

# Development and Validity of the Persian Handwriting Assessment Tool for Primary School-Aged Children

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## Abstract

**Background:** Handwriting difficulties are one of the most common reasons for referral to school-based occupational therapy. Assessing handwriting performance using standardized tools is necessary for scientific research and clinical assessment.

**Objectives:** The objective of this study was to develop and validate the Persian handwriting assessment tool to evaluate legibility and speed in near-point copying and dictation domains in primary school-aged children.

**Methods:** This methodological study was conducted in Tehran, Iran during 2015 - 2016. Measurement items were selected by reviewing the past literature and considering the opinions of an expert panel. The scale development, the analysis of content validity, and item analysis were performed in phase one using the data from 131 students in grades two and three. Exploratory factor analysis and discriminant validity were analyzed in phase two using the data from 208 subjects. Sampling was conducted using the random cluster method. Confirmatory factor analysis was conducted on a randomly split sample of half of the data.

**Results:** The content validity ratio of most of the criteria was greater than 0.57. Item analysis confirmed the writing assignments in the copying and dictation domains. Principal component analysis revealed that measurements in the copying and dictation domains loaded into three components separately, which accounted for 71.96% of the variance in the copying domain and 70.46% of the variance in the dictation domain. Confirmatory factor analysis also confirmed the accuracy of the three-dimensional structure designated through exploratory factor analysis. Discriminant validity showed that handwriting speed and legibility increased with maturation.

**Conclusions:** The Persian handwriting assessment tool as a comprehensive and quickly scored tool that can help therapists identify primary school students with handwriting problems so that appropriate interventions for these students can be implemented.

**Keywords:** Handwriting, Educational Assessment, Primary Schools, Students, Validation Studies

## 1. Background

Handwriting is defined as the visible trace of spoken language (1). Based on the child and youth edition of the international classification of functioning, disability and health, handwriting is an essential activity for learning and using knowledge (2). Primary school students spend 31% - 60% of a school day using handwriting and other fine motor tasks (3, 4).

Handwriting problems have been found in 11% - 32% of school-aged children (5). Poor handwriting abilities affect a student's performance in school activities. Apart from academic success, failure to obtain handwriting competency in school also has long-term negative effects on a student's self-esteem, self-efficacy, and participation (3). Handwriting difficulties are one of the most common reasons for referral to school-based occupational therapy (6).

Assessing handwriting performance using standardized and valid tools is necessary for scientific research and clinical assessment (7). Handwriting is a language-

dependent skill (8, 9). A number of evaluation tools have been developed to assess English, Chinese, Spanish, and Hebrew writing, but these tools are not applicable for the evaluation of Persian handwriting (10-13). Like other languages, Persian handwriting has a unique and complex writing method, letter and word formation and structure, and pronunciation (14).

Only a few studies have been conducted to develop handwriting assessment tools in Iran. Ragheb (2005) designed a handwriting achievement test for healthy students in grade one. The disadvantages of his study are that the scoring system is not well defined and the psychometric properties of the test are not evident. Additionally, the test has a long administration time (15).

Hadavand-Khani et al. (2007) developed a Persian handwriting checklist to assess the handwriting skills of 9 - 19-year-old children with mental retardation. This checklist evaluates the legibility and speed in only the near-point copying domain. The reliability and validity of the check-

list are reported (0.6 to 0.93). According to the developers of this tool, this tool is not a valid tool to use with healthy students and a separate tool should be developed for healthy students (16).

Javan Tash et al. (2012) explored the normal speed of handwriting in healthy students (grades two through five) in Tehran. In their study, the criteria used for the compilation of the writing assignment were not well defined, and other components of handwriting, such as legibility and ergonomic factors, were not considered. Additionally, the long duration of their test can lead to fatigue and can decrease a participant's writing speed (17).

These tools are weak because they fail to measure all the components of handwriting. There is no valid and reliable tool to evaluate all the components of handwriting in healthy students in Iran. Grades two and three are the best time to assess children's handwriting abilities (18). Therefore, developing standardized and comprehensive evaluation tools according to the characteristics of Persian handwriting for primary school-aged children in grades two and three is necessary.

## 2. Objectives

The purpose of this study was to develop and validate the Persian handwriting assessment tool (PHAT) for primary school students in grades two and three (8 - 10 years old) to assess handwriting legibility and speed in the near-point copying and dictation domains of handwriting.

## 3. Methods

This methodological study was performed in Tehran, Iran during 2015 - 2016. ethical approval for the study was sought from the ethical committee of Iran University of Medical Sciences (code: IR.IUMS.REC.1394.9211525209). This study was conducted in two phases: phase one (scale development and determination of content validity) and phase two (exploratory factor analysis [EFA], confirmatory factor analysis [CFA], and discriminant validity).

### 3.1. Phase One: Scale Development and Determination of Content Validity

Five expert panels (e.g., expert occupational therapists, speech and language pathologists, audiologists, and school teachers) were formed to monitor and critique the development of the PHAT to ensure that the constructs of the tool were valid.

#### 3.1.1. Selection of Measurement Items

By reviewing the past literature on this topic and considering the opinions from the expert panel, measurement items were selected from three major handwriting components (legibility, speed, and ergonomic factors) and two major handwriting domains (near-point copying and dictation). The legibility component included word formation, size, space, and alignment and text slant (3, 7, 19). Handwriting speed was defined as the amount of time required to write specific text and the number of letters written per minute (10, 20). Ergonomic factors were standardized during the evaluation protocol and were controlled (3, 21, 22).

#### 3.1.2. Compilation of the writing assignment

It was divided into five steps.

##### 3.1.2.1. Identification of Sources for Word Selection

Words that have been frequently used and written by students should be identified (20). There were no studies that recommended appropriate words for Persian language writing in primary school. Experts recommended using grade one through three Persian literature books in order to select the words.

##### 3.1.2.2. Extraction and Confirmation of the Criteria

Ten criteria were identified by the literature and experts' opinions for the selection of words and the compilation of the writing assignments (3, 12, 20, 23). Fourteen experts were invited to assess the content validity (Lawshe's method) of the criteria (level of agreement: 0.57) (24). Most of the identified criteria were confirmed (Table 1).

##### 3.1.2.3. Selection of the Words

The 1100 most frequently used words were selected from the grade one through three Persian literature and were placed into a word pool. Then, words with more than six letters were removed. Next, in order to determine the level of complexity, three experienced school teachers rated 963 words into one of three categories: easy to write, proper to write, and difficult to write. According to these teachers' recommendations, words with repeated letters were deleted. Finally, the pronunciation clarity of 897 words was determined by three speech and language pathologists. Words with a high sonority level and low neighborhood density were determined to be clear words for designing a dictation assignment.

##### 3.1.2.4. Designing the Writing Assignments

According to the confirmed criteria, four series of words for dictation and two series of words for near-point

**Table 1.** Content Validity Ratio of the Criteria for Word Selection and the Compilation of the Dictation and Copying Assignments of the Persian Handwriting Assessment Tool

Number	Criteria	Dictation	Copying
1	Words that are familiar to students and that are used by students are used	1	0.71
2	Words that represent a wide variety of complexity are used	0.85	0.85
3	Words with two to six letters are used in order to minimize the involvement of working memory	0.71	0.71
4	Concrete words are used in order to reduce cognitive involvement	0.14	0.28
5	All letters of the alphabet are used as much as possible in the writing assignment	0.85	0.85
6	Meaningful words are included in the writing assignment	1	1
7	The writing assignment has a low volume in order to prevent fatigue	1	1
8	Words with clear pronunciation are used in the dictation assignment	1	-
9	Words that are similar in terms of reading and writing are used	- 0.14	-
10	A clear and specified font is used in the writing assignment	-	1

copying were designed. The brainstorming phase was conducted by a team of experts who determined which series would be most appropriate for a writing assignment. Finally, two series of words for dictation and one series of words for near-point copying were approved.

#### 3.1.2.5. Determination of Appropriateness and Final Revision

A pilot study was conducted in three governmental primary schools in the center of Tehran based on the random cluster sampling method. According to the literature, a minimum size of 100 subjects is sufficient for a pilot study (20). In total, 131 8 - 10-year-old native Persian-speaking students were recruited (grade two,  $n = 65$ ; grade 3,  $n = 66$ ). Monolingual students with no documented mental, neurological, or physical impairment were included (20). Five bilingual students were excluded from the study. Informed consent was collected from each of the participants. We ensured students that withdrawal from the study was voluntary. Moreover, we assured them of the confidentiality of their information.

In this pilot study, each student was asked to sit on desk and copy words from a near-point sample in a quiet room at school. Each student was asked to dictate two series of words on lined paper. They were told to write as "you usually do when you are trying to use good handwriting" (25). The time each student took to complete the task was recorded in order to calculate writing speed. The percentage of words correctly copied and dictated was analyzed by descriptive statistics. For item analysis, the difficulty index and discrimination index were calculated using a formula, and the correlation coefficient was analyzed using Spearman's test. An acceptable range for item analysis included a difficulty index of 0.3 - 0.7, a discrimination index of 0.5 or higher, and a correlation coefficient of 0.3 or higher. Having two items in the acceptable range designated an item

sufficient for admission (26). Ultimately, twelve words with 46 letters for the copying assignment and 12 words with 50 letters for the dictation assignment were approved.

#### 3.1.3. Development of the Assessment Protocol

An effort was made to develop a sufficiently meaningful protocol to simulate real-life context (27). In the administration of the PHAT, a quiet and well-lit room was required. The desk and chair provided were of an appropriate height for the participants. Writing on slanted surface (20 - 30°) can improve a student's pencil grasp (3). The equipment required were a pencil (HB model), eraser, sharpener, clipboard, and a piece of preprinted A4-size lined paper. Additionally, an antislip was placed on the table to prevent the movement of the clipboard. The paper on the clipboard was slanted on the table so that the clipboard was parallel to the forearm of the writing hand. This angle of the paper enabled each child to see his or her written assignment and to avoid smearing his or her writing (3, 7).

#### 3.1.4. Scoring Procedure

The amount of time to write the copy assignment was recorded. Then, a formula was used to calculate the number of letters written per minute: number of letters / number of seconds =  $x / 60$ .

Legibility is often evaluated in terms of its components formation, space, alignment, size and text slant. The components of legibility were scored with a five-point Likert scale (ranging from very poor to very good). The size of a word was rated in different ways (ranging from very small to very big) (10). Finally, the mean score of the twelve words for each component was considered to be the subject score. Orthographic errors in the dictation assignment were also recorded.

### 3.2. Phase two: the Construct Validity of the PHAT

EFA and CFA were conducted and discriminant validity was determined in order to measure the construct validity of the PHAT. According to the recommended sample size in a study on construct validity, there should be 5 - 10 subjects per measurement item (26). Based on the PHAT's measurement items, a minimum size of 70 subjects was required. In this phase, 208 monolingual students from grades two and three were included from three governmental primary schools in the center of Tehran. Participants who were diagnosed with developmental delay, neurological deficits, or physical or mental disability were excluded from the study. An informed consent letter for each participant was obtained from teachers or parents. Participants were individually evaluated in a quiet room to control confounding factors. The PHAT only takes a few minutes to administer, which prevents test subject fatigue.

#### 3.2.1. Statistical Analysis

Principal component analysis with a varimax rotation was used to examine the nature of the interrelationship of the PHAT measurements and the group-correlated measurements. The appropriateness of the factor analysis model and the sampling adequacy were assessed using Bartlett's test of sphericity and the Kaiser-Meyer-Olkin test, respectively. We used eigenvalues greater than 1 and a scree plot in order to determine the number of factors (28). CFA was used to test the accuracy of the three-dimensional structure designated through EFA, which was performed to detect the validity of the PHAT in the copying and dictation domains. CFA was conducted on a randomly split sample of half of the data.

The discriminant validity of the PHAT was established by demonstrating statistically significant differences between the students' performance. Based on current research findings and clinical observations, children's handwriting speed and legibility have been hypothesized to improve with maturation (18, 29). The scores of the two groups were compared using an independent samples t-test with a significance level less than 0.05. SPSS version 20 was used for data analysis (EFA and discriminant validity). For the CFA, Lisrel 8.80 was used.

## 4. Results

Five expert panels were formed to aid in the development and in the determination of the validity of the PHAT. According to the level of agreement (0.57), most of the extracted criteria used to design the writing assignment were confirmed (Table 1). After extracting the words from

the Persian literature books and excluding some of the extracted words, the level of complexity of the words was determined by three experienced school teachers. The final list of words included 156 easy words, 517 proper words, and 224 difficult words.

After a pilot study was conducted on 131 students in grades two and three (81 boys, 50 girls; age:  $8.92 \pm 0.692$  years), copying speed was calculated. Copying speed ranged from 39 to 162 seconds (70.76 to 17.03 letters per minute). The percentage of words correctly copied and dictated was also analyzed. This percentage ranged from 97.7% to 100% with the copying assignment and 96.9% to 100% with the dictation assignment. In the final step of phase one, item analysis showed that all the selected words were acceptable (Table 2).

In phase two, 208 students in grades two and three (104 boys, 104 girls; age:  $8.99 \pm 0.653$  years) participated in a study intended to examine the construct validity of the PHAT. Principal component analysis showed that the measurement items in the copying and dictation domains loaded into three components separately (Table 3), which accounted for 71.96% of the variance for the copying domain and 70.46% of the variance for the dictation domain. The results of the Kaiser-Meyer-Olkin test and Bartlett's test of sphericity showed that the study sample was adequate (copying: 0.696, dictation: 0.712) and that the correlation matrix was suitable for factor analysis, respectively (copying:  $\chi^2 = 172$  and  $P < 0.001$ ; dictation:  $\chi^2 = 185$  and  $P < 0.001$ ). The goodness of fit index of items with respect to CFA results are presented in Table 4. The fit index values showed that this model fits well. The road map for the structure of the PHAT (copying and dictation domains) are provided in Figures 1 and 2. The assessment of discriminant validity showed that handwriting speed and legibility increased with maturation (Table 5).

## 5. Discussion

Since no standardized Persian handwriting assessment tool has been available, no normative sample could be developed and individuals' handwriting skills were difficult to compare. Because of the lack of such assessment tools, developing valid evaluation tools according to the characteristics of Persian handwriting is necessary.

Students with proficient handwriting reached a stable level in grade two, but students with handwriting difficulties continued to develop strongly during grade two and the first half of grade three (18). Hamstra-Bletz and Blote (1993) reported that children who had handwriting problems in grade two still had writing problems in subsequent grades (8). Therefore, grades two and three are the best time to screen children for handwriting problems (18).

**Table 2.** Item Analysis for the Selected Words in the Copying and Dictation Assignments of the Persian Handwriting Assessment Tool

Item	Domain	Difficulty Index	Discrimination Index	Correlation Coefficient	Considerations
Word 1	Copy	0.48	0.96	0.77	Accepted
	Dictation	0.4	0.75	0.65	
Word 2	Copy	0.46	0.81	0.74	Accepted
	Dictation	0.4	0.75	0.65	
Word 3	Copy	0.37	0.75	0.73	Accepted
	Dictation	0.33	0.54	0.61	
Word 4	Copy	0.28	0.51	0.54	Accepted
	Dictation	0.48	0.78	0.73	
Word 5	Copy	0.42	0.78	0.66	Accepted
	Dictation	0.25	0.51	0.62	
Word 6	Copy	0.51	0.84	0.69	Accepted
	Dictation	0.27	0.54	0.66	
Word 7	Copy	0.4	0.69	0.58	Accepted
	Dictation	0.42	0.72	0.73	
Word 8	Copy	0.3	0.6	0.67	Accepted
	Dictation	0.45	0.9	0.66	
Word 9	Copy	0.45	0.78	0.63	Accepted
	Dictation	0.53	0.75	0.53	
Word 10	Copy	0.37	0.63	0.62	Accepted
	Dictation	0.3	0.6	0.65	
Word 11	Copy	0.42	0.84	0.73	Accepted
	Dictation	0.33	0.6	0.73	
Word 12	Copy	0.4	0.69	0.6	Accepted
	Dictation	0.54	0.72	0.62	

Handwriting is commonly agreed to consist of three major components: speed, legibility, and ergonomic factors (3, 30, 31). Most standardized handwriting evaluations involve only a single component of handwriting, which might not be sufficient to capture the many aspects of a child's handwriting performance (10). In the present study, legibility and speed were chosen as measurement items. Ergonomic factors were standardized and controlled in the evaluation protocol. In some studies, accuracy is considered to be one of the handwriting components. Accuracy is the most challenging component to evaluate. Teachers and clinicians evaluate the children's handwriting accuracy with different standards and personal preferences. Few studies have been conducted to investigate handwriting accuracy (31). We did not measure handwriting accuracy.

Most existing handwriting scales did not specify the

rationale underlying their choice of handwriting assignment, and in many tools, no validity studies were conducted (23). In our study, many criteria were chosen in order to design the writing assignment. A writing assignment should be able to simulate what students frequently write at school with diverse complexity (3, 11). Therefore, the selection of words used in our assignment started with the most frequently used words learned by students in grades one through three. In order to diversify the complexity of the included words, words using all the letters of the alphabet, words with two to six letters, and words with one to three syllables were used in the writing assignments. Most importantly, three experienced teachers determined the words' level of complexity.

There is a trade-off between the legibility, speed, and complexity of the completion of a handwriting task (32). As a result, words with a proper level of complexity were

**Table 3.** Factor Loading of the Measurements of the Persian Handwriting Assessment Tool in the Principal Component Analysis and Rotated Using Varimax

Domain	Measurement Items	Component 1	Component 2	Component 3
Copying	Formation	0.698		
	Space	0.496		
	Alignment	0.836		
	Text Slant	0.752		
	Size		0.987	
	Copying Speed (Time)			- 0.966
	Copying Speed (Letters/Minute)			0.962
Dictation	Formation	0.715		
	Space	0.848		
	Alignment	0.602		
	Text Slant	0.417		
	Size		0.945	
	Orthographic Error			- 0.808

**Table 4.** Confirmatory Factor Analysis Error and Goodness of Fit Indices of Scale for the Persian Handwriting Assessment Tool (Copying and Dictation Domains)

Fitness Criteria	Acceptable Fitness	Copying	Dictation
$\chi^2/Df/P$	$0 < \chi^2/sd < 3 - P < .05$	19.68/11/P = 0.049	14.78/6/P = 0.022
GFI	GFI > 0.90	0.96	0.97
AGFI	$0.80 \leq AGFI \leq 0.90$	0.9	0.89
RMR	RMR < 0.05	0.019	0.013
NFI	NFI > 0.90	0.93	0.94
NNFI	NNFI > 0.90	0.94	0.9
IFI	IFI > 0.90	0.97	0.96
CFI	CFI > 0.90	0.97	0.96
RMSEA	$0.05 \leq RMSEA \leq 0.10$	0.07	0.09

used, which was confirmed by item analysis. Words with two to six letters likely reduce the involvement of working memory during test administration. Therefore, students can better concentrate on other aspects of written language, such as spelling and word structure, with words of this length (33). In addition, selected words should be able to represent a wide variety of structural forms and stroke units. Because of this, all the letters of alphabet were included in separated and connected forms.

Based on the criteria for this tool, meaningful words should be used in the assignments. The use of such words motivates participants during test administration (25). The teachers on the panel believed that the selected words should be tangible and meaningful for students. This issue was considered, and words with related meanings were arranged next to each other in final revision.

Legibility and speed tend to decrease with a prolonged handwriting task (34). Thus, effort was made to use a low number of words in the writing assignments. Participants had to write the copying assignment first. In addition, they had to read the words until they were familiar with all words and then write it.

Using words with high sonority in the dictation assignment and words with clear and specified font in the copying assignment may lead to high test audibility and readability. In addition, equal conditions should be created during test administration (10, 25, 35).

The results of the pilot study showed that 97.2% to 100% of words in the copying assignment and 96.9% to 100% of the words in the dictation assignment were written correctly by students. Joyce (2009) mentioned that over the 93% is acceptable range for Chinese students in grades two

**Table 5.** Comparison of the Mean and Standard Deviation of Variables Between Students in Grades Two and Three

Domain	Variable	Grade	Mean	SD	P
	Formation	2	3.01	0.297	0.000
		3	3.41	0.344	
	Space	2	3.44	0.457	0.000
		3	3.79	0.32	
	Alignment	2	3.65	0.296	0.035
		3	3.75	0.302	
Copying	Size	2	2.79	0.572	0.602
		3	2.83	0.446	
	Text Slant	2	3.87	0.343	0.978
		3	3.87	0.373	
	Copying Speed (Time)	2	85.98	23.04	0.000
		3	73.71	21.58	
	Copying Speed (Letters/Minute)	2	34.26	8.86	0.000
		3	40.33	10.86	
	Formation	2	3	0.284	0.000
		3	3.46	0.324	
	Space	2	3.5	0.426	0.000
		3	3.86	0.255	
Dictation	Alignment	2	3.62	0.317	0.001
		3	3.77	0.275	
	Size	2	2.81	0.563	0.806
		3	2.83	0.448	
	Text Slant	2	3.88	0.331	0.637
		3	3.9	0.337	
	Orthographic Error	2	0.28	0.543	0.06
		3	0.14	0.412	

and three (20).

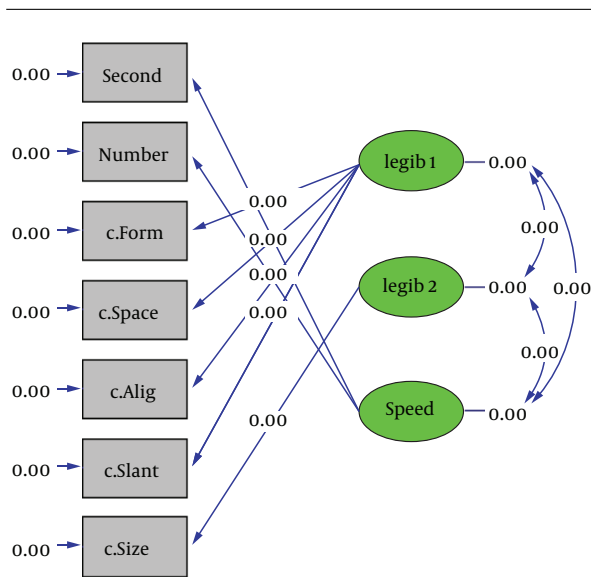
Item analysis in the pilot study confirmed the copying and dictation assignments. Selecting words based on confirmed criteria and using words with diverse complexity, which was determined by teachers, may be responsible for the results of this analysis.

Principal component analysis showed that the measurement items in the copying and dictation domains loaded into three components separately. CFA confirmed the accuracy of the three-dimensional structure that was designated through EFA. According to the literature, speed and legibility are components of handwriting, but their scores are reported separately (3, 4, 29, 36). The results of our study are in accordance with the literature and the opinions of the expert panel. Word size in the two

domains and orthographic error in the dictation domain were loaded in a separate component. The reason for this separation could be that the scoring methods were different for these variables. Li-Tseng (2013) also reported that character size is loaded in different component (11).

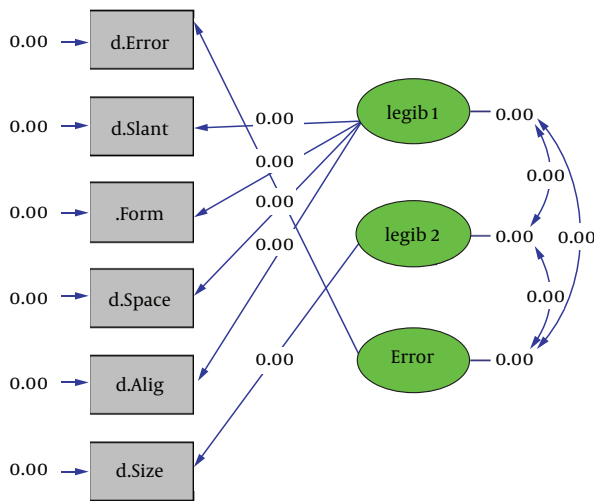
The assessment of the discriminant validity of the PHAT revealed that handwriting speed in grade three was significantly better than in grade two. These results supported the hypothesis that handwriting speed improves with maturation (18, 20, 29, 37), but according to Summers' study, most changes in writing speed are related to primary school and do not occur in older ages (21).

In the copying and dictation domains, significant differences in legibility components (formation, space, and alignment) were observed between the two groups. Scores



Chi-Square = 19.68, df = 11, P-value = 0.04989, RMSEA = 0.073

**Figure 1.** Significance Levels of the Rates, Latent Variables, and Explained Observed Variables for the Three-Dimensional Model of the PHAT (Copying Domain)



Chi-Square = 14.78, df = 6, P-value = 0.02202, RMSEA = 0.099

**Figure 2.** Significance Level of the Rates, Latent Variables, and Explained Observed Variables for the Three-Dimensional Model of the PHAT (Dictation Domain)

in word size and text slant were better in the grade three participants, but there was no significant difference between the two groups. Graham (1998) reported that students' handwriting became more legible during primary grades (29). Some studies that focused on normal children also confirmed that handwriting was found to be charac-

terized by rapid quality improvement during grade one that reached a plateau by grade two with further improvements seen by grade three (3, 31), but Overvelde (2010) reported different results in children with DCD (18).

Text slant scores were similar in both groups. Rosenblum (2003) mentioned that the type of paper (lined or unlined) influences writing performance (23). Therefore, the use of lined paper may be the cause of the results of this study.

There was no significant difference between groups in relation to word size. This result might be related to the sampling. In addition, the size of the writing reportedly does not usually change over time in healthy children (3, 23, 29).

Orthographic errors in the grade two participants were higher than in the grade three participants, but there was no significant difference between the two groups. This result may be related to the sampling and the selection of familiar words for the writing assignment.

The PHAT showed reasonable and satisfactory item analysis, factor analysis, and discriminant validity results. This study would have been more comprehensive if students with learning disabilities could have been compared with healthy students in order to examine the PHAT's discriminant validity. Only students from three governmental primary schools in Tehran were invited to participate in this study. By expanding our sample size, the validity of the PHAT can be improved. Although there are still ergonomic, biomechanical, or unspecified aspects that may not be determined by this tool, the PHAT can be used as a comprehensive and quickly scored tool that can help therapists identify primary school students with handwriting problems so that appropriate interventions for these students can be implemented.

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**Footnotes**

**Authors' Contribution:** Naser Havaei performed study concept and design, the literature review, the implementation of the project, the analysis and interpretation of data, the drafting of the manuscript, and the statistical analysis; Akram Azad supervised the study and data analysis, made critical revisions to the paper, and prepared the last revision of the manuscript; Mehdi Alizadeh Zarei supervised



the study; Abbas Ebadi supervised the analysis and interpretation of data, the drafting of the manuscript, and statistical analysis.

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## References

- Athenes S, Sallagoity I, Zanone PG, Albaret JM. Evaluating the coordination dynamics of handwriting. *Hum Mov Sci.* 2004;**23**(5):621-41. doi: [10.1016/j.humov.2004.10.004](https://doi.org/10.1016/j.humov.2004.10.004). [PubMed: [15589625](https://pubmed.ncbi.nlm.nih.gov/15589625/)].
- World Health Organization. . International classification of functioning, disability, and health: Children & youth version: ICF-CY. World Health Organization; 2007.
- Feder KP, Majnemer A. Handwriting development, competency, and intervention. *Dev Med Child Neurol.* 2007;**49**(4):312-7. doi: [10.1111/j.1469-8749.2007.00312.x](https://doi.org/10.1111/j.1469-8749.2007.00312.x). [PubMed: [17376144](https://pubmed.ncbi.nlm.nih.gov/17376144/)].
- Hoy MM, Egan MY, Feder KP. A systematic review of interventions to improve handwriting. *Can J Occup Ther.* 2011;**78**(1):13-25. [PubMed: [21395194](https://pubmed.ncbi.nlm.nih.gov/21395194/)].
- Karlsdottir R, Stefansson T. Problems in developing functional handwriting. *Percept Mot Skills.* 2002;**94**(2):623-62. doi: [10.2466/pms.2002.94.2.623](https://doi.org/10.2466/pms.2002.94.2.623). [PubMed: [12027360](https://pubmed.ncbi.nlm.nih.gov/12027360/)].
- Feder K, Majnemer A, Synnes A. Handwriting: current trends in occupational therapy practice. *Can J Occup Ther.* 2000;**67**(3):197-204. [PubMed: [10914482](https://pubmed.ncbi.nlm.nih.gov/10914482/)].
- Case-Smith J, O'Brien JC. Occupational therapy for children and adolescents. 7 ed. Elsevier Health Sciences; 2015.
- Hamstra-Bletz L, Blote AW. A longitudinal study on dysgraphic handwriting in primary school. *J Learn Disabil.* 1993;**26**(10):689-99. [PubMed: [8151209](https://pubmed.ncbi.nlm.nih.gov/8151209/)].
- Koziatek SM, Powell NJ. A validity study of the Evaluation Tool of Children's Handwriting-Cursive. *Am J Occup Ther.* 2002;**56**(4):446-53. [PubMed: [12125834](https://pubmed.ncbi.nlm.nih.gov/12125834/)].
- Feder KP, Majnemer A. Children's handwriting evaluation tools and their psychometric properties. *Phys Occup Ther Pediatr.* 2003;**23**(3):65-84. [PubMed: [14664312](https://pubmed.ncbi.nlm.nih.gov/14664312/)].
- Li-Tsang CW, Wong AS, Leung HW, Cheng JS, Chiu BH, Tse LF, et al. Validation of the Chinese Handwriting Analysis System (CHAS) for primary school students in Hong Kong. *Res Dev Disabil.* 2013;**34**(9):2872-83. doi: [10.1016/j.ridd.2013.05.048](https://doi.org/10.1016/j.ridd.2013.05.048). [PubMed: [23816625](https://pubmed.ncbi.nlm.nih.gov/23816625/)].
- Rosenblum S, Weiss PL, Parush S. Handwriting evaluation for developmental dysgraphia: Process versus product. *Reading and writing.* 2004;**17**(5):433-58.
- Roston KL, Hinojosa J, Kaplan H. Using the minnesota handwriting assessment and handwriting checklist in screening first and second graders' handwriting legibility. *J Occupational Therapy, Schools, & Early Intervention.* 2008;**1**(2):100-15.
- Solimanpour F, Sadri J, Suen CY, editors. Standard databases for recognition of handwritten digits, numerical strings, legal amounts, letters and dates in Farsi language. Tenth international workshop on frontiers in handwriting recognition. 2006; Suvisoft.
- Ragheb H HM. ;(;). . A preliminary study of validity and reliability for handwriting achievement test in primary school student (grade 1). *Except Child.* 2005;**11-14**(4):51-62.
- Hadavand-Khani F, Bahrami H, Behnia F, Farahbod M, Salehi M. Handwriting evaluation in mentally retarded students: Identifying an instrument. *J Rehabilitation.* 2008;**8**(4):45-52.
- Javan Tash A, Mirzakhani N, Pashazadeh Z. The quest for exploring the normal speed of handwriting in students of grade 2-5 in Tehran. *Rehabilitation Med.* 2012;**1**(1):57-63.
- 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**(2):540-8. doi: [10.1016/j.ridd.2010.12.027](https://doi.org/10.1016/j.ridd.2010.12.027). [PubMed: [21269805](https://pubmed.ncbi.nlm.nih.gov/21269805/)].
- Falk TH, Tam C, Schellnus H, Chau T. On the development of a computer-based handwriting assessment tool to objectively quantify handwriting proficiency in children. *Comput Methods Programs Biomed.* 2011;**104**(3):102-11. doi: [10.1016/j.cmpb.2010.12.010](https://doi.org/10.1016/j.cmpb.2010.12.010). [PubMed: [21376418](https://pubmed.ncbi.nlm.nih.gov/21376418/)].
- Cheng S. Development and validation of a Chinese handwriting assessment tool (CHAT) for primary school students. [Department of Rehabilitation Sciences], The Hong Kong Polytechnic University; 2010.
- Summers J, Catarro F. Assessment of handwriting speed and factors influencing written output of university students in examinations. *Aust Occup Ther J.* 2003;**50**(3):148-57.
- Tomchek S, Schneck C. evaluation of handwriting. hand function in the child: foundations for remediation. 2006 :291-309.
- Rosenblum S, Weiss PL, Parush S. Product and process evaluation of handwriting difficulties. *Educ Psychol Review.* 2003;**15**(1):41-81.
- Ayre C, Scally AJ. Critical values for lawshe's content validity ratio revisiting the original methods of calculation. *Meas Eval Couns Dev.* 2014;**47**(1):79-86.
- Reisman JE. Development and reliability of the research version of the minnesota handwriting test. *Phys Occup Ther Pediatr.* 1993;**13**(2):41-55.
- Plichta SB, Kelvin EA, Munro BH. Munro's statistical methods for health care research: Wolters Kluwer Health/Lippincott Williams & Wilkins. 2012
- Sudsawad P, Trombly CA, Henderson A, Tickle-Degnen L. The relationship between the Evaluation Tool of Children's Handwriting and teachers' perceptions of handwriting legibility. *Am J Occup Ther.* 2001;**55**(5):518-23. [PubMed: [14601811](https://pubmed.ncbi.nlm.nih.gov/14601811/)].
- Portney LG, Watkins MP. Foundations of clinical research: Applications to practice (3rd edn) pearson prentice hall. 2009
- Graham S, Berninger V, Weintraub N, Schafer W. Development of handwriting speed and legibility in grades 1-9. *J Educat Res.* 1998;**92**(1):42-52.
- Schneck CM, Amundson SJ, Case-Smith J, O'Brien JC. Prewriting and handwriting skills. *Occupational therapy for children.* 2010;**6**:555-80.
- Stefansson T, Karlsdottir R. Formative evaluation of handwriting quality. *Percept Mot Skills.* 2003;**97**(3 Pt 2):1231-64. doi: [10.2466/pms.2003.97.3f.1231](https://doi.org/10.2466/pms.2003.97.3f.1231). [PubMed: [15002869](https://pubmed.ncbi.nlm.nih.gov/15002869/)].
- Tseng MH, Chow SM. Perceptual-motor function of school-age children with slow handwriting speed. *Am J Occup Ther.* 2000;**54**(1):83-8. [PubMed: [10686631](https://pubmed.ncbi.nlm.nih.gov/10686631/)].
- Crouch AL, Jakubecy JJ. Dysgraphia: How it affects a student's performance and what can be done about it. *TEACHING Exceptional Children Plus.* 2007;**3**(3):n3.
- Dennis JL, Swinth Y. Pencil grasp and children's handwriting legibility during different-length writing tasks. *Am J Occup Ther.* 2001;**55**(2):175-83. [PubMed: [11761133](https://pubmed.ncbi.nlm.nih.gov/11761133/)].
- Hammerschmidt SL, Sudsawad P. Teachers' survey on problems with handwriting: referral, evaluation, and outcomes. *Am J Occup Ther.* 2004;**58**(2):185-92. [PubMed: [15068154](https://pubmed.ncbi.nlm.nih.gov/15068154/)].
- Brossard-Racine M, Mazer B, Julien M, Majnemer A. Validating the use of the evaluation tool of children's handwriting-manuscript to identify handwriting difficulties and detect change in school-age children. *Am J Occup Ther.* 2012;**66**(4):414-21. doi: [10.5014/ajot.2012.003558](https://doi.org/10.5014/ajot.2012.003558). [PubMed: [22742689](https://pubmed.ncbi.nlm.nih.gov/22742689/)].
- Rosenblum S, Dvorkin AY, Weiss PL. Automatic segmentation as a tool for examining the handwriting process of children with dysgraphic and proficient handwriting. *Hum Mov Sci.* 2006;**25**(4-5):608-21. doi: [10.1016/j.humov.2006.07.005](https://doi.org/10.1016/j.humov.2006.07.005). [PubMed: [17011656](https://pubmed.ncbi.nlm.nih.gov/17011656/)].