ($r = 0.522$, $P < 0.001$), copying shapes ($r = 0.867$, $P < 0.005$), coloring shapes ($r = 0.881$, $P < 0.041$), copying letters ($r = 0.577$, $P < 0.003$),

copying words ($r = 0.959$, $P < 0.001$), and copying numbers ($r = 0.554$, $P < 0.001$) indicated excellent reliability of the tested items. Also, the results of test-retest of VMI subtotal score ($r = 0.962$, $P < 0.003$), HS subtotal score ($r = 0.948$, $P < 0.001$) and VMI-HS total score ($r = 0.942$, $P < 0.001$) indicated excellent reliability of the VMI-HS assessment battery.

- (2) Internal consistency reliability of VMI-HS assessment battery: It is an internal consistency estimate of reliability of VMI-HS. This was analyzed using reliability coefficient α (Cronbach's α) test. Values of α are considered excellent when $\alpha \geq 0.9$, good $0.8 \leq \alpha < 0.9$, and acceptable when $0.7 \leq \alpha < 0.8$. The high alpha values of copying lines ($\alpha = 0.90$), copying shapes ($\alpha = 0.92$), coloring shapes ($\alpha = 0.87$), copying letters ($\alpha = 0.89$), copying words ($\alpha = 0.94$), and copying numbers ($\alpha = 0.88$) in all subtotal scores denotes intercorrelation between VMI-HS items.

Regression analysis

Stepwise linear regression analyses were used to identify the strongest predictors of HS. Results demonstrated that copying lines was the best predictor of copying letters, copying words, copying numbers, and total HS score as revealed by the higher β value (Table 6).

Discussion

The present study aimed at examining the relationship between visual-motor skills and HS in Arabic-speaking Egyptian children at the age of 4-6 years as well as testing the validity and reliability of the proposed assessment tool.

A sample of 200 typically developing kindergarten Arabic-speaking children in the age range between 4 and 6 years was subjected to assessment of both VMI and HS. Children were asked to copy lines and two-dimensional geometric shapes and color geometric shapes for the purpose of assessment of VMI. The

Table 2 Comparison among the studied groups in their performance in handwriting skills assessment

	Group I (n=90)	Group II (n=90)	Group III (n=20)	F	P
Copying letters	23.46±0.88	23.94±0.23	23.90±0.31	15.103	<0.001**
Copying letters time	57.61±3.06	53.73±3.68	43.25±5.20	132.200	<0.001**
Copying words	14.13±3.89	20.32±0.91	20.90±0.31	136.028	<0.001**
Copying words time	778.34±17.46	561.30±28.95	497.50±33.38	2127.805	<0.001**
Copying numbers	20.69±0.61	20.93±0.25	20.90±0.31	6.854	0.001**
Copying numbers time	55.66±3.19	51.17±2.13	40.25±4.13	242.525	<0.001**
Handwriting skills total time	891.61±18.63	666.67±27.42	581.00±33.66	2463.018	<0.001**
Handwriting skills total	58.27±4.43	65.20±0.88	65.80±0.41	133.390	<0.001**

F=analysis of variance test. **P≤0.001.

Table 3 Correlation between total score of visual-motor integration and total score of handwriting skills in the three studied groups

	Visual-motor integration total score					
	Group I		Group II		Group III	
	r	P	r	P	r	P
Handwriting skills total score	0.562	<0.001**	0.861	0.019*	0.500	0.001**

r=Pearson's correlation. *P<0.05. **P≤0.001.

Table 4 Correlation between visual-motor integration total and its subtotal score

	Visual-motor integration total score	
	r	P
Copying lines	0.916	<0.001**
Copying shapes	0.804	<0.001**
Coloring shapes	0.354	<0.001**

Pearson's correlation: 0<r>-1 means negative correlation, r=0 means no correlation and +1<r>0 means positive correlation. **P≤0.001.

Table 5 Correlation between handwriting skills total and its subtotal score

	Handwriting skills total score	
	r	P
Copying letters	0.504	<0.001**
Copying words	0.974	<0.001**
Copying numbers	0.358	<0.001**

Pearson's correlation: 0<r>-1 means negative correlation, r=0 means no correlation and +1<r>0 means positive correlation. **P≤0.001.

copying tasks were chosen based on the work of Beery and Buktenica [18] and Van der Zee [19] who stated that the ability to copy basic shapes including lines is an indication of the extent to which an individual's visual and motor abilities have been integrated. Coloring was considered as a part of manual dexterity development of the child according to Will [20], and as one of visual discrimination tasks according to Reynolds and Pearson [21].

According to Klein et al. [22], imitation is achieved before direct copying because during imitating, eye movements are rehearsed while the task is being

demonstrated. To copy forms, a child must first be visually aware of location and direction. This awareness is made possible through voluntary eye movement in a given direction. The child then proceeds to a constructive realization of this location through arm movements that correspond to the eye movements.

The use of unlined paper during VMI assessment was supported by the work of Ritchey [23] who reported that kindergarteners had difficulty copying shapes on paper that used top, middle, and bottom lines. The use of single base-lined paper during HS assessment was supported by the work of Asher [24] who suggested that beginning writers who had not mastered letter formation should initially use paper with no lines or a single baseline. Some authors [6,25] found that using paper without lines increased the legibility of beginning writers as they did not have to attend to the lines. On the contrary, Daly et al. [16] concluded that there was no significant difference in letter writing legibility between students who used paper with or without lines.

The calculation of the duration taken for tasks completion revealed that as age increased, the child consumed lesser duration and also the performance improved. This finding agreed with studies of Ziviani [26] and Karlsdottir and Stefansson [27] who found negative correlation between the age and time consumed by children. As stated by Hill [28], this would be expected owing to maturity and classroom training which improve the HS of children.

Observation of the pencil grip for the studied children revealed that the static tripod grip was the most

Table 6 Linear regression for the relationship between visual-motor integration and handwriting skills

	Copying letters		Copying words		Copying numbers		Handwriting skills total score	
	β	r^2	β	r^2	β	r^2	β	r^2
Copying lines	1.160**	0.996	1.088**	0.977	1.064**	0.996	1.972**	0.998
Copying shapes	0.027		0.239*		0.045		1.036**	
Coloring shapes	0.080		0.285		0.027		0.406*	

Linear regression. * $P < 0.05$. ** $P \leq 0.01$.

observed at age 4 years to 5 years 9 months, although the immature quadripod (four fingers) grip predominated at the age of 4 years to 4 years 3 months. Similar results were reported by Benbow [29] and Schneck and Henderson [30] who stated that children initially use immature grasps (such as four fingers and static tripod) when they first hold pencils or crayons and then this progresses into mature (such as dynamic tripod and dynamic quadripod) grasp patterns. At the age of 5–6 years, most of the studied children demonstrated dynamic tripod grip. The dynamic quadripod grip was the most observed grip at the age of 6 years. According to the work of Dennis and Swinth [31], children acquired four fingers grip at the age of 4 years and the tripod grasp typically develops in children between the ages of 4 and 6 years, whereas Graham *et al.* [32] found that dynamic tripod was acquired at 6 years and dynamic quadripod at 6–7 years [29]. The variation in the reported prevalence of the four common grasp patterns might be explained by differences in teaching practices over time and changes in emphasis in school curricula.

The readiness factors for mastering handwriting were explored in several studies. VMI was found to indicate readiness of formal handwriting instruction [6,33,34]. Beery and Buktenica [18] and Van der Zee [19] stated that the ability to copy basic shapes is a prerequisite for writing and an indication of the extent to which an individual's visual and motor abilities have been integrated. The present study revealed significant positive correlation between VMI and HS in Arabic-speaking kindergarten children. Similar result was obtained in a number of studies performed on English-speaking children. Examples of these studies are Sovik [35], Cornhill and Case-Smith [36], Daly *et al.* [16], Volman *et al.* [37], Feder and Majnemer [38], and Klein *et al.* [22]. All these studies concluded that VMI is a significant predictor of HS in young students and that this relationship is more important in early grades, particularly because young students tend to rely more on visual feedback and motor information to guide their movements to form and copy letters. Sovik [35] found that VMI was the most significant

variable to a child's HS, particularly when copying from printing material. Volman *et al.* [37] showed that good fine motor coordination was the only significant predictor of good handwriting and that poor handwriting quality was particularly related to deficits in VMI.

Stepwise linear regression analyses were used to identify the strongest predictors of HS. Results showed that copying lines was the best predictor of copying letters, copying words, copying numbers, and total HS score. This result agreed with that of Weil and Amundson [6] who observed that as patient's ability to copy the forms on the VMI increased, a concomitant increase in ability to copy letters accurately was seen. Letters and numbers are comprised of vertical, horizontal, and diagonal strokes. The ability to form these lines is an essential foundation skill for the future development of printing [39].

Reliability and validity of the VMI and HS assessment battery were tested and proved to be excellent. These batteries can be used as baseline for future studies on children with dysgraphia.

Conclusion

The VMI is an important prerequisite for Arabic HS. Copying lines was found to be the best predictor of copying letters, copying words, and copying numbers. Reliability and validity of the designed VMI and HS assessment battery proved to be excellent.

Limitations

This study was limited by its cross-sectional design and small sample size.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- 1 Hamstra-Bletz L, Blote AW. A longitudinal study on dysgraphic handwriting in primary school. *J Learn Disabil* 1993; 26:689–699.

- 2 Beery KE. The Beery-Buktenica developmental test of visual-motor integration: VMI with supplemental developmental tests of visual perception and motor coordination: administration, scoring and teaching manual. Parsippany, NJ: Modern Curriculum Press 1997.
- 3 Beery KE, Buktenica NA, Beery NA. The Beery-Buktenica developmental test of visual-motor integration. 3rd ed. Cleveland, OH: Modern Curriculum Press; 1989.
- 4 Beery KE. The developmental test of visual-motor integration. 3rd ed. Cleveland, OH: Modern Curriculum Press; 1989.
- 5 Johnson RA, Blair RJ, Zaba J. The visual screening of title I reading students. *J Behav Optom* 2000; 11:3-6.
- 6 Weil MJ, Amundson SJ. Relationship between visuomotor and handwriting skills of children in kindergarten. *Am J Occup Ther* 1994; 48:982-988.
- 7 Choo CM. Prehandwriting activities for young children: early childhood. USA: Academic Therapy Publications; 2009. pp. 156-170.
- 8 Marr D, Cermak S. Consistency of handwriting development in early elementary years: a literature review. *Isr J Occup Ther* 2001; 10:109-129.
- 9 Graham S, Weintraub N, Berninger VW. The relationship between handwriting style and speed and legibility. *J Educ Res* 1998; 91:290-297.
- 10 Smits-Engelsman BC, Niemeijer AS, van Galen GP. Fine motor deficiencies in children diagnosed as DCD based on poor grapho-motor ability. *Hum Mov Sci* 2001; 20:161-182.
- 11 Overvelde A, Hulstijn W. Handwriting development in grade 2 and grade 3 primary school children with normal, at risk, or dysgraphic characteristics. *Res Dev Disabil* 2011; 32:540-548.
- 12 Abu-Rabia S, Taha H. Reading and spelling error analysis of native Arabic dyslexic readers. *Read Writ* 2004; 17:651-689.
- 13 Ramadan M. Preventative program to early diagnosis and remediation of dyslexic pupils in primary school in Egypt. Unpublished PhD thesis, Bani-Seuf University (Egypt) 2009.
- 14 Abu-Rabia S, Sammour R. Spelling errors analysis of regular and dyslexic bilingual Arabic-English students *Open J Mod Linguist* 2012; 3:58-68.
- 15 Mirdehghan M. Persian, Urdu, and Pashto: a comparative orthographic analysis. *Writing Systems Research* 2010; 2:9-23.
- 16 Daly CJ, Kelley GT, Krauss A. Relationship between visual-motor integration and handwriting skills of children in kindergarten: a modified replication study. *Am J Occup Ther* 2003; 57:459-462.
- 17 Beery KE, Buktenica NA, Beery NA. Beery-Buktenica developmental test of visual-motor integration. 6th ed. San Antonio, TX: Pearson; 2010.
- 18 Beery KE, Buktenica NA. Developmental test for visual motor integration. New Jersey: Modern Curriculum Press; 1997.
- 19 Van der Zee F. Occupational therapy report and discussion. Visual integration skills. Available at: <http://www.visionandlearning.org/visualintegration.html>. [Accessed 4 July 2010].
- 20 Will EJ. An introduction to forensic document examination instrumentation: the college of microscopy. Instructional course at the college of microscopy. Westmont, IL; 2001.
- 21 Reynolds CR, Pearson NA. Developmental test of visual perception: adolescent and adult. Austin, TX: PRO-ED Inc.; 2002.
- 22 Klein S, Guiltner V, Sollereeder P, Cui Y. Relationships between fine-motor, visual-motor, and visual perception scores and handwriting legibility and speed. *Phys Occup Ther Pediatr* 2011; 31:103-114.
- 23 Ritchey K. The building blocks of writing: learning to write letters and spell words. *Read Writ* 2008; 21:27-47.
- 24 Asher A. Handwriting instruction in elementary schools. *Am J Occup Ther* 2006; 60:461-471.
- 25 Lindsay G, McLennan D. Lined paper: Its effects on the legibility and creativity of young children's writing. *Br J Educ Psychol* 1983; 53:364-368.
- 26 Ziviani J. Qualitative changes in dynamic tripod grip between seven and fourteen years of age. *Dev Med Child Neurol* 1983; 25:778-782.
- 27 Karlsdottir R, Stefansson T. Problems in developing functional handwriting. *Percept Mot Skills* 2002; 94:623-662.
- 28 Hill S. Developing early literacy: in assessment and teaching. 2nd ed. Parhan, Victoria, Australia: Eleanor Curtain Publishing; 2006. pp. 414-425.
- 29 Benbow M. Sensory and motor measurements of dynamic tripod skill. Boston: University, Boston; 1987.
- 30 Schneck CM, Henderson A. Descriptive analysis of the developmental progression of grip position for pencil and crayon control in non-dysfunctional children. *Am J Occup Ther* 1990; 44:893-900.
- 31 Dennis JL, Swinth Y. Pencil grasp and children's handwriting legibility during different-length writing tasks. *Am J Occup Ther* 2001; 55:175-183.
- 32 Graham S, Harris KR, Mason L, Fink-Chorzempa B, Moran S, Saddler B. How do primary grade teachers teach handwriting? A national survey. *Read Writ* 2008; 21:49-69.
- 33 Oliver C. A sensori-motor program for improving writing readiness skills in elementary-age children. *Am J Occup Ther* 1990; 44:111-116.
- 34 Benbow M, Hanft B, Marsh D, Royeen CB. Handwriting in the classroom: improving written communication. Bethesda, MD: American Occupational Therapy Association; 1992. pp. 5-60.
- 35 Søvik N. Developmental cybernetics of handwriting and graphic behavior. Norway: Oslo University; 1975.
- 36 Cornhill H, Case-Smith J. Factors that relate to good and poor handwriting. *Am J Occup Ther* 1996; 50:732-739.
- 37 Volman MJM, Van Schendel B, Jongmans MJ. Handwriting difficulties in primary school children: A search for underlying mechanisms. *Am J Occup Ther* 2006; 60:451-460.
- 38 Feder KP, Majnemer A. Handwriting development, competency, and intervention. *Dev Med Child Neurol* 2007; 49:312-317.
- 39 Goyen TA, Duff S. Discriminant validity of the developmental test of visual-motor integration in relation to children with handwriting dysfunction. *Aust Occup Ther J* 2005; 52:109-115.