

The role of visual perception and executive functions on writing skills with learning disabilities: The case of Turkish-speaking children

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Abstract

This study examined the effects of visual perception and executive function skills on the writing skills of Turkish students with learning disabilities and typically developing Turkish students. Given the unique features of the Turkish language, such as vowel harmony and articulatory structure, this research addresses a significant gap in understanding how these factors influence writing abilities in this population. The study employed a comparative design involving students with learning disabilities and typically developing students and analysed their writing errors, executive function and visual perception levels. Significant differences were found between the two groups, with students with learning disabilities performing worse across all the measures. Correlation analysis indicated significant relationships between writing errors and visual perception, working memory and executive functioning. Multiple regression analysis further revealed that these cognitive factors were crucial predictors of writing skills. These findings underscore the importance of considering visual perception and executive functions when formulating and implementing writing instruction strategies for Turkish students with learning disabilities.

KEYWORDS

executive functions, learning disabilities, Turkish language structure, visual perception, writing skills

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Key insights

What is the main issue that the paper addresses?

This paper examines the impact of visual perception and executive function skills on the writing abilities of Turkish-speaking students with learning disabilities.

What are the main insights that the paper provides?

The study reveals that weaknesses in visual perception and executive functions significantly hinder writing skills in students with learning disabilities. It highlights the necessity of targeted educational strategies to support these cognitive areas in improving writing outcomes.

INTRODUCTION

Writing, in conjunction with speaking, is a fundamental component of communication. A systematic approach to the development of writing skills is crucial for enhancing other language-related abilities. Writing development is a lifelong process and an important life skill (Cormier et al., 2016; Cuenca-Sanchez et al., 2012; Dragomir & Niculescu, 2020; Graham & Harris, 1997; OECD, 2021; Sheronovna, 2022). The main models of writing development emphasise the interaction between cognitive processes and physical components of writing. In this context, Flower and Hayes' (1981) cognitive process model suggests that the writing process consists of three main components: planning, text production and revision. This model states that the writing process is dynamic and recursive and that writers constantly refer to information in this process. On the other hand, Scardamalia and Bereiter's (1987) knowledge expression and knowledge transformation models suggest that the writing process can be considered in two separate processes: knowledge expression and knowledge transformation. These models suggest that in knowledge expression, writers rephrase existing knowledge, whereas in knowledge transformation, they combine existing knowledge with new knowledge to create meaningful texts. Kellogg's (1996) cognitive model emphasises the role of working memory in the writing process. According to this model, the management of the cognitive load during the writing process directly affects writing performance. Finally, Berninger and Winn's (2006) developmental model states that writing development is shaped by the interactions of biological, environmental, physical and social factors. This model emphasises the importance of individual differences and various developmental processes by adopting a child-centred approach to the development of writing skills. These basic writing models help us understand the complexity of the writing process and how its various components interact with each other.

Given this critical importance, successful writing skills have a significant impact on overall academic achievement (Hoover et al., 2012; Kuiken & Vedder, 2020; Rietdijk et al., 2017). However, students with learning disabilities (LD) may face difficulties in developing their writing skills. These difficulties are particularly evident for these students because of the complex nature of their written expressions (Walker et al., 2005). Writing represents the most sophisticated and intricate aspect of mastering a language system, encompassing three key components: penmanship, orthography and composition (Bender, 2004; Berninger, Abbott, Jones, et al., 2006). Penmanship refers to the physical act of writing, encompassing the formation of letters and the overall handwriting quality. It

plays a fundamental role in communication, as legible handwriting enhances the readability and comprehension of written texts. Orthography, on the other hand, pertains to correct spelling and the use of writing conventions within a language. This involves understanding the rules and patterns governing the formation of words, including grammar, punctuation and syntax. Proficiency in orthography is essential for effective written communication because errors in spelling and grammar can impede the clarity and coherence of a text. Composition is the third component of writing mastery and involves the organisation and expression of ideas in written form. It encompasses the ability to cohesively structure sentences and paragraphs, develop coherent arguments and convey information effectively. Strong composition skills are vital for producing engaging and persuasive written works across various genres and formats. Handwriting is an essential communication tool that students use to express and record information and ideas and is the first stage of the writing process (Mackenzie & Spokes, 2018). Legibility is related to the visual characteristics of the written product, such as appropriately writing letters in the appropriate size and proportion, leaving appropriate spaces between letters and words, and following a line (Spier & Pytleski, 2022). Handwriting fluency involves writing letters and words without error (Berninger et al., 2008; Olive et al., 2009). Handwriting requires the correct perception of sound symbols, visual and motor coordination, hand–eye coordination and the ability to retain letters and words in visual and kinesthetic memory (Berninger et al., 2008; Gilboa et al., 2010). Students with learning disabilities have difficulty writing fluent and legible handwriting because they lack these skills (Berninger et al., 2009). Additionally, it has been noted that high-level cognitive skills are associated with various dimensions of writing such as writing quality, productivity and accuracy (Kim & Graham, 2022), and the cognitive characteristics of the writer, along with their individual differences, influence the writing process (Graham, 2018).

The development of handwriting and spelling skills is an important aspect of literacy acquisition in children. Research has demonstrated a strong relationship between handwriting fluency and spelling accuracy (Yuan et al., 2020). Handwriting fluency, which includes automaticity in transcription skills, becomes increasingly important as students progress across grades and achieve higher spelling accuracy (Yeung et al., 2016). Research has shown that handwriting skills, particularly fluency, improve with age and schooling, and that individual differences in these skills predict children's writing proficiency (Semeraro et al., 2019). Furthermore, the reciprocal relationship between handwriting and spelling has emphasised that the cognitive skills required for handwriting overlap with spelling skills, and that there is a mutually reinforcing link between handwriting fluency and spelling accuracy (Yuan et al., 2020). The acquisition of good handwriting skills has been associated with helping spelling and visual organisation, and the importance of handwriting in developing spelling abilities has been emphasised (Doug, 2019; Harrison et al., 2009; Wallen et al., 2013).

Spelling success depends on proficiency in orthographic decoding, phonological awareness, phonological decoding, visual perception and executive function skills (Caravolas et al., 2001; Friend & Olson, 2008). Owing to their inadequacies in these areas, students with learning disabilities are not as successful in spelling skills as their peers with normal development (Caravolas & Volín, 2001; Cassar et al., 2005). They perform letter-syllable skipping, letter-syllable addition, letter-syllable substitution and reverse writing errors more frequently than their peers with normal development (Caravolas & Volín, 2001). In addition, the writing of students with learning disabilities is characterised by punctuation, capitalisation, spelling and grammatical errors (García & Fidalgo, 2008; Graham & Harris, 2020). The difficulties faced by students with LD in writing are often attributed to deficits in visual perception and executive function skills (Borsting, 2006; Graham et al., 2021; Gray, 2022; Lim, 2022).

Executive functions and writing difficulties

Executive functioning skills significantly impact writing skills (Graham et al., 2021; Lim, 2022; Oddsdóttir et al., 2020). This refers to the capacity to focus and control thoughts during the writing process, aiding tasks such as planning and revising the text (Kamran et al., 2023; Re et al., 2023; Tarchi et al., 2021). That is, while writing, a person can maintain attention, consciously focus on details and sustain the mental effort and attention required for the writing task thanks to executive functioning skills. In this process, essential steps, such as composing, revising and editing text, can be performed more effectively (Oddsdóttir et al., 2020). Executive function skills strongly predict text quality (Cordeiro et al., 2020; Salas & Silvente, 2020).

Deficits in executive functioning are associated with writing difficulties in individuals with learning disabilities (Rodríguez et al., 2020; Tarchi et al., 2021). These deficits can negatively affect students' ability to organise their thoughts, develop written expressions and complete writing tasks (Costa et al., 2018; Mulchay et al., 2021). Therefore, it is essential to consider the effect of executive function when assessing and supporting students with LD in their writing skills. Researchers have found that children with LD often have difficulties in transcription skills, working memory and executive function, resulting in poor spelling and overall writing quality (Hebert et al., 2018; Kamran et al., 2023; Re et al., 2023). Berninger and Richards (2002) argue that executive function skills are essential for successful writing and that difficulties in these skills may contribute to writing difficulties in individuals with learning disabilities.

Visual perception and writing difficulties

Visual perception refers to the ability to interpret and make sense of the visual information. It plays a crucial role in writing, as it involves tasks such as letter formation, spacing and alignment (Grewal et al., 2014; Méary et al., 2005; Taverna et al., 2020; Torres, 2018). Researchers have divided visual perception into subdomains to better understand its components and processes (Borsting, 2006; Erhardt & Duckman, 2005). These subdomains include eye–motor coordination, visual discrimination, visual shape–ground discrimination, visual completion and spatial relations (Murai & Yotsumoto, 2016). These subdomains of visual perception are necessary for processing, analysing and discriminating visual information (Grewal et al., 2014; Méary et al., 2005). They contribute to the correct interpretation and understanding of visual stimuli, which is crucial for tasks such as writing (Borsting, 2006; Erhardt & Duckman, 2005). For example, eye–motor coordination helps control hand and finger movements during letter formation. Visual discrimination helps distinguish between different letters and shapes (Murai & Yotsumoto, 2016). Visual shape–ground discrimination helps perceive letters as separate entities from the background. Visual completion enables mental completion of missing letters or words. Spatial relations help maintain appropriate spacing and alignment between letters and words (Grewal et al., 2014; Méary et al., 2005; Taverna et al., 2020). It has also been found that visual perception is an important predictor of reading and writing skills, and students who are successful in visual discrimination are more successful in recognising letters and have higher overall academic achievement (Gudwani et al., 2021; Mantovani et al., 2021; Ratzon et al., 2007; Sanghavi & Kelkar, 2005; Vernet et al., 2022).

The coping skills of individuals with learning disabilities are often based on visual perception difficulties. This can negatively affect the development of basic academic skills, especially reading and writing (Borsting, 2006; Gray, 2022; Hoorn et al., 2013; Kurtz, 2006; Swanson & Hsieh, 2009). Studies involving copying tasks provide an important resource for

understanding the impact of visual perception on writing skills (Hoorn et al., 2013). It has been reported that students with learning disabilities often have difficulty in letter recognition, distinguishing similar letters and words, size perception, shape-ground discrimination and other visual perception skills (Lerner & Johns, 2014). Such skill deficits can occur even in simple tasks such as copying and can often negatively affect the development of reading and writing skills.

The existing literature has examined the effects of visual perception and executive functions on writing skills in a wide range of languages, but most of these studies do not adequately cover writing skills in languages with special language features such as Turkish. The transparent orthography and articulatory structure of Turkish makes the development of writing skills in this language different from other languages (Durgunoğlu & Öney, 1999; Göksel & Kerslake, 2005). For example, studies in orthographically transparent languages such as Spanish emphasise the effects of visual perception and executive functions on writing skills in such languages (De Jong et al., 2009; Jiménez et al., 2020). Similarly, studies in languages such as Italian and Finnish have shown that the orthographic transparency of these languages increases the importance of visual perception and executive functions in the writing process (Holopainen et al., 2001; Tressoldi et al., 2001). However, there is a need for more research on how these relationships work in languages such as Turkish, which has both orthographic transparency and agglutinative language. In this context, it is of great importance that the present study aims to fill this gap in the literature and examine the effects of Turkey's unique language structure on writing skills in the context of visual perception and executive functions. Such studies will make significant contributions to both national and international literature and help better understand the educational needs of Turkish students.

In the literature, the effect of visual perception on writing skills has been examined in detail, and it has been stated that the subcomponents in this area play a critical role in the writing process (Grewal et al., 2014; Méary et al., 2005; Taverna et al., 2020; Torres, 2018). However, research on how these components are affected in students with learning disabilities and how this situation is reflected in their writing skills is limited (Borsting, 2006; Erhardt & Duckman, 2005). For example, more information is needed on the specific effects of subdomains, such as eye-motor coordination, visual discrimination, visual figure-ground discrimination, visual completion and spatial relations, on writing performance (Murai & Yotsumoto, 2016). In addition, the difficulties that deficiencies in these skills create in the writing process and how these difficulties affect academic success have not been sufficiently investigated (Lerner & Johns, 2014). In Turkey's current education system, especially considering its unique language structure, more comprehensive studies need to be conducted in this area. These deficiencies constitute the rationale for this study, which examines the effects of visual perception and executive function on the writing skills of Turkish students and aims to better understand the needs of students with learning difficulties. This study aims to provide a more in-depth understanding of the education system and student needs in Turkey while contributing to international literature.

Current study

In this study, the role of visual perception and executive functions on the writing skills of Turkish students with and without learning disabilities and the relationships between these variables were examined. Turkish language structure has a significant effect on writing skills with its features such as vowel harmony and agglutinative structure (Durgunoğlu & Öney, 1999; Göksel & Kerslake, 2005). Turkish is an agglutinative (articulative) language based on the Latin alphabet. This may require Turkish vocabulary structure and grammar to be learned and used differently from other languages (Lewis, 2001). The impact of

the Turkish structure on writing skills is, therefore, different from that of other languages. Turkish writing is transparent in that it is written as it is read (Durgunoğlu & Öney, 1999). Furthermore, in Turkish, the form of suffixes changes depending on the vowel at the end of the root word, following a rule known as vowel harmony. Suffixes take shape based on the final vowel of the root word. If the final vowel of the root word is 'a', 'ı', 'o' or 'u', the suffix appears as 'da'. However, if the final vowel of the root word is 'e', 'i', 'ö' or 'ü', the suffix appears as 'de'. For example, when adding the '-de' suffix to the word 'ev' (home), the appropriate form is 'de' because the final vowel of the root word is 'e'. Consequently, the word 'ev' is written as 'evde'. Similarly, when adding the '-da' suffix to the word 'okul' (school), the appropriate form is 'da' because the final vowel of the root word is 'u'. Thus, the word 'okul' is written as 'okulda'. These rules ensure that suffixes in Turkish are used in harmony with root words. Additionally, consonants such as p, b, d and t are critical in the Turkish alphabet for representing both their own sound properties and phonological processes like consonant lenition. These processes allow for changes in the pronunciation of voiced consonants depending on their position within a word. For example, in the word 'kapıda', the 'p' consonant in 'kapi' undergoes a lenition process, becoming 'b' at the end of the word and pronounced as 'kapıda'. These features, including certain grammatical structures and affixes in Turkish, can be complex for children, making it challenging for them to form words correctly. This can create difficulties in the development of children's writing skills.

In the literature, there is no study in the Turkish language comparing the writing skills of students with and without learning disabilities in terms of visual perception and executive functions. Since learning disabilities are usually diagnosed under a single umbrella in Turkey, this study aims to examine this broad population of students with learning disabilities by addressing the various difficulties of students with learning disabilities more comprehensively. In Turkey, the diagnostic process and infrastructure for specific learning disabilities diagnoses are still in their infancy compared with other countries. Therefore, this study considered a broad spectrum of students with learning disabilities and addressed this group of students in general. The importance of this study lies in its potential to fill the gap in the field of education by focusing on the writing skills of students with learning disabilities in Turkey. The fact that the diagnostic and classification processes in Turkey generally do not focus on specific learning disabilities increases the value of this study, while simultaneously contributing to the international educational literature. In particular, the results of this study may help teachers, educational policymakers and researchers to develop more effective strategies to improve the writing skills of students with learning disabilities. Therefore, in addition to existing knowledge in international literature, this study is expected to make a significant contribution to the literature by providing a deeper understanding of the education system and student needs in Turkey. By focusing on the writing skills of students with learning disabilities, we aim to provide a more detailed understanding of the educational context in Turkey. This study, which was conducted to overcome these deficiencies, aims to make an essential contribution to the literature on the education and development of writing skills by providing comprehensive and up-to-date information on the effects of Turkish on writing skills, visual perception and executive function. As students develop their writing skills and encounter more complex linguistic structures, this study was conducted with fourth grade students.

For this purpose, we sought answers to the following questions:

1. Is there a significant difference between students with and without learning disabilities in terms of writing skills, visual perception and executive function performances?
2. Is there a significant relationship between visual perception, executive functions and writing skills of Turkish students with learning disabilities?
3. Do visual perception and executive function skills of students with learning disabilities predict their writing skills?

METHOD

Participants

The study group consisted of 90 fourth-grade students attending primary schools in the Central Anatolia region of Turkey, including students with typical development ($n=45$; 25 girls and 20 boys; age 9.74 years, $SD=3.64$) and students diagnosed with specific learning disabilities and receiving support education from special education institutions ($n=45$; 25 girls and 20 boys; age 9.82 years, $SD=3.95$). Typically developing students were included in the study using a simple random sampling method from the class where the students with learning disabilities are located. Simple random sampling aims to provide each sampling unit with an equal opportunity to be selected in order to sample the units to be selected (Büyükoztürk et al., 2014).

The mothers of 7% of the students with learning disabilities were illiterate, 33% had completed primary school, 10% had completed secondary school, 39% had completed high school, 5% had an associate degree and 6% were university graduates. The mothers of 3% of typically developing (TD) students were illiterate, 10% had completed primary school, 20% had completed secondary school, 40% had completed high school, 9% had an associate degree and 18% were university graduates. The fathers of 5% of the students with learning disabilities were illiterate, 17% were primary school graduates, 3% were secondary school graduates, 45% were high school graduates and 30% were university graduates. Of the TD students, 6% of fathers had graduated from secondary school, 44% from high school, 2% with an associate degree and 48% from university. According to the information determined by the SED Index Form (Ergül & Demir, 2017): 20 of the LD children had lower socioeconomic status (SES) and 25 had medium SES, and 22 of the TD children had lower SES and 23 had medium SES. In addition, all students participating in the study were right-handed.

Since dysgraphia is not diagnosed in Turkey, students in this group were directly defined as having learning disabilities. The difficulties experienced by students with learning disabilities emerge towards the end of the first grade of primary school when academic learning occurs. In our country, they are diagnosed as early as the second grade (Çakmak, 2017). In this study, the following prerequisites were sought to identify students with learning disabilities and those with typical development. For students with learning disabilities, the criteria included being a fourth-grade student, having been diagnosed with learning disabilities based on the medical board report (Special Needs Report for Children) in the students' file, scoring 90 and above on the Wechsler Intelligence Test for Children, and having a 15-point difference between the verbal and performance parts of the test. Additionally, these students needed to have difficulty in writing based on the teacher's opinion and not have any additional disabilities, such as visual or hearing impairments. For the identification of TD students, the prerequisites included being at a similar grade level as students diagnosed with learning disabilities, not having a diagnosis of any disability and performing at a reasonable level in terms of writing performance according to teachers' views.

Measures

SES index parent information form (Ergül & Demir, 2017)

The tool used to determine the SES of children participating in the study was completed by the parents. The form includes variables such as mother's and father's education level, occupational information, home ownership status, the number of books in their home and participation in cultural activities. Owing to the information obtained from the form, five SES levels are defined as lower, lower-middle, middle, upper-middle and upper.

Writing sentences and writing skills assessment form

Five different sentences were used to evaluate the student's writing by copying in a close range. The researchers created the sentences, and expert opinions were obtained on their appropriateness. Each sentence was written on lined paper in a 13-point Comic Sans MS font. Three lines of space were left between the sentences for the students to write. Four sentences were used to evaluate students' writing by copying at a distance, which were also created by the researchers and for which expert opinions were obtained. These sentences were written in 60 point font size and Comic Sans MS typeface on cartons and hung four steps away from the evaluated student. Five sentences developed by Erden et al. (2002), for which expert opinions were taken on comprehensibility and appropriateness, were used to evaluate students' writing of the dictated text. In the sentences used in all three conditions, consonant letters, such as p, b, d, t, m, n, v and f, were frequently used (the letters most frequently confused by students with LD; for example, demek instead of demet).

A writing skills assessment form was used to evaluate students' writing. The researchers created this form at the end of the literature review, and expert opinions were obtained about its suitability for the research. The form consists of four sections: student information, formal features of the writing (such as line following, spacing between letters and words, capitalisation and lowercase letter ratios), spelling–punctuation (use of capital letters and punctuation marks) and writing errors (such as skipping and/or adding letters–syllables–words, mixing letters).

The format and spelling punctuation features of the students' writings were scored as 'completely appropriate, partially appropriate, and inappropriate' on the form by examining the writings. When writing errors were evaluated, each error was given one point.

Bender–Gestalt Test

Wertheimer developed the Bender–Gestalt Visual Motor Perception Test forms to apply the principles of Gestalt psychology to perception. In 1938, Bender adapted these forms and developed a test to measure visual–motor perception. The Bender–Gestalt Test was administered to children aged between 5 years, 6 months and 10 years, 11 months. It consisted of nine cards with shapes on these cards. The first card was labelled A, and the others numbered 1–8. The Koppitz scoring system is used in scoring. In this system, each error is given one point (Koppitz, 1964). The highest possible score is 30. Because the Bender–Gestalt Test is scored according to errors, a high score is considered an indicator of low performance and a low score is an indicator of high performance. The subdomains of visual perception are critical for tasks such as letter formation, spacing and alignment, which are important for writing. This assessment tool was chosen because it is thought to be effective in assessing these tasks in these areas. The Cronbach's α coefficients calculated for the reliability of the subscales in this study were found to be 0.73.

Childhood Executive Functioning Inventory

The Childhood Executive Functioning Inventory was developed by Thorell and Nyberg (2008) and adapted for Turkish by Kayhan. (2010). The Inventory consists of four subdimensions and 26 items. The dimensions were working memory (11 items), planning (four items), inhibitory control (six items) and organisation (five items). When the factors were examined, it was found that the first factor included items related to working memory and planning subdimensions, and the second factor included items related to inhibitory control and regulation subdimensions. The scale was organised into 26 items, 15 of which were related to

working memory and 11 of which were related to inhibitory control. The inventory is a five-point Likert-type scale (1 = absolutely not true, 5 = true) filled in by the teacher and takes 5–10 min on average (Thorell & Nyberg, 2008). The minimum score that can be obtained from the inventory is 0 and the maximum score is 130. High scores on the inventory are interpreted as children having difficulty with executive function skills (Kayhan., 2010; Thorell & Nyberg, 2008). The Cronbach's α coefficients calculated for the reliability of the subscales in this study were found to be 0.95 for the working memory subscale and 0.91 for the inhibitory control subscale. The fact that this instrument focuses on working memory and inhibition is especially important to understand the difficulties faced by children with learning disabilities in writing tasks. Therefore, this instrument was selected.

Procedure

This research adhered to the tenets of the Helsinki Declaration of 1975 as revised in 2000. Firstly, study approval was received from Çankırı University Scientific Research and Ethical Review Board. The research was conducted in the primary schools and private special education institutions that students attended in the second semester of the 2022–2023 academic year. Firstly, the families of the determined students were informed about the study, and permission was obtained from the family for the study. Then, the purpose of the study was explained to the students, and they were asked whether they had volunteered. Research data were collected by working one-on-one with students. Before the study, the students were introduced to the researcher and they chatted briefly, and they were accustomed to the researcher and environment. The students' evaluations were carried out individually in an empty classroom in the schools they attended.

This study adhered to ethical guidelines for research involving children with learning disabilities. Informed consent was obtained from the parents or guardians of the participants, and assent was sought from the children, where appropriate. To ensure confidentiality, all data were anonymised, and information was securely stored and accessible only to the research team. The well-being of participants was a priority throughout the study. The research team took steps to minimise any potential distress or discomfort, provided support as needed and ensured that participation was entirely voluntary.

While collecting the data on writing by copying at a close range, the students were shown a lined paper on which the sentences were written and asked, 'There are five sentences in this paper and blank lines under the sentences. I want you to write the same sentences in your best writing on the lines below them.' The students were given paper, a pencil and an eraser and were expected to write all of the sentences. When collecting data on copying from a distance, the students were given blank lined paper and told, 'Write the sentences written on the cardboard in front of you on this paper in your best writing.' They were expected to write all of the sentences. While evaluating the students' writing of the dictated text, blank lined paper was given to the students, and they were told, 'Now I am going to read a few sentences to you. I want you to write the sentences I read to you in your best writing and carefully on the paper before you.' The researcher read the sentences in phrases of a few words according to the student's writing speed. When writing errors were evaluated, each error was given a score. For example, students who skipped vowel or consonant letters in the dictated word sequence (e.g. 'madnoz' instead of 'maydonoz') were given one point for their mistake. Another example is that students who omitted the syllables they should use in the dictated word sequence were given one point each for their mistakes (e.g. 'Dün gece yolda giken' instead of 'Dün gece yolda giderken'). The content of the writing skills assessment form is explained above. In order to ensure the reliability of the scoring for the evaluation of writing errors, all data collected from all participants were re-evaluated by an

independent researcher who did not have the student's diagnosis information. For the errors that were thought to be different in the evaluation, the researchers met, discussed and reached a consensus. In this study, inter-rater reliability was determined as 0.98.

During the application of the Bender–Gestalt test, the students were told 'I will show you some shapes, draw these shapes on the paper as you see on the card'. The test started with card and then the patterns from 1 to 8 were given one after the other. The papers on which the patterns were to be drawn were plain white and unlined. The test was not limited to a certain period of time and the patterns were not removed before they were drawn. The test was re-evaluated by an independent researcher as in the case of writing errors. In this study, inter-rater reliability was determined as 0.99. The Childhood Executive Functioning Inventory Parent Form was completed by the parents of the children included in the study for the children who received the intervention.

Data analysis

In this study, firstly, MANOVA (Multivariate Analysis of Variance) was used to test whether the students' writing error (distant, close and dictation) performances, visual perception and executive function performances differed significantly according to the student group (learning disability and typical development). Secondly, the relationships between writing, visual perception and executive function variables were analysed using Pearson's correlation coefficient. Thirdly, predictors of writing skills in children with learning disabilities were analysed using a regression analysis.

Before the analysis, univariate and multivariate normality assumptions were tested, missing and extreme values were examined for all variables and descriptive statistics (skewness, kurtosis coefficients, means, and standard deviations) were calculated. No missing data were found for any of the variables in the dataset, and the skewness kurtosis coefficients of all variables were very close to the value ranges of -1 and $+1$. The data met the requirements of univariate and multivariate normality, linearity, and lack of autocorrelation. Multicollinearity was not observed.

RESULTS

Error averages of students with learning disabilities regarding their writing skills

Table 1 reveals the errors in the writing skills of students with learning disabilities by analysing their mean errors in different writing situations. In dictated sentences, students' error rates (skipping letters, skipping syllables, writing backward, mixing letters, skipping words and adding words) were significantly higher than in the other two cases. This shows that dictated sentences are more challenging for students and that this type of writing activity challenges students' writing skills more.

Findings related to student groups

A MANOVA was used to examine whether the groups showed a significant difference in terms of the total number of errors they made in the conditions of writing by looking at close and far distances and writing the dictated text. In this study, the groups differed in variables Pillai's trace = 0.91, $F(6, 83) = 152.13$, $p < 0.001$. Because the groups differed in more than

TABLE 1 Average errors in writing skills of students with learning disabilities ($N=45$).

Features observed in writing	Writing from close distance <i>M</i> (SD)	Writing from far distance <i>M</i> (SD)	Writing dictated sentence <i>M</i> (SD)
Formal assessment of writing			
Starts writing with enough space from the left side of the paper	1.02 (0.16)	1.11 (0.40)	1.25 (0.50)
Writes by following the line	1.31 (0.58)	1.14 (0.35)	1.22 (0.54)
Writes with appropriate spacing between letters	2.34 (0.72)	2.40 (0.55)	2.34 (0.72)
Writes with appropriate spacing between words	1.22 (0.54)	1.28 (0.54)	1.28 (0.51)
Writes with proportional and appropriately sized uppercase and lowercase letters	1.57 (0.65)	1.54 (0.65)	1.48 (0.65)
Spelling and punctuation			
Starts the sentence with a capital letter and uses capital letters where necessary within the sentence	5.28 (5.80)	5.02 (4.83)	5.42 (5.65)
Uses appropriate punctuation marks at the end and within the sentence	5.22 (5.51)	5.01 (4.60)	6.34 (6.72)
Evaluation of writing errors			
Letter omission	12.02 (13.42)	12.62 (13.94)	18.94 (19.34)
Syllable omission	9.31 (9.59)	9.34 (9.67)	13.71 (13.31)
Letter addition	11.22 (12.49)	10.22 (11.64)	14.54 (15.78)
Syllable addition	10.05 (11.23)	10.08 (11.28)	13.17 (12.45)
Reversing letters	8.08 (9.28)	8.05 (9.13)	12.08 (0.28)
Mixing letters	5.37 (6.66)	5.45 (6.72)	8.02 (8.79)
Word omission	7.01 (8.58)	6.46 (6.88)	13.51 (12.88)
Word addition	5.02 (6.16)	5.05 (6.23)	10.08 (11.28)
Inventing words	3.05 (3.12)	3.02 (0.316)	9.35 (9.16)
Incorrectly dividing words at the end of a line	5.08 (6.28)	5.28 (6.52)	7.37 (6.77)
Incorrect spelling of words	3.08 (3.28)	3.05 (3.12)	8.94 (7.60)
Total average	5.40 (6.29)	5.34 (4.98)	8.28 (6.08)

Abbreviations: *M*, Mean; *SD*, standard deviation.

one variable, Pillai's trace was preferred as the test statistic (Olson, 1979; Stevens, 1979). This result shows that writing errors, executive function and visual perception levels vary according to the student group.

Table 2 shows that the levels of writing errors, executive function and visual perception differed significantly according to student group. It was analysed whether the students' near, far and dictation writing error scores were significantly different according to the student group. It was observed that there was a statistically significant difference in the near ($F(1, 88) = 30.70, p < 0.001, \eta^2 = 0.26$), far ($F(1, 88) = 34.86, p < 0.001, \eta^2 = 0.28$) and dictation ($F(1, 88) = 73.74, p < 0.001, \eta^2 = 0.46$) writing error scores of the students according to the student group. After analysing the error averages, it was revealed that students with learning disabilities made a higher number of mistakes in their writing skills.

TABLE 2 MANOVA results of writing errors, executive function and visual perception levels according to student group ($n=45$ for each group).

Dependent variable	Group	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>SD</i>
Close distance looking writing	LD	5.40	6.29	0.39	1–88
	TD	0.63	1.05		
Writing by looking into the distance	LD	5.34	4.98	1.66	1–88
	TD	1.11	1.67		
Writing what is dictated	LD	8.28	6.08	1.62	1–88
	TD	0.94	1.64		
Visual perception	LD	3.06	2.16	0.87	1–88
	TD	1.40	1.52		
Working memory	LD	62.44	11.09	0.71	1–88
	TD	18.95	1.46		
Inhibition	LD	44.06	7.84	0.85	1–88
	TD	23.71	7.51		

Abbreviations: LD, learning disabilities; *M*, Mean; *SD*, standard deviation; *SE*, standard error; TD, typical development.

When evaluating the visual perception scores of students, it was discovered that there was a statistically significant difference between the groups ($F(1, 88) = 17.76, p < 0.001, \eta^2 = 0.17$). Moreover, it became evident that the visual perception performance of students with learning disabilities was lower than that of their peers with typical development. In addition, analysis of working memory (WM) performance revealed a statistically significant difference between the groups ($F(1, 88) = 679.99, p < 0.001, \eta^2 = 0.88$). The WM performance of students with learning disabilities was lower than that of their peers with normal development. Furthermore, when analysing inhibition performances, a statistically significant difference was found between the student groups ($F(1, 88) = 157.95, p < 0.001, \eta^2 = 0.64$). It was found that the inhibition performances of students with learning disabilities were at a lower level than their peers with normal development.

The relationship between writing, executive function and visual perception skills of children with learning disabilities

The relationship between writing, executive function (working memory and inhibition) and visual perception skills was examined to answer the second research question. The correlation coefficients between variables were calculated using Pearson's correlation test. Pearson's correlation coefficients between visual perception, working memory, inhibition and writing in children with learning disabilities showed statistically significant relationships, indicating that these cognitive functions are interconnected with writing performance. A moderate negative correlation was observed between the Writing Error score and visual perception ($r = -0.57, p < 0.001, 95\% \text{ CI} = 0.350, 0.264$), working memory ($r = -0.33, p < 0.001, 95\% \text{ CI} = -0.591, -0.070$) and inhibition ($r = -0.35, p < 0.001, 95\% \text{ CI} = -0.499, -0.001$). As the executive function and visual perception scores of students with learning disabilities were enhanced, their writing error scores diminished. Additionally, a moderate positive correlation was found between the visual perception score and working memory ($r = 0.48, p < 0.001, 95\% \text{ CI} = 0.223, 0.697$) and inhibition ($r = 0.44, p < 0.001, 95\% \text{ CI} = 0.159, 0.680$). Moreover, a moderate positive correlation was observed between working memory and inhibition ($r = 0.73, p < 0.001, 95\% \text{ CI} = 0.002, 0.020$). According to

the correlation results, as the visual perception, working memory, and inhibition scores of the students with learning disabilities participating in the study increased, their writing errors decreased.

Findings on the prediction of writing skills of students with learning disabilities

The prediction of the study's independent variables, executive function and visual perception skills on the dependent variable, writing, were tested using multiple linear regression analysis. Regarding the adequacy of the sample size, Siddiqui (2013) used the standard of 15–20 observations for each of the independent variables in the regression analysis. In this study, visual perception, WM and inhibition were independent variables. Before analysis, the dataset was examined to meet the regression analysis assumptions. First, the suitability of the data for normal distribution was evaluated. The data met the normality assumption.

For the regression analysis to provide accurate results, there should be a low degree of relationship between the predictor variables. When a correlation above 0.80 is observed between the predictor variables, the possibility of multicollinearity should be emphasised (Büyüköztürk, 2005). Since the correlations between the variables in the regression model of the study ranged between 0.33 and 0.73, it was considered that there was no multicollinearity problem.

The VIF (Variance Inflation Factor) values were 1.03 for visual perception, 8.82 for working memory and 8.42 for inhibition. The values examined to determine whether there is a multicollinearity problem between the variables in the linear regression model ($VIF < 10$) indicate that the variables are suitable for analysis (George & Mallery, 2010). The Durbin–Watson statistic value obtained is 1.98 and it is understood that the independence of observations is not violated (no autocorrelation). It is recommended that the Durbin–Watson statistic should be around 2 (1.5–2.5) for the error variances to be uncorrelated. Accordingly, it can be said that there is no relationship between the error variances of the model.

As seen in Table 3, where the results of the regression analysis are summarised, the model established as a result of the analysis using the enter method is significant ($F(3, 41) = 3.44, p < 0.001$). When the parameters obtained as a result of regression analysis are examined, it is seen that WM ($\beta = -1.60, t = -2.24, p < 0.001, 95\% \text{ CI} = -2.83, -0.09$), inhibition ($\beta = -1.15, t = -1.20, p < 0.001, 95\% \text{ CI} = -2.59, -0.68$) and visual perception ($\beta = -1.99, t = -1.82, p < 0.001, 95\% \text{ CI} = -3.96, -0.51$) have an effect on the predicted variable of writing according to the standardised regression coefficient. Accordingly, the predictor variables explained 20% of the change in writing achievement of students with learning disabilities. Considering the standardised beta coefficients, the relative order of importance of the

TABLE 3 Regression analysis results on the predictors of writing.

Variables	β^a	SE B ^b	β^c	<i>t</i>	<i>p</i>	VIF	Uncorrelated error variances
Constant	117.67	15.38		7.64	0.02		Durbin Watson 1.98
Visual perception	-1.99	1.09	-0.29	-1.82	0.04	1.03	
Working memory	-1.60	0.71	-0.93	-2.24	0.03	8.82	
Inhibition	-1.15	0.96	-0.48	-1.20	0.02	8.42	
$R = 0.45, R^2 = 0.20$							

^aUnstandardized beta coefficient.

^bStandardized beta coefficient.

^cNew standardized beta coefficient.

predictor variables on the dependent variable writing skill was working memory, inhibition and visual perception. According to [Table 3](#) it can be said that visual perception, WM and inhibition are predictors of the writing skills of students with learning disabilities.

DISCUSSION

This study aimed to examine the effects of visual perception and executive functions on the writing skills of Turkish students with and without learning disabilities, and the relationships between these variables. The results of the study show significant differences between student groups in terms of writing errors, executive function and visual perception levels. In particular, students with learning disabilities had higher error scores and exhibited lower visual perception and executive functioning skills. The findings also revealed significant relationships between the writing errors of children with learning disabilities and visual perception, working memory and inhibition. Finally, executive function and visual perception skills were found to play important roles in predicting the writing skills of students with learning disabilities.

The findings of this study were consistent with those of previous studies. It has been observed that students with learning disabilities' weaknesses in visual perception and executive functions directly affect their performance in writing skills (Berninger et al., 2009; Borsting, 2006; Caravolas et al., 2001). This emphasises the importance of focusing on visual perception and executive function to improve the writing skills of students with learning disabilities. In addition, in this study, children with learning disabilities made significantly more errors than typically developing children in all three writing conditions (close-range-looking writing, far-range-looking writing and dictated writing). This difference was most pronounced in the dictated writing condition, suggesting that children with LD had greater difficulties in dictated writing skills. Visual perception has several subdomains that affect writing skills, each of which may play an important role in the writing performance of children with learning disabilities. For example, spatial relations play a critical role in the correct placement and alignment of letters and words on a paper. Deficits in this skill can lead to irregular or illegible writing. Visual discrimination is the ability to distinguish between small differences between letters and words. Children who are weak in this skill may confuse similar letters and make spellings. Visual memory involves the capacity to remember what they see and reproduce it in writing. Students with weak visual memory may have difficulty writing words correctly and remembering sentence structure. Each of these subdomains can lead to significant difficulties at different stages of the writing process and can negatively affect the writing performance of children with learning disabilities. Therefore, assessing and supporting each of these skills separately is vital for improving their writing skills.

These findings of the study on various subdomains affecting writing skills support the existing literature on the writing skills of children with learning disabilities (Koutsoftas & Nicotera, 2023; Raof et al., 2023; Re et al., 2023). For example, Re et al. (2023) found that children with learning disabilities write more slowly and make more errors than do children with typical development. Gillespie and Graham (2014) conducted a meta-analysis to examine the writing skills of children with learning disabilities. Their findings showed that children with learning disabilities had significantly higher error rates in dictation-based writing tasks. These studies strengthen the validity of the current study's findings.

The results of this study confirm the relationship between writing error scores and visual perception, working memory and executive function skills. This relationship indicated that inadequate executive function and visual perception skills may lead to an increase in writing errors. Similarly, it has been reported that lack of executive function skills negatively affects the writing process (Alloway et al., 2009; Baddeley & Hitch, 1974; Berninger, Abbott,

Vermeulen, & Fulton, 2006; Gathercole, 2008; Graham et al., 2021; Oddsdóttir et al., 2020). Various studies have emphasised that writing is a complex cognitive process, and that executive functions play a critical role in the effective management of this process (Baddeley & Hitch, 1974; Berninger & Winn, 2006; Kamran et al., 2023; Re et al., 2023). For example, working memory is directly related to the ability to retain and process information during writing, and deficiencies in this skill can negatively affect the coherence and fluency of writing (Berninger & Winn, 2006; Gathercole, 2008). Students with poor working memory may forget previous sentences in the middle of writing them, which may lead to a breakdown in coherence of meaning. Inhibitory control involves the ability to focus attention and suppress distractions; inadequacy of this skill can lead to frequent errors and focusing problems during writing (Graham et al., 2021). For example, external noise or internal thoughts while writing can easily distract students with low inhibition control, which can interrupt the writing process. Cognitive flexibility refers to the ability to switch between different writing tasks and organise written expressions. Lack of this skill can cause writing to be monotonous and full of errors (Kamran et al., 2023). A lack of cognitive flexibility may reduce the quality of students' written expressions by limiting their ability to revise and correct their writing. In this context, deficits in executive functions indicate that individuals with learning disabilities have difficulty organising their writing, ensuring coherence and getting their written expressions down on paper without making mistakes (Alloway et al., 2009; Baddeley & Hitch, 1974). Understanding how each component contributes to different aspects of the writing process may enable the development of more targeted interventions to support the writing skills of children with learning disabilities. Another important finding was the impact of visual perception skills on the writing process. Visual perception plays a central role in key elements of the writing process such as letter formation, correct alignment and appropriate spacing (Grewal et al., 2014; Méary et al., 2005). Children with learning disabilities may make errors in writing tasks because of their deficits in these skills. In particular, the literature warns about how the visual perception difficulties of individuals with learning disabilities can affect their written expression (Borsting, 2006; Gray, 2022). These results emphasise the importance of educators and pedagogues focusing on these skills to support the writing process of individuals with learning disabilities.

The results of the regression analysis showed that the independent variables of visual perception, working memory and inhibition significantly explained writing skills. This finding reveals that the effects of these variables on writing skills are significant. In particular, it emphasises that executive functions, such as visual perception, working memory and inhibition, play a central role in the writing process, and that deficiencies in these factors can increase writing errors (Alloway & Alloway, 2010; Swanson & Sachse-Lee, 2001). In this context, the variance ratio obtained allows for the identification of areas that should be targeted in the development of writing skills (Barkley, 2012). Visual perception and executive functions should be strengthened while developing educational practices and intervention strategies (Diamond, 2013). These results reveal the importance of considering executive functions and perceptual skills in interventions to improve writing skills (Barkley, 2012; Swanson & Sachse-Lee, 2001).

The results of this study revealed that visual perception and executive function are important factors affecting Turkish students' writing skills. It was observed that the weaknesses of students with learning disabilities in these areas were clearly reflected in their writing skills. The structure of Turkish is full of features, such as vowel harmony and articulation. This may require students to learn word structure and grammar differently than in other languages. The development of writing skills in students with learning disabilities, especially in the Turkish context, is influenced by various factors specific to language structure (Kaldırım & Tavşanlı, 2021). As a syllable-based, phonetically transparent and agglutinative language, Turkish presents unique challenges for acquiring writing skills for individuals with

LD (Kaldırım & Tavşanlı, 2021). Students with LD may face difficulties in the writing process because of weaknesses in visual perception and executive functions, which may be exacerbated by the complexity of the transparent orthographic language structure (Pourfaraman & Taher, 2022). Cultural factors also have a significant impact on the development of writing skills and learning disabilities. Educational practices and cultural attitudes towards learning disabilities in Turkey can significantly influence the findings of this study. As the level of awareness and acceptance of learning disabilities is still developing in Turkey, support and interventions appropriate to the needs of these students may not be adequately provided (Diken, 2010). Students with learning disabilities may face additional challenges in developing their writing skills owing to the fear of stigmatisation. Culturally, the importance of academic skills such as writing and reading shapes the expectations of families and teachers in these areas. Therefore, the findings of this study should be considered in light of Turkey's educational and cultural contexts. Educators and policymakers should develop more comprehensive and responsive strategies to support the writing skills of children with learning disabilities, taking into account cultural factors.

The findings of this study emphasise the need for a better understanding of the development of writing skills in the Turkish educational system. In particular, it is important to develop programmes and interventions to support students' visual perception and executive function. Such programmes can be designed to meet students' visual perception needs and improve their executive function during the writing process. Moreover, it is important for teachers to implement different teaching strategies to support students' writing skills by considering these factors (Sittiprapaporn, 2020).

LIMITATIONS AND RECOMMENDATIONS

Limitations

This study has certain limitations. First, sample selection was limited to a specific region or school group, which may have reduced the generalisability of the results. Using a larger and more diverse sample size could enhance the generalisability of our findings. Second, employing different research methods or measurement tools might provide a deeper understanding of the results. Third, the structure of Turkish may have a determining effect on writing skills. Features such as vowel harmony and agglutinative structures could pose additional challenges for children with learning disabilities. As this study is the first to examine the effects of visual perception and executive function on writing skills in Turkish, it contributes significantly to the literature. However, this study alone is insufficient to determine the extent to which Turkish language structure affects the writing skills of children with learning disabilities. Therefore, future studies should examine the impact of the Turkish language structure on writing skills in more detail.

Recommendations

In line with the findings of this study, it is recommended that research be conducted to explore how strategies that support visual perception and executive function can be applied in education. Specifically, studies and interventions that evaluate the effects of special education programmes designed to improve visual perception and executive function on writing skills can fill this knowledge gap. For example, experimental studies could determine how games that strengthen visual perception, or techniques that support executive functions in the writing process, contribute to students' writing performance.

Based on these research findings, individualised education programmes should be developed to support the writing skills of children with learning disabilities. These programmes should include activities that strengthen visual perception and executive functions. Educators can improve students' writing skills using visual perception games and executive function exercises. Additionally, special training and awareness programmes for teachers should be offered to help them better understand the needs of students with learning disabilities and to provide effective interventions. Support programmes should also be developed for families to provide guidance on how to support their children's writing skills at home. Policymakers should create policies that provide more resources and support to students with learning disabilities. These recommendations are crucial steps towards addressing the current deficiencies in the education system and improving children's writing skills.

To determine the effects of Turkish's unique linguistic features on children with learning disabilities, comprehensive studies involving cultural and linguistic factors should be conducted. These studies can reveal the effects of language structure and explain how educational practices can be shaped. Considering the limitations of this study, longitudinal studies examining the development of writing skills and the long-term effects of visual perception and executive functions are recommended. Such studies may help us better understand the changes in writing skills over time and their relationship with visual perception and executive functions.

Educational implications

Educators and pedagogues play important roles in supporting the writing skills of students with learning disabilities. Strategies targeting cognitive aspects such as visual perception and executive functions can significantly improve the writing output of students with LD and help them overcome barriers associated with both their cognitive processes and the linguistic structure of Turkish. This study contributes to potential strategies aimed at improving writing outcomes by elucidating the role of executive function and visual perception skills in writing difficulties in children with LD.

This research can strengthen evidence-based practices aimed at supporting the writing skills of children with learning disabilities by using a transparent orthographic language. Therefore, the salient findings of this study can be used as a resource for the creation and implementation of educational programmes designed to improve the writing skills of children with learning disabilities.

CONFLICT OF INTEREST STATEMENT

As the author, I declare that there is no financial support or other conflict of interest associated with the execution of this study. This research has been conducted with the principles of objectivity and impartiality and does not reflect any commercial or financial interests.

DATA AVAILABILITY STATEMENT

Researchers who wish to obtain additional data or conduct further analysis may contact the author to request supplementary information or materials. The author is willing to collaborate and provide the necessary information to support the results presented in the article.

ETHICS STATEMENT

Data collection from students for this study was conducted with the utmost consideration for ethical standards. The study protocol was reviewed and approved by the appropriate

educational authorities, ensuring that the research adhered to ethical guidelines and safeguarded the well-being of the participants. This study adhered to ethical guidelines for research involving children with learning disabilities. Informed consent was obtained from the parents or guardians of the participants, and assent was sought from the children, where appropriate. To ensure confidentiality, all data were anonymised and information was securely stored and accessible only to the research team. The well-being of participants was a priority throughout the study. The research team took steps to minimise any potential distress or discomfort, provided support as needed and ensured that participation was entirely voluntary. This study received ethical approval from the Social and Human Sciences Ethics Committee of University.

DECLARATIONS

The author confirms that the work submitted here is not published or submitted for publication elsewhere.

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