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Handwriting Speed, Visual-Motor Skills, and Attitudes Toward Writing in the Context of Handwriting Legibility of Students with Learning Disabilities

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ABSTRACT

Many studies on learning disability (LD) have focused on the reading skills of students; however, many students with LDs struggle with basic handwriting skills, which are fundamental for all ages in school and everyday functioning. The purpose of this study was to examine the handwriting legibility of students with LDs in conjunction with their handwriting speed, visual-motor skills, and attitudes toward writing. The sample included 75 third- to fourth-grade students in a metropolitan city in Türkiye. The assessment task aligned with the research purpose: for the students to copy the Turkish text, copy geometrical figures, and answer questions related to attitudes toward writing. Correlations among variables varied; however, the results confirmed that handwriting speed, visual-motor skills, and attitudes toward writing predicted the handwriting legibility of students with LDs. There are intricate relationships between handwriting speed, visual-motor skills, and attitudes toward writing. The results have implications for research and practice.

Introduction

According to the Diagnostic Manual of Mental Disorders V Text Revision (DSM-V-TR), learning disability (LD) consists of a heterogeneous population that experiences problems in reading, writing, and math depending on the individual case (American Psychiatric Association, 2022). Due to the heterogeneity of this group (Fletcher & Miciak, 2024) and research documenting generic problems with the handwriting of students with LDs (Bray et al., 2021; Lam et al., 2011; Martínez-García et al., 2021), the evidence is still unclear, demonstrating the necessity of investigation. Students with LDs have different profiles of handwriting skills and related aspects, such as legibility, visual-motor skills, and attitudes toward writing. For instance, students with dyslexia struggle with handwriting (Angelelli et al., 2010), suggesting a reciprocal relationship between reading and writing (Graham et al., 2021). Furthermore, dysgraphia can be undiagnosed (Chung & Patel, 2015), suggesting the underrepresentation of dysgraphia and the research gap in the field of LD. Despite the acknowledged value of handwriting in elementary school, many students still find it difficult, especially those with LDs. However, further research is needed to determine which areas should be strengthened regarding the handwriting of students with LDs.

The majority of the texts composed at schools are written by hand regardless of the type of subjects and grade levels (Santangelo & Graham, 2016) because it is the foundation of literacy

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development (Limpo & Graham, 2020). In addition, handwriting influences other writing processes, such as planning and text generation, which in turn ensure legibility and fluency in handwriting (Santangelo & Graham, 2016). This consideration is valid for students with LDs (Graham, 1999). Despite the prevalence of LD, few studies have examined handwriting problems in this population. Early on, LD research has focused mainly on the reading skills of students with LDs; however, deficits in handwriting are also prevalent since reading and writing skills are interrelated, implying the need for a more thorough examination. Given the above research findings, we aim to examine the handwriting legibility of students with LDs in conjunction with their handwriting speed, visual-motor skills, and attitudes toward writing.

Handwriting

Children spend roughly 18%−47% of their school days performing fine motor activities, yet 85% of these make up handwriting activities at the elementary school level (McMaster & Roberts, 2016), implying its importance in school success (Graham et al., 1998).

Any difficulty can lead to a referral to occupational therapy for handwriting difficulties due to difficulties in letter formations, alignment of the letters to the line, size of letters, and spacing within/between words (Hammerschmidt & Sudsawad, 2004).

Handwriting is an integral part of the overall task of writing (Barnett & Prunty, 2021).

Considering handwriting solely and excluding expressive and orthographic components, the legibility and speed of one's production are considered to be essential aspects of writing (Capodieci et al., 2018). The aspect of handwriting legibility is defined simply as the feature of written text contributing to "readability" (Rosenblum et al., 2004). The other aspect is handwriting speed, defined as how quickly one can produce letters or words correctly (Limpo & Graham, 2020; Skar et al., 2022). Two aspects of handwriting (legibility and speed) are critical from elementary to high school (Graham et al., 1998). The development of legibility in handwriting often follows a pattern characterized by change in performance.

Handwriting legibility and speed become particularly important for those with LDs since they are more likely to have problems with these skills. Children with dyslexia perform more slowly and less accurately in handwriting tasks than do those in a chronological age-matched group (Martinez-Garcia et al., 2021). In a recent comprehensive meta-analysis (Graham et al., 2021), the results fully showed that children with reading difficulties scored lower than children matched for age and children matched for reading ability in all writing measures, including handwriting, which may be explained by the rhetorical relations theory of reading and writing (Nelson & Calfee, 1998; Tierney & Shanahan, 1991). Similar results were revealed in a study examining Chinese handwriting in students with dyslexia and students without dyslexia, which showed that students with dyslexia performed more poorly in terms of speed and accuracy (Lam et al., 2011).

The relationship between handwriting speed and legibility is complex. Studies investigating these relationships have shown mixed results (Gosse et al., 2021; Graham et al., 1998). According to a longitudinal study conducted with French-speaking children, there was a negative relationship between handwriting speed and handwriting quality in copying tasks for the 4th and 5th grades, revealing that fast writing is detrimental (Gosse et al., 2021). Researchers concluded that faster writing leads to less legible handwriting (Gosse et al., 2021). In the same study, handwriting speed continued to develop until 5th grade, while handwriting quality peaked in 2nd grade. In another study, handwriting was found to be a significant predictor of legibility on the two free-writing tasks but not on the copied task (Graham et al., 1998). For instance, after a 10-min copying task, the legibility of handwriting decreased, whereas the writing speed increased for both typically developing children and children with handwriting problems in a sample of 120 fourth-grade students (Schwellnus et al., 2012). To sum up, "*writing well is not just an option for young people—it is a necessity, and it is a predictor for academic success*" (Graham & Perin, 2007, p. 3).

It is well known that students with LDs are struggling academically. As students with LDs move to upper grades, they will face more complex writing assignments that necessitate both legibility and speed. However, to the best of our knowledge, no study has been conducted, implying a more thorough examination of handwriting with students with LDs.

Visual-motor skills

Visual-motor skills can be simply described as the ability to coordinate visual information with motor skills (Stevens & Bernier, 2021). Therefore, they have an important role in handwriting, which is a complex functional activity for all ages simultaneously, as shown by accumulating evidence (Klein et al., 2011; Lee, 2022; Prunty et al., 2016; Tseng & Murray, 1994). For instance, Klein et al. (2011) reported that "skilled" handwriters had higher visual-motor integration scores than "unskilled" handwriters in a sample predominantly diagnosed with ADHD and LD from 3rd grade to 6th grade. Similarly, poor handwriters had lower scores on most of the perceptual-motor tests than good handwriters did in a study conducted with typical children from the 3rd grade to the 5th grade (Tseng & Murray, 1994). Further evidence has indicated that visual-motor skills, particularly name writing, predict handwriting performance in kindergarten students in conjunction with positive correlations among reading, writing, visual-motor, and fine motor skills (Frolek Clark & Luze, 2014). However, contrary findings also exist, particularly with young children, predominantly in 2nd grade but also in 3rd grade, which may be explained by the fact that these children have yet to reach their final handwriting quality level (Overvelde & Hulstijn, 2011). For instance, a weak correlation was noted between visual-motor skills and handwriting of students from the 1st grade to the 3rd grade even though one or more subcomponents of visual perceptual skills, particularly eye-hand coordination, copying, figure-ground, and spatial relations, were found to be positively related to handwriting (Lee, 2022). Overall, visual-motor skills are foundational for many academic tasks (Carames et al., 2022). Challenges in visual-motor skills can influence not only the mechanics of handwriting and drawing but also students' ability to organize their work and participate in-class activities, such as note-taking, copying from the board, and completing writing assignments. Considering that students with LDs have more academic challenges, understanding the relationship between visual-motor skills and handwriting legibility is noteworthy. Since this relationship is not well understood for students with LDs, current study will attempt to provide empirical evidence into the field.

Attitudes toward writing

Attitude is generally defined as "a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object" (Ajzen & Fishbein, 1975, p. 6). Having knowledge about students' attitudes toward writing can serve as important information for designing teachers' instructional practices (Kear et al., 2000). Writing attitude is operationally defined as an affective disposition related to how the act of writing makes the writer feel, ranging from very unhappy to very happy (Graham et al., 2007). We use the same operational definition for writing attitudes as in the study of Graham et al. (2007).

Attitudes toward writing shape how a person achieves the task of writing. Graham et al. (2007) tested the structural relationship between attitudes toward writing and writing achievement through three different models: "(a) writing attitude influences writing achievement in a unidirectional manner, (b) writing achievement influences writing attitude in a unidirectional manner, (c) the effects of writing attitude and achievement are bidirectional and reciprocal" (p. 516). Among these three models yielding a good description of the data in only one model, which showed that writing attitudes are predictors of the writing achievement of third-grade students. In the same study, the researchers illustrated the results with the example that children with positive attitudes toward writing would

spend more effort while composing and prefer writing over other tasks. In comparison, children who have negative attitudes would spend less effort while composing and prefer to avoid writing. In a recent study, handwriting fluency and writing quality were found to be related to attitudes toward writing (Skar et al., 2022). As students with LDs have problems in writing (Graham et al., 2021), the role of attitudes toward writing on handwriting skills needs to be examined since they are more likely to experience failure while writing, which, in turn, may lead to negative attitudes toward writing (Harris et al., 2008). In addition, understanding the potential attitudes of students with LDs will help educators to build a supportive classroom environment where their students feel valued.

Grade level and gender

The current study will address the relative need about handwriting legibility of students with LDs as well as their handwriting speed, visual-motor skills, and attitudes toward writing. Examination of the variables, as mentioned earlier, in conjunction with gender and grade level, is supported by evidence. For instance, it has been noted that handwriting speed develops linearly during the elementary school years and continues to develop in secondary school (Feder & Majnemer, 2007). According to published data (Limpo & Alves, 2013, 2018a, 2018b) by Limpo and Graham (2020), an increase in handwriting ability, particularly in alphabet letters and copied words, was observed in students from Grade 4 to Grade 9 and in college students, revealing a continuous process of handwriting. Likewise, student age-predicted name writing (Frolek Clark & Luze, 2014). In addition, gender differences are cited in the literature (Fogel et al., 2022; Graham et al., 1998; Re et al., 2023; Skar et al., 2022; Skar et al., 2023). The most extensive study to date showed that girls produced higher-quality papers than boys, and the difference tended to increase with increasing grades (Skar et al., 2022). As observed with the typically developing students, there has been a gender difference in the writing skills of children with LDs (Berninger et al., 2008). Together, these findings suggest that the handwriting skills of students with LDs are worth examining in terms of gender and grade to capture potential differences. Examining the grade level and gender of students with LDs is crucial because it can reveal differences in handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing, which, in turn, inform teachers about these students' instructional and educational needs. In addition, exploring the unique profiles of students with LDs can guide professionals to implement appropriate interventions.

Purpose of the research

The purpose of this study was to examine the handwriting legibility of students with LDs in conjunction with their handwriting speed, visual-motor skills, and attitudes toward writing. The following research questions were addressed in line with the research purpose:

a. Are there significant differences in handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing of students with LDs by gender and grade level?
b. Do handwriting speed, visual-motor skills, and attitudes toward writing predict the handwriting legibility of students with LDs?

Materials and methods

Participants

The official diagnosis of LD in Türkiye, two types of institutions, state/university hospitals and Guidance and Research Centers, are involved into the process (GRC; Sakız et al., 2015). While the medical diagnosis takes place in state hospitals or university hospitals, the educational

diagnosis takes place in the GRC that is supervised by the Ministry of Education and is responsible for administering IQ tests and measuring the academic performance of children in reading, writing, and mathematics (Sakız et al., 2015). Regarding placement, all students identified with LDs should be educated in general education classrooms as full-time inclusion students.

Purposive sampling was preferred in this study. The researchers contacted the administrators of the Special Education and Rehabilitation Centers (SERCs), which are special education institutions that provide support to students who are officially diagnosed with special needs. SERCs are state-funded or private-funded institutions where students, including those with LDs, are eligible to receive one-on-one education, group education, or one-on-one plus group education (Special Education Institutions Regulation [Özel Eğitim Kurumları Yönetmeliği], 2012). We recruited students from the 3rd and 4th grades for a set of reasons. First, handwriting legibility and speed start to develop as students move to higher grades in elementary school years (Duiser et al., 2020; Graham et al., 1998; Hamstra-Bletz & Blöte, 1990). It can be misleading to make a decision by relying on handwriting at the early stage of acquisition (Duiser et al., 2020). Another reason for recruiting students from the 3rd and 4th grades is that students with LDs are not identified until the 3rd grade (LD Report, n.d.).

The participant recruitment process included a set of inclusion and exclusion criteria. The inclusion criteria were as follows: (a) had been officially diagnosed with LD, (b) attended public elementary schools (c) were 3rd or 4th grade students. The exclusion criteria were as follows: (a) had comorbidity (e.g. ADHD, giftedness, and speech and language impairments) and (b) were bilingual. The research participants were 75 students with LDs attending 19 SERCs in 13 districts of a metropolitan city in Türkiye. In multiple linear regression analyses, the sample size (N) is calculated by the following formula: $N \geq 8x + 50$ as if x is the number of independent variables (Green, 1991). Since there were three independent variables in this study, the minimum number of necessary sample size is calculated as 74. The minimum requirement was met because the sample size was 75 in this study. The mean age of the participants was 9 years, 6 months, and 18 days. Table 1 presents the demographic characteristics of the participants.

Procedures

The study was approved by the X University Ethical Committee dated December 22, 2022, with the decision number 2022/08-4. The researchers used two types of consent letters in this study to ensure confidentiality. One consent letter was developed for the purpose of informing the administrators of the SERCs about the research, indicating that they grant permission to conduct the research on their site. The other consent letter was developed for the purpose of informing the parents of students with LDs about the research, indicating that their children will complete writing tasks with their permission. Both consent letters included brief information about the research (the purpose, steps, etc.) and the assurance that participation was voluntary, that participants had the right to terminate the research at any time, and that the data were protected confidentially. Furthermore, the researchers provided a simple verbal description to the child, and a verbal indication of willingness to participate was obtained as a final step of consent to agree.

Table 1. Research participants.

	Grade 3		Grade 4		Total	
	N	%	*n*	%	*n*	%
Gender						
Male	23	30.7	26	34.7	49	65.3
Female	13	17.3	13	17.3	26	34.7
Total	36	48	39	52	75	100

Note. $N = 75$.

Prior to data collection, each researcher conducted a pilot study with a total of seven participants to ensure that the data collection was appropriate in terms of suitability and the length and order of the data collection instruments. Primary data collection took place from December 16, 2022 to February 22, 2023. To collect the data, the researchers visited a total of 19 SERCs in one of the cities in Türkiye. The data collection process took place in individual sessions lasting 13 min and 40 sec on average. Individual data collection sessions were conducted in a quiet room provided by the administrators of the SERCs. The researchers asked students with LDs to copy the Turkish text created by the researchers, to copy geometrical figures in the Bender Visual-Motor Gestalt Test (Yalın, 1980; Yalın & Sonuvar, 1987; Somer, 1988), and to answer questions related to attitudes toward writing in the Writing Attitude Scale (Yıldız & Kaman, 2016).

Interrater reliability

To ensure reliability in scoring the data related to handwriting speed, handwriting legibility, and visual-motor skills, all the researchers worked independently and then collaboratively. Initially, 20% of the data were randomly selected. Second, each researcher scored the same set of data as an independent rater. The researchers discussed the disagreements until reaching a consensus. Third, the researchers independently scored another 20% of the data, and the agreement percentage was 88% for handwriting speed, 85% for handwriting legibility, and 92% for visual-motor skills. Finally, the researchers independently scored the remaining students' tasks. The consensus meetings were arranged if needed. The researchers used a similar process for the Bender Visual-Motor Gestalt Test by comparing the student's product with examples in the test manual.

Measures

In line with the research purpose, the researchers used multiple measures, including a demographic information form, the Handwriting Skills Observation Form, the Bender Visual-Motor Gestalt Test, and the Writing Attitude Scale.

Demographic information

The demographic form included the name of the SERC, the data collection date and duration, the gender, grade level, and date of birth of students with LDs. The researchers, if needed, asked for clarification from the administrators of the SERCs.

Handwriting legibility

The participants were given an unlined blank paper and a text that included all 29 letters of the Turkish alphabet. The text was originally obtained from a 3rd grade Turkish textbook approved by the Ministry of National Education. After the pilot study, the authors decided to shorten the original text. Finally, the adapted text consisted of 137 letters, 20 unique words, and three sentences. This text is written in 12-point font. Students were asked to copy the text onto the paper. The Turkish alphabet, based on the Latin alphabet, has 29 letters, eight of which are vowels. Differently, seven letters of the Turkish alphabet have been modified from the Latin alphabet (Ç-ç, Ş-ş, Ğ-ğ, I-ı, İ-i, Ö-ö, Ü-ü). The letters Q, W, and X of the basic Latin alphabet do not exist in the Turkish alphabet. In addition, letters are written from left to right. It has regular spelling-to-sound correspondences, and each letter maps directly to a sound. This invariant correspondence of the letter-sound makes word coding easy and contributes to the acquisition of both writing and reading.

To evaluate handwriting legibility, we used the Handwriting Skills Observation Form, which has 10 criteria, namely, writing letters accurately, size of letters, upright, space between letters,

extensions of letters, writing on the line, space between the words, writing words in capitals, clean writing, and tidy writing (Bayat, 2016). Each of the 10 criteria is rated on a 5-point scale ranging from poor (a score of 1) to very good (a score of 5). The minimum possible score is 10, and the maximum possible score is 50, with a higher score indicating a greater level of legibility. Before the administration of the form, we received expert reviews to ensure the suitability for the current study. The Cronbach's alpha reliability coefficient in the original scale study was 0.83 (Bayat, 2016), whereas it was found to be 0.89 in the present study.

Handwriting speed

Either alphabet tasks or copying tasks have been used in the literature as measures of handwriting speed (Berninger et al., 1992). Handwriting speed is generally assessed outside text production through alphabet and copy tasks since the other processes within the writers' cognitive skills can affect the rate of composing (Limpo & Graham, 2020). In addition, it is a good tool to capture the problems of children with writing problems (Re et al., 2023). Handwriting speed was calculated based on the number of letters copied correctly per minute. The number of letters per minute is a frequently used way to measure handwriting speed in the literature (Akyol et al., 2014; Graham et al., 1998; Lam et al., 2011). The total time spent writing the given text was measured while the students were writing. The total number of correctly copied letters was subsequently calculated. Finally, handwriting speed was calculated by dividing the total number of letters by the total time in minutes.

The Bender visual-motor Gestalt test

The test was originally developed by Bender (1938) and adapted to Turkish by Yalın (1980), Yalın and Sonuvar (1987), and Somer (1988). It includes nine geometric shapes that are presented sequentially to the child, who is asked to copy each design on blank paper. The test–retest reliability was 0.80 for the first grade, 0.73 for the second grade, and 0.81 for the third grade (Somer, 1988). Koppitz's scoring system (Koppitz, 1963), which is based on four types of errors, such as distortion (shape is severely misshapen and/or the size is disproportioned), rotation (part or whole figure is rotated by 45 degrees or more), perseveration (extreme number of dots or curves are presented), and integration (shapes have poor integration, such as they are not joined or overlapped), was utilized in this study. The total error scores ranged from 0 to 30 in Koppitz's system, in which a higher score represented a greater level of visual-motor problems. We used the scoring form in the examiner's manual for the Turkish Bender Visual-Motor Gestalt Test. The scoring form consists of four types of errors. The researchers calculated scores based on the four types of errors and the total number of errors. The Bender Visual-Motor Gestalt test has also been used in different research studies conducted with students with LD (i.e., Tafti et al., 2021; Tremblay et al., 2014).

Writing Attitude Scale

The Writing Attitude Scale was developed by Graham et al. (2007) based on items measuring attitudes toward reading (McKenna et al., 1995). The Turkish version of the Writing Attitude Scale was adapted by Yıldız and Kaman (2016) and is a 4-point Likert scale ranging from very unhappy (a score of 1) to very happy (a score of 4) and consisting of five items. The minimum possible score is 5, and the maximum possible score is 20, with a higher score indicating a greater positive attitude toward writing (Yıldız & Kaman, 2016). During the data collection of this study, the researcher read each item, asked the student to select the most appropriate image of a cartoon character representing how he/she feels, and circled his/her response. In addition, the Cronbach's

alpha reliability coefficient was 0.77 for the original single-factor scale (Yıldız & Kaman, 2016), whereas it was found to be 0.84 in the present study.

Data analysis

We calculated descriptive statistics (mean, standard deviation, skewness, and kurtosis). Normality was determined by skewness and kurtosis. The acceptable range of normality of skewness is between −2 and +2, while that of kurtosis is between −7 and +7 (Hair et al., 2010; Byrne, 2016). In this study, the skewness indices ranged between −0.79 and 1.27, while the kurtosis indices ranged between −0.67 and 2.84 for all the variables, indicating that the skewness and kurtosis values were acceptable.

An independent sample *t*-test was conducted to compare the variables by grade level. Due to the small sample size (26 female students and 49 male students), for gender, a Shapiro–Wilk test was applied to calculate the normality, showing that the distribution of the variable departed significantly from normality ($p < 0.05$). Thus, the Mann–Whitney U test was used to compare the groups by gender. Next, the relationships among handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing were examined using Pearson's product-moment correlation. Finally, multiple linear regression with the enter method was carried out to predict the handwriting legibility of students with LDs based on handwriting speed, visual-motor skills, and attitudes toward writing. The data analysis was performed using IBM SPSS Statistics 24.

Results

The means, standard deviations, skewness, and kurtosis of handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing are presented in Table 2.

Handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing by gender and grade level

A Mann–Whitney U test was conducted to compare students' handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing by gender. There was no significant difference between male students and female students in terms of visual-motor skills ($Z = -0.22$ $p = 0.82$) and attitudes toward writing ($Z = -0.72$ $p = 0.48$). On the other hand, there was a significant difference between male students and female students' handwriting legibility ($Z = -2.40$, $p = 0.02$) and handwriting speed ($Z = -2.17$, $p = 0.03$). The results suggest that female students' handwriting legibility and speed were higher than those of male students. Table 3 presents the results of the Mann–Whitney U test.

An independent sample *t*-test was conducted to compare students' handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing according to grade. Moreover, there were no significant differences between 3rd-grade students and 4th-grade students in terms of handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing. Table 4 presents the results of the independent sample *t*-test.

Correlations between handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing

A Pearson product-moment correlation coefficient was computed to assess the correlation between handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward

Table 2. Descriptive statistics.

	M	*SD*	*N*	*Skewness*	*Kurtosis*
Handwriting legibility					
Male	34.45	5.72	49	−0.79	0.38
Female	37.81	6.85	26	−0.91	0.71
3rd grade	34.92	6.44	36	−0.61	0.10
4th grade	36.26	6.18	39	−0.63	0.54
Total	35.61	6.30	75	−0.61	0.23
Handwriting speed					
Male	27.11	10.61	49	0.42	−0.35
Female	36.64	18.07	26	1.00	1.39
3rd grade	27.95	12.35	36	1.01	2.15
4th grade	32.69	15.68	39	1.27	2.75
Total	30.41	14.29	75	1.25	2.84
Visual-motor skills					
Male	5.39	3.36	49	0.77	0.31
Female	5.15	3.26	26	0.54	−0.02
3rd grade	5.44	3.49	36	0.62	−0.67
4th grade	5.18	3.16	39	0.78	1.41
Total	5.31	3.30	75	0.69	0.15
Attitudes toward writing					
Male	14.00	3.97	49	−0.67	−0.24
Female	14.58	4.38	26	−0.62	−0.50
3rd grade	14.58	4.19	36	−0.79	−0.28
4th grade	13.85	4.03	39	−0.50	−0.28
Total	14.20	4.10	75	−0.61	−0.40

Table 3. Results of Mann–Whitney *U* test by gender.

		Mean Rank	Sum of Ranks	*N*	*U*	*Z*	*p*
Handwriting legibility	Male	33.61	1647.00	49	422*	−2.40*	0.02
	Female	46.27	1203.00	26			
Handwriting speed	Male	34.02	1667.00	49	442*	−2.17*	0.03
	Female	45.50	1183.00	26			
Visual-motor skills	Male	38.41	1882.00	49	617	−0.22	0.82
	Female	37.23	968.00	26			
Attitudes toward writing	Male	36.69	1798.00	49	573	−0.72	0.48
	Female	40.46	1052.00	26			

*$p < 0.05$.

Table 4. Results of independent sample t-test by grade level.

		M	*SD*	*n*	*t*	*df*	*p*
Handwriting legibility	3rd grade	34.92	6.44	36	−0.92	73	0.36
	4th grade	36.26	6.18	39			
Handwriting speed	3rd grade	27.95	12.35	36	−1.45	73	0.15
	4th grade	32.69	15.68	39			
Visual-motor skills	3rd grade	5.44	3.49	36	0.35	73	0.73
	4th grade	5.18	3.16	39			
Attitudes toward writing	3rd grade	14.58	4.19	36	0.78	73	0.44
	4th grade	13.85	4.03	39			

*$p < 0.05$.

writing (Table 5). Handwriting legibility was found to be correlated with all variables. Results are as follows for handwriting legibility: attitudes toward writing ($r = 0.24$; $p = 0.02$), handwriting speed ($r = 0.62$, $p = 0.00$), and visual-motor skills ($r = -0.43$, $p = 0.00$). In addition, handwriting speed was correlated with visual-motor skills ($r = -0.27$, $p = 0.01$).

Before conducting multiple regression analysis, the assumptions of normality, linearity, independence, multicollinearity, and homoscedasticity were met in this study. Normality and linearity assumptions can be checked in Tables 2 and 5, respectively. The Durbin–Watson statistic was 1.82, showing that the residuals are independent. The VIF scores were well below 10, tolerance

Table 5. Correlations between handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing.

	Handwriting legibility	Handwriting speed	Visual-motor skills	Attitudes toward writing
Handwriting legibility	1			
Handwriting speed	0.62*	1		
Visual-motor skills	−0.43*	−0.27*	1	
Attitudes toward writing	0.24*	0.12	0.01	1
N	75	75	75	75

*$p < 0.05$.

Table 6. Multiple regression analysis results on the prediction of handwriting legibility.

	Unstandardized Coefficients		Standardized Coefficients		
	B	*SE*	*Beta*	*t*	*p*
Constant	27.73	2.43		11.41	0.00
Handwriting speed	0.22	0.04	0.52	5.75	0.00
Visual-motor skills	−0.55	0.17	−0.29	−3.26	0.00
Attitudes toward writing	0.27	0.13	0.18	2.09	0.04

scores were above 0.1, and correlations among independent variables were less than 0.7, suggesting no multicollinearity (Field, 2005). Specifically, the VIF were 1.10, 1.08, and 1.02 for handwriting speed, visual-motor skills, and attitudes toward writing, respectively. In addition, the tolerance scores were 0.91, 0.92, and 0.98 for handwriting speed, visual-motor skills, and attitudes toward writing, respectively. The correlation coefficients between two independent variables were 0.01, 0.12, and −0.27 for attitudes toward writing and visual-motor skills, attitudes toward writing and handwriting speed, and visual-motor skills and handwriting speed, respectively. Scatter plots showed no obvious signs of funneling, making the data homoscedastic.

Predicting handwriting legibility by handwriting speed, visual-motor skills, and attitudes toward writing

The predictor variables that made significant contributions to the model were handwriting speed, visual-motor skills, and attitudes toward writing. The *F* value for determining the effect of these variables together on handwriting legibility was calculated as 22.12 at the $p = 0.00$ significance level. The predictor variable explained 48% of the variance in the outcome variable, handwriting legibility.

According to Table 6, a one-point increase in attitudes toward writing scores increased the handwriting legibility score by 0.27 points, a one-point increase in handwriting speed scores increased the handwriting legibility score by 0.22 points, and a one-point increase in visual-motor scores decreased the handwriting legibility score by 0.55 points. For LD students, the regression equation for the prediction of handwriting legibility by the predictor variables, namely, handwriting speed, visual-motor scores, and attitudes toward writing, is as follows:

$$\text{Legibility} = 27.73 + 0.22 \text{ x Speed} - 0.55 \text{ x Visual} - \text{motor} + 0.27 \text{ x Attitudes}$$

Discussion

The purpose of this study was to examine the handwriting legibility of students with LDs in conjunction with their handwriting speed, visual-motor skills, and attitudes toward writing. The results clearly show that the current assessment helps us to gain a considerable understanding of handwriting legibility and its predictors for students with LDs. To assess handwriting, we used the Handwriting Skills Observation Form (Bayat, 2016). In addition, we calculated the number of correctly written letters per minute copied from the given text to measure handwriting speed.

One of the noteworthy results is related to the proportion of female and male students in this study (65.3% male students and 34.7% female students). This finding aligns with the proportions of individuals with learning disabilities in the literature (Robinson, 1997; Cortiella & Horowitz, 2014). In addition, there were significant differences in handwriting legibility and handwriting speed according to gender. Handwriting legibility and handwriting speed were favorable for female students in this study. This result ties well with previous studies showing that female students produced higher quality papers than male students did (Skar et al., 2022) or that female students with LDs were less impaired in terms of handwriting production (Berninger et al., 2008). Roivainen (2011) explained the abovementioned result by stating that "*females seem to have an advantage in processing speed tasks involving digits and alphabets as well as in rapid naming tasks*" (p. 148). In contrast to the gender difference, we were not able to find a significant difference in handwriting legibility and handwriting speed by grade level, which can be explained by the sample of this research. Prior research supports the idea that handwriting speed starts to develop during the elementary school years and linearly continues to develop during the secondary school years (Feder & Majnemer, 2007). This continuous growth can be observed from the 4th grade to the 9th grade (Limpo & Alves, 2013, 2018a, 2018b, Limpo & Graham, 2020). Considering that the sample of this study included consecutive grades, namely, 3rd- and 4th-grade students, it is predictable that a difference across the grade levels could not be detected. In addition, it is important to note that students with LDs may not be able to receive a substantial amount of special education support until 3rd grade (Lyon et al., 2001). Future research should be conducted with a sample that includes different grade levels. The lack of difference can be explained by the heterogeneous nature of the sample, which may guide future researchers to examine variables such as the age at which students with LDs learned reading and writing in conjunction with their preschool experiences.

It is worth discussing the lack of significant results related to visual-motor skills by gender and grade level. This pattern of results is inconsistent with the synthesized literature showing that females with LDs performed better in terms of visual-motor abilities than males with LDs (Vogel, 1990). The most compelling explanation for our finding could be related to sample characteristics, implying the need for further research. Keppeke et al. (2013) described visual-motor skills as "readiness for learning". A strong consensus highlights the importance of visual-motor maturation, which occurs in middle adolescence (Bender, 1938; Decker, 2008). The mean scores of visual-motor integration skills were inconsistent across the 3rd, 4th, 5th, and 6th grades (Klein et al., 2011). While mixed results exist in the previous literature (Klein et al., 2011; Lee, 2022; Prunty et al., 2016; Tseng & Murray, 1994), our results support the notion that students with LDs are not able to reach their final maturity at that grade level.

In contrast to prior research conducted with typical students (Knudson, 1995; Skar et al., 2022), we were not able to find a significant difference in attitudes toward writing by gender or grade level. While it is difficult to explain such results, this can be construed as a situation related to the LD sample. Because LD students exhibit different characteristics from general education students, there is a need for in-depth research on the learning disability population in terms of attitudes toward writing.

A further finding is the prediction of handwriting legibility by handwriting speed, visual-motor skills, and attitudes toward writing, which all have individual roles in the formation of variances in handwriting legibility. Since the current study is correlational in nature, additional research is needed to determine whether there is a causal relationship between handwriting legibility, handwriting speed, visual-motor skills, and attitudes toward writing.

Graham et al. (1998) recommended identifying potential factors influencing handwriting legibility. One of the key results of the present study is that handwriting speed predicts handwriting legibility. In line with previous research (Graham et al., 1998), we found that handwriting speed

significantly contributed to handwriting legibility. This could simply mean that handwriting speed and legibility are different constructs of writing even during copying (Parush et al., 2010).

Our results also indicated that handwriting speed was not the only factor involved in predicting handwriting legibility. Moreover, visual-motor scores negatively predicted the handwriting legibility of students with LDs in this study. Specifically, students who had higher visual motor scores (representing more problems) had less legible handwriting. This finding is consistent with what has been shown in studies showing that children with poorer visual-motor skills have poorer handwriting for students with developmental coordination disorders (Bo et al., 2014) and children without developmental disorders (Kaiser et al., 2009). A similar pattern has been shown in many other studies (Cornhill & Case-Smith, 1996; Klein et al., 2011; Tseng & Murray, 1994; Weintraub & Graham, 2000). For instance, visual-motor integration uniquely contributes to the handwriting legibility of both poor and good handwriters (Cornhill & Case-Smith, 1996; Weintraub & Graham, 2000) and children with learning and behavioral problems (such as ADHD, DCD, and LD). Considering that visual-motor skills involve translating visual stimuli into precise motor movements, which is a fundamental skill in forming letters accurately (Feder & Majnemer, 2007), illegible handwriting may result from poor visual-motor skills leading to problems in spacing and forming letters consistently.

The other key finding was that attitudes toward writing predicted the handwriting legibility of students with LDs. The influence of attitudes toward writing on legibility echoes the findings of Graham et al. (2007). Individuals with more positive attitudes are more likely to write better and work harder while composing than students with less positive attitudes (Graham et al., 2007). Overall, positive attitudes lead to increased engagement, effort, and time investment in writing tasks, leading to greater legibility. Graham et al. (2012) aimed to examine whether attitudes toward writing were a significant contributor to the writing performance of beginning writers, namely, first-graders and third-graders. The results showed that attitudes toward writing significantly predicted writing performance variables, namely, the quality and length of handwriting and the sequence of the longest correct word at the third-grade level. Consistent with prior research, the current study highlighted that handwriting is a complex skill influenced by different factors, such as handwriting speed, visual-motor skills, and attitudes toward writing.

Limitations

It is important to note that the data were collected in individual sessions from 19 SERCs in 13 districts in one city in Türkiye, revealing that the sample was distributed across a large geographic area. This, in turn, led to the sample not being easily accessible to the researchers. In addition, this study was conducted with the Turkish alphabet, which may serve as a limitation for generalization. Another limitation is that it was not possible to access students' records (e.g. students' IQ scores or assessments related to reading and writing skills) even for research purposes, leading us to conduct the study with limited sample characteristics. Finally, we were not able to narrow the sample to students with dyslexia, dysgraphia or dyscalculia since students are diagnosed with LD rather than the subtypes of LD in Türkiye.

Recommendations for future research and practice

Addressing the handwriting legibility of students with LDs has significant implications for researchers and practitioners. Future research and school practices should focus on interventions aimed at improving handwriting speed, visual-motor skills, and attitudes toward writing to improve the handwriting legibility of students with LDs. These variables do not operate in isolation; they collectively contribute to overall handwriting legibility, implying the need for holistic interventions. A combined intervention that integrates techniques for controlling pacing and

developing visual-motor skills (e.g. perceptual-motor training, tracing exercises, fine motor activities) can yield synergistic benefits for improving handwriting legibility. Educators and practitioners should recognize that interventions addressing one variable may indirectly impact the others. Another finding of the study is the absence of significant results by grade level (3rd and 4th grades), suggesting cross-sectional studies with larger samples and grade levels (K-12) and longitudinal studies to observe the same students over the time. Future research should be conducted with the subtypes of students with LDs to compare the characteristics of students with dyslexia, dyscalculia, and dysgraphia.

Conclusion

Despite its limitations particularly related to sample size, this research can be seen as a first step in Türkiye toward estimating the prevalence of writing problems within a sample of LDs. The other conclusion may be drawn from this study is the intricate relationships between handwriting speed, visual-motor skills, and attitudes toward writing, as they are the key variables affecting the handwriting legibility of students with LDs. Within the context of this population, these predictive factors may have implications, necessitating tailored interventions that comprehensively address specific problems of students with LDs. The results of this study may imply the need for the administration of multifactor assessments in handwriting both for formal purposes (e.g. diagnosis, individualized education plan) and informal purposes (e.g. progress monitoring, informing teachers).

Disclosure statement

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