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Understanding Typing Skill in Students With Developmental Disorders

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Abstract

Purpose of Review Typing is an important skill for education and beyond and is often recommended for those with developmental coordination disorder (DCD) and/or specific learning disorder (SLD) when handwriting is a challenge. This review outlines a model of typing to demonstrate the language, perceptual, and motor components involved. It then summarises selected research on typing skill in DCD and SLD. The purpose of the review is to identify current knowledge of typing skill in these groups to enhance understanding and inform future work on assessment, accommodations, and intervention.

Recent Findings Thirteen relevant studies, published between 2008 and 2024, were identified. These vary widely in the types of disorder/difficulties studied, participant age, and language. They also include a range of tasks (alphabet writing, writing to dictation, copywriting, compositional writing) and employ different measures of typing. Taken together, they examine aspects of the typed 'product' (speed and accuracy), the 'process' of typing (efficiency, gaze, and finger movements), and student 'perceptions' of typing. Despite the varied groups studied and methods employed, findings are consistent. Most studies report that in groups with developmental disorders, typing is poorer than handwriting, and typing is poorer compared to typically developing peers.

Summary The findings have important implications for research and practice. They indicate the need for further research on typing in specific diagnostic groups. They also emphasise the need for practical tools to assess typing performance across a range of tasks. This will aid the identification of typing difficulties and help plan appropriate accommodations and/or intervention.

Keywords Developmental coordination disorder (DCD) · Specific learning disorder (SLD) · Dyslexia · Dysgraphia · Handwriting · Keyboarding

Introduction

Written language arose out of the need to have a more permanent record of the spoken language. Early writing systems used simple drawings or pictograms and over time, more efficient orthographies were developed to capture the sounds, syllables, and words of different languages. The alphabetic systems now used in many countries provide a particularly efficient and economical way of representing language in a written format.

By the age of 5 years, most children have acquired a large vocabulary that enables them to produce well-formed sentences [1] and early in education, they will start to be taught the written conventions of their language. These writing skills continue to be important for progress through education and in the workplace [2], where handwriting and increasingly typing are required. A substantial body of research has been conducted on aspects of writing in individuals with developmental disorders and particularly within the diagnostic categories [3] of developmental coordination disorder (DCD) and specific learning disorder (SLD, which incorporates dyslexia and dysgraphia). As writing involves the complex interaction of a range of language, cognitive, perceptual, and motor skills, it is hardly surprising that this is challenging for these groups. One aspect that has received considerable attention is handwriting. Handwriting difficulties are often apparent in DCD and SLD from the early school years and persist into young adulthood [4, 5].

While handwriting support may be offered where an individual experiences difficulty, typing is often recommended as an alternative mode for written work, with computers

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provided for class work and/or in written examinations [6]. However, little is known about who may benefit from typing rather than handwriting. Therefore, in what follows, we present a review of selected literature on typing skill in individuals with developmental disorders, with a focus on DCD and SLD.

Typing today involves pressing keys on a keyboard to produce the required characters of a written language on a computer screen, usually in conjunction with a word processing package. In contrast, the first mechanical typewriters typically comprised a cylindrical roller to hold a sheet of paper in place, an inked ribbon, and an array of keypads, each linked to a single character. Striking a key firmly caused a typebar ('hammer') with a corresponding character to hit the ribbon against the paper, thereby printing the character.

Today, the standard layout for Latin-based alphabets is the QWERTY keyboard,[1] which reflects the order of the first six keys on the top letter row. In this arrangement, frequently used letters are spread apart to avoid the clashing of letter 'hammers' on the original typewriters. Although no longer relevant to word processing on a computer, the QWERTY keyboard remains in use. Different keyboard arrangements are available for different languages, reflecting their different alphabets, with the location of keys based on the characters most frequently used.

'Touch typing' has traditionally been advocated as an efficient technique. This involves placement of all the fingers on 'home' keys in the central row of the keyboard and moving each finger to other prescribed keys above and below, without visually monitoring them. This enables the typist to visually monitor the screen, reading the text as it is produced. However, this takes practice and time to learn and everyday computer users employing self-taught typing techniques can perform at similar speeds to touch typists [7].

Typing can confer potential benefits over handwriting. It enables the writer to produce consistently clear written output through finger taps on the keyboard. This is a simpler action than controlling the fingers to hold and move a pen to form letter strokes, and, with practice, typing can be produced accurately and at a fast pace. Combined with the advantages of word processing, typing provides a valuable tool for producing, checking, editing, and revising text.

Although some aspects of motor coordination may be regarded as simpler in typing, it does involve some complex elements of perceptual motor control which take time to learn. Furthermore, typing is part of the broader process of writing, which involves a range of demands.

[1] Or variants of the QWERTY keyboard. For example, the QWERTZ layout is used for German-based languages and AZERTY layout in France and Belgium.

Typing as Part of the Broader Writing Process

Typing (like handwriting) involves producing written language. Therefore, a psycholinguistic framework is useful to understand the complete process [8]. Logan and Crump [9] proposed a hierarchical model, acknowledging the many components involved in skilled typewriting, described in two nested feedback loops. An 'outer loop' starts with text generation (coming up with ideas). The writer must decide how to structure the text and select the appropriate words to be typed. An 'inner loop' starts with a word. The word is translated into letters and into the required series of keystrokes. This hierarchical processing, with feedback loops, is depicted in Fig. 1, together with finer components of performance also encompassed by the model.

The 'inner loop' represents the perceptual-motor elements of typing. Starting with a word, the appropriate letter and letterform/allograph (lower case or capital) are selected and a motor plan is activated to produce the required finger movements. Action of the two hands is coordinated and individual finger movements are controlled to ensure the correct keys are pressed at the right time, in the right sequence, and with appropriate force. Movement speed must also be modulated to maintain accuracy [10]. The control of typing relies on the sense of proprioception or kinaesthesis. This provides feedback of where the hands and fingers are located and the 'feel' of the keys, their position, and resistance. This information is monitored to detect any errors and help plan subsequent movements. Studies suggest that skilled typists do not know the details of how their movements are executed; they are so 'automatic' and well learned that this knowledge is implicit [9].

The'outer loop' visually monitors the accuracy of words on the screen, which lies in a different position/plane to the keyboard. When errors on the screen are detected, skilled typists can simultaneously correct these while continuing to monitor the screen. Less skilled typists use fewer fingers when typing and rely more on vision to locate the keys. This need to visually attend to the keyboard means that tapping the keys is suspended while monitoring text on the screen [11], thus slowing down performance.

The range of writing components shown in Fig. 1 competes for limited working memory resources [12]. Some components can be practiced to the extent that they become automatic and consume less resources. As a consequence, more resources can be devoted elsewhere. Indeed, research has consistently shown that increased speed of typing is associated with a higher quality written text, in terms of compositional content and cohesiveness [13]. This suggests that as the motor elements become more automatized, greater attention can be devoted to aspects of text generation, such as planning, organising, reviewing, and revising.

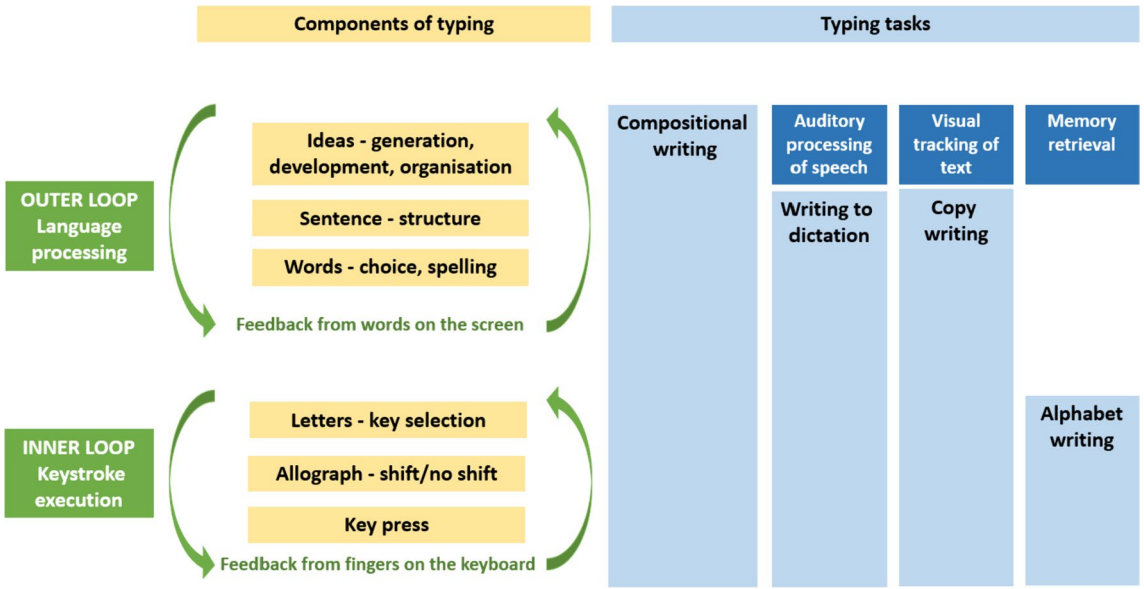

Fig. 1 A model of typing and the components of typing tasks. This shows the 'inner' and 'outer' feedback loops proposed by Logan and Crump [9], the components of typing from idea generation to making a key press, and the various components and demands involved in different typing tasks

Research on Typing in Developmental Disorders

Although research on typing skill is now receiving more attention, information on typing in those with developmental disorders is scarce. A literature review of research on handwriting and typing/keyboarding and a range of SpLD terms was conducted, and a selection of more recent research is summarised in Table 1 and 2. The studies include eight on school-aged students aged 4–17 years and five in post-secondary settings, aged 18 years and over. The studies included students writing in English (US/Canadian), Spanish, German, Hebrew, and Arabic. Reviewing this work is complicated by the different terms used to describe the participants with developmental disorders, selection measures, and criteria applied for inclusion. Some studies report that participants were included on the basis of formal diagnostic assessment; for example, Klein et al. [14] describe the measures used to indicate that their Canadian participants met the DSM-IV [15] criteria for DCD. Other studies use more general terms such as 'Learning Disability' or 'Specific Learning Disability/Disorder', reflecting the use of different terms in different countries [16]. Some studies selected participants only on the basis of poor literacy performance. For example, Bisschop et al. [17] selected Spanish children with poor handwriting and/or poor spelling.

Across these studies, a range of writing tasks were employed, and different techniques used to measure aspects of typing performance. This includes the 'product' (the actual writing produced), the 'process' (the way in which this was achieved), and student 'perceptions' of typing. These aspects are briefly reviewed below, after first outlining the range of writing tasks employed in the selected research.

Writing Tasks

The different tasks employed in the literature on typing in developmental disorders are shown in Table 2 and listed below. These range from very short tasks of a few seconds to longer tasks up to 10 min. Studies vary in the way task performance was measured and the number of different writing tasks employed. Each of the tasks outlined below involve varying cognitive, linguistic, and perceptual demands, as shown in Fig. 1.

Alphabet Writing

This involves retrieving the sequence of the alphabet from memory. Four studies [17–19, 21] with younger participants employed this task.

Writing to Dictation

This involves auditory processing of speech. Jiménez et al. [21] included word dictation tasks in Spanish; one involved typing words with inconsistent spelling patterns and one typing pseudowords. Jung et al. [22] included dictation of 'gapped' sentences, where participants were required to fill in real and pseudowords in German.

Table 1 Details of selected studies

Author (year)/language	Grade/age	Developmental disorder groups		TD group
			n	*n*
Children				
[18] Beers et al. (2017) English (US)	Grades 4–9 Age 9–14 yrs	**Specific learning difficulties in written language (SLD-WL)**		
	Mean age = 11.98 yrs	Dyslexia	20	
		Dysgraphia	19	
		Total	39	15
[19] Berninger et al. (2009) English (US)	Grade 4 Age 9–10	**Specific learning disabilities** in transcription skills	8	12
[17] Bisschop et al. (2017)	Grades 1–3	**Poor writing skills**		
Spanish	Age 6–9 yrs	Poor handwriting	105	
		Poor spelling	97	
		Poor handwriting and spelling	106	
		Total	308	334
[20•] Foxworth et al. (2019) English (US)	Grade 5 Age 10–11 yrs	**Language-based learning disorder (LD)**	6	39
[21] Jiménez et al. (2017)	Grades 1–3	**Poor writing skills**		
Spanish	Age 6–9 yrs	Poor handwriting	106	
		Poor spelling	97	
		Poor handwriting and spelling	104	
		Total	307	118
[22] Jung et al. (2021) German	Mean age = 11.45 yrs	**Developmental dyslexia**	22	30
[23] Khoury-Shaheen (2024) Arabic	Grade 4–5 Mean age = 10.15 yrs	**Probable developmental coordination disorder (pDCD)**	17	31
[14] Klein et al. (2008) English (Canadian)	Grades 3–5 Age 7–10 yrs (mean age = 9 yrs)	**Developmental coordination disorder (DCD)**	6	NA
Adults				
[24••] Abecassis et al. (2023) Hebrew	19–29 yrs	**Specific learning disorder (SLD)** with reading or writing difficulties	35	30
[25] Weigelt-Marom and Weintraub (2015)	20–37 yrs (mean age = 25 yrs)	**Learning disability (LD)**		
Hebrew		Reading difficulties	11	
		Handwriting difficulties	18	
		Reading and handwriting difficulties	15	
		Total	44	30
[26] Weigelt-Marom and Weintraub (2018) Hebrew	20–37 yrs (mean age = 25 yrs)	**Specific learning difficulties (SLD)** with reading or handwriting difficulties	25	17
[27] Rosenberg-Adler and Weintraub (2020) Hebrew	18–33 yrs	**Specific learning disorder (SLD)** with handwriting difficulties (HD)		
		Handwriting difficulties only	38	
		Handwriting difficulties and slow typing speed	12	
		Total	50	40
[28••] Rosenberg-Adler and Weintraub (2020)	22–30 yrs (mean age = 25 yrs)	**Specific learning disability (SLD)**		
Hebrew		Handwriting difficulties 'dysgraphia' only	12	
		Handwriting and reading difficulties	13	
		Total	25	NA

TD typically developing, *yrs* years

Table 2 Typing tasks and measures used in the selected studies

Author (year)/ language	Typing tasks employed				Typing measures				
					Product		Process		Student perceptions
	Alphabet writing	Writing to dictation	Copywriting	Compositional writing	Speed	Accuracy	Efficiency	Technique	
Children									
[18] Beers et al. (2017)[a,b]	-15 secs	-	-	-Autobiographical narrative (10 min)	-Number of letters in correct order typed in 15 s (alphabet writing) -Number of words -Total time -Words per min	-% spelling errors	-	-	-
[19] Berninger et al. (2009)[a,b]	-15 secs	-	-	-Sentence -Essay (10 min)	-Number of letters in correct order typed in 15 s (alphabet writing) -Number of words in sentence -Number of words in essay	-	-	-	-
[17] Bisschop et al. (2017)[b]	-5 min allowed	-	-	-	-Number of letters in correct order typed in 1 min	-Number of omitted letters in 1 min	-	-	-
[20•] Foxworth et al. (2019)[b]	-	-	-Paragraph (2 min)	-	-Total words per min	-Correct words per min	-	-	-Questions on self-perceptions about typing skills
[21] Jiménez et al. (2017)[b]	-5 min allowed	-20 words with an inconsistent spelling -20 pseudowords	-10 words	-2 sentences	-Total number of letters typed in the time taken (alphabet writing)	-Number of letters typed correctly in the right order in 1 full minute (alphabet writing)	-	-	-

Table 2 (continued)

Author (year)/ language	Typing tasks employed				Typing measures				
					Product		Process		Student perceptions
	Alphabet writing	Writing to dictation	Copywriting	Compositional writing	Speed	Accuracy	Efficiency	Technique	
[22] Jung et al. (2021)[a,b]	-	-34 real words in gapped sentences -20 pseudowords in gapped sentences	-	-	-Writing time (ms/graphemes)	-% Spelling accuracy -Number of self-corrections	-	-	-
[23] Khoury-Shaheen (2024)[a,b]	-	-Detail not specified (3 min)	-Paragraph (5 min)	-	-Characters per min	-% characters typed correctly	-	-	-
[14] Klein et al. (2008)[a]	-	-	-Sentence (2 min)	-Story (5 min)	-Letters per min	-	-	-Live observation of number of fingers and use of visual feedback	-
Adults									
[24••] Abecassis, et al. (2023)[b]	-	-Detail not specified (but used for measuring typing technique)	-13 sentences (106 words)	-	-Characters per min (copying task)	-% correct characters (copying task)	-Keystrokes per character -Error correction efficiency -Overall % correctly typed characters in process of typing (all measures in copying task)	-Recorded observation of number of fingers used during dictation task -Recorded observation of screen gaze time divided by total time taken on dictation task	-
[25] Weigelt-Marom and Weintraub (2015)[b]	-	-	-3 paragraphs (3 min for each)	-	-Number of keys typed per min (based on keystroke logging software)	-% total correct keys (based on keystroke logging software)	-	-Live observation using a 5-level scale of the number of hands and fingers used and whether visual or kinesthetic feedback was used	-

Table 2 (continued)

Author (year)/ language	Typing tasks employed				Typing measures				
					Product		Process		Student perceptions
	Alphabet writing	Writing to dictation	Copywriting	Compositional writing	Speed	Accuracy	Efficiency	Technique	
[26] Weigelt-Marom and Weintraub (2018)[a,b]	-	-	-Paragraph (3 min)	-	-Characters per min	-	-	-	-
[27] Rosenberg-Adler and Weintraub (2020)[a,b]	-	-	-Not specified (6 min)	-	-Characters per min	-	-	-Live observation using a 6-level scale of the number of hands and fingers used and whether visual or kinesthetic feedback was used	-
[28••] Rosenberg-Adler and Weintraub (2020)	-	-	-Not specified	-	-Characters per min	-	-	-	-Rating of pain or discomfort using a 10-point scale on completion of typing task

[a]Study included a comparison between handwriting and typing speed for the developmental disorder group

[b]Study included comparison of typing in the developmental disorder group(s) to typically developing (TD) peers

Copywriting

This involves visual tracking of the text to be copied. Studies have required participants to copy a word, a sentence, or a paragraph. For example, Jiménez et al.'s [21] study included copying ten words. Others used the standard sentence, 'The quick brown fox jumps over the lazy dog'. In Klein et al.'s [14] study, this sentence was copied repeatedly for 2 min. Some studies involved copying extended text; for example Khoury-Shaheen [23] asked participants to copy a paragraph in Arabic for 5 min. Foxworth et al. [20•] also included paragraph copying but this was in English and for only 2 min. All five studies in the older age group included a copying task in Hebrew. This ranged from individual sentences to a 3- and 6-min copying task.

Compositional Writing

This involves higher-level cognitive and linguistic skills, deciding what to write, choosing words, and working out sentence structure and spelling. Jiménez et al. [21] asked participants to compose two sentences. In Klein et al.'s [14] study, participants were required to generate a story within 5 min; no further information was provided on the topic. Berninger et al. [19] asked their participants to 'Write a good sentence that begins with the word *reading*' and also to write for 10 min to 'Explain what a robot is and what it does to someone who has never seen one or used one'.

Product

The selected studies also varied in how the final typed product was assessed in terms of speed and accuracy. Some studies measured the number of letters/characters or words produced in the allotted time to give the speed of typing skill. Some also measured accuracy in terms of the proportion of accurately typed letters/characters. When dictation and copying tasks were used, this was compared directly with the text provided. Some studies also measured the number of omitted letters/characters. Foxworth et al. [20•] considered both speed and accuracy together by measuring the number of correct words written when copying a paragraph minus the number of errors.

Process

Various methods can be used to record the way in which people type. A popular method in typing research is to employ software to record all keystrokes made and the time intervals between each one. This allows for deletions and revisions to be recorded, which are not visible in the final product. For example, Abecassis et al. [24••] used keystroke logging software to calculate the number of keystrokes per character to provide a measure of typing efficiency. They also measured error correction efficiency and used an overall measure of accuracy (the percentage of correctly typed characters in the process of typing).

Another aspect of the process of typing is the general technique used. This refers to the posture and positioning of the fingers and thumbs on each hand and the type and extent of visual monitoring. For example, Klein et al. [14] observed each child's typing behaviour, describing how many fingers were used, and the extent to which they relied on visual observation of finger position on the keyboard. In their study of young adults, Rosenberg-Adler and Weintraub [27] also observed typing technique, using six descriptive categories relating to the number of fingers used and the degree of visual monitoring. Abecassis et al. [24••] recorded typing technique using two cameras, one to capture the number of fingers used (including thumbs) and one to capture eye movements to gauge the proportion of time spent looking at the screen.

Perceptions

Understanding the writer's perceptions of their own experience is an important aspect of assessment, particularly for goal setting and intervention planning [29]. Foxworth et al. [20•] used a brief student survey, asking three questions: (1) Do you consider yourself a strong typist?; (2) given the opportunity to write or type an essay, which method do you prefer?; and (3) why do you prefer this method? Rosenberg-Adler and Weintraub [28••] asked their participants to rate the degree of pain or discomfort experienced when typing on a scale from zero (no pain/ discomfort) to ten (unbearable pain).

In the following two sections, we review findings from the selected studies in relation to two main aspects. Firstly, we consider how typing performance compares to handwriting in students with developmental disorders. Secondly, the focus is on a comparison between typing performance in those with developmental disorders compared to typically developing (TD) peers.

Typing Compared to Handwriting in Developmental Disorders

When considering how to best support an individual with handwriting difficulties, it is important to know how their handwriting skill compares to their typing skill. This may help to determine whether typing might be a useful alternative mode of production. Of the studies in Table 2, seven included a direct comparison of handwriting and typing performance in the group(s) with developmental disorders. The only study to report a significant advantage for typing across

most measures investigated was Beers et al.'s [18] study of 9–14 year olds. Across all of the SLD groups, more alphabet letters were produced from memory when typing compared to handwriting. There were also longer texts when typing on a 10-min narrative writing task.

The remaining six studies of both younger and older ages found typing slower than handwriting across a range of measures. In the younger groups, Klein et al. [14] found fewer letters per minute for sentence copying when typing and similar results for their compositional writing task. Similar results were reported by Khoury-Shaheen [23] on a paragraph copying task. Berninger et al. [19] reported no significant difference in typing versus handwriting in the alphabet writing task but longer times to compose a sentence and essay when typing. Jung et al. [22] found that typing words was slower than handwriting across groups (with no group difference).

In the older groups, Weigelt-Marom and Weintraub [26] reported typing was slower than handwriting overall for both groups at their pre-test and post-test, although this difference was not statistically significant within each of the groups. However, at a 3-month follow-up after intervention, typing was faster for both groups and for the SLD group, typing speed was significantly faster than handwriting. Rosenberg-Adler and Weintraub [27] studied 50 students with SLD and handwriting difficulties. They found 24% were also slow at typing (falling below 1.5 SDs of the mean of the TD group on typing speed).

In summary, for those studies that compared typing to handwriting skill, most showed an advantage for handwriting across the various tasks and measures investigated. Where interventions were implemented to improve typing skill, these showed that typing could become faster than handwriting [14, 25, 26].

Typing in Developmental Disorders Compared to TD Peers

Another important issue regarding typing in those with developmental disorders is whether their performance is different to same-age peers. Eleven of the studies reviewed report on typing performance relative to a typically developing (TD) comparison peer group (see Table 1). We report first on the group findings relating to the speed and accuracy of typing across the different tasks, followed by the typing process, and finally, student perceptions of typing (see Table 2).

Product

First considering the younger age groups, Khoury-Shaheen's [23] study of a 'probable' DCD group was significantly slower than the TD group when typing to copy a paragraph but there were no significant group differences in typing accuracy. Berninger et al. [19] do not directly report group differences on typing speed but analyses of the data presented show that mean amounts written are lower in their LD group on all three typing tasks employed. Bisschop et al. [17] report that their three groups with writing difficulties were significantly less fluent in typing the alphabet than TD peers. When looking at the groups separately, this difference was not significant for the poor handwriters but the poor spellers and the mixed group produced significantly fewer letters than TD peers (with no significant difference between these two groups). Jiménez et al. [21] used a wider range of typing tasks, collapsed into broader factor scores (sentence production, visual-orthographic processing, and phonological processing). Using these factor scores, they report similar findings to Bisschop et al. [17]: poor spellers performed significantly more poorly than the TD group in all three factors, while for the group with poor handwriting, there were no significant differences when compared to the TD group.

Using smaller groups with full diagnostic assessment (dyslexia and dysgraphia) compared with TD peers, Beers et al. [18] report significant group effects on words produced per minute and the percent of incorrectly spelled words on the 10-min narrative writing task. The dyslexia group wrote significantly fewer words per minute and fewer words overall than the TD group. Both the dyslexia and dysgraphia groups had significantly more spelling errors than the TD group (with no significant differences between the two diagnostic groups). Foxworth et al.'s [20•] group of six students with language-based learning disorder typed significantly fewer words overall in a text copying task and fewer correct words per minute than peers without disabilities. Jung et al. [22] found that the groups with dyslexia were slower in the typing to dictation task and made less self-corrections and were less accurate, although their accuracy rate was similar to the TD controls for pseudowords.

In the older age groups, Abecassis et al. [24••] reported that their SLD group typed significantly slower and less accurately than the TD group on the copying task. Weigelt-Marom and Weintraub [25, 26] reported typing was slower for the SLD group compared to peers at their pre-test and 3-month follow-up post-typing intervention. Rosenberg-Adler and Weintraub [27] identified 12 students in their study with both slow typing and handwriting difficulties and 38 with handwriting difficulties only. Of the 12 with combined difficulties, their typing speed was significantly slower than the handwriting difficulties only group and the TD group (with no significant difference between the latter).

Process

Abecassis et al. [24••] reported that their SLD group had a significantly lower overall accuracy measure compared to the TD group. There were no significant group differences in typing efficiency or in error-correction efficiency measures. They also report a similar number of fingers used in typing

compared to the TD group but a significantly lower percentage of screen gaze time. Using a system of six categories, Rosenberg-Adler and Weintraub [27] found the majority of students in their two SLD groups typed using two to four fingers in each hand. They also report that in the 12 students identified with slow typing all relied on visual rather than kinesthetic feedback of the fingers/hands.

Perceptions

Foxworth et al. [20•] reported results for their group of six students with learning disorder. Three considered themselves strong typists and three did not. Five preferred typing over writing, stating that typing was either 'easier' or 'quicker' than handwriting. In the one study where students rated pain levels [28••], these were lower (or about the same) when typing compared to handwriting (although some still experienced high levels of pain when typing).

In summary, these studies demonstrate that typing skill is less well developed in those with developmental disorders compared to their TD peer group. Typing speed has been shown to be slower across a range of tasks, and, where measured, some (but not all) studies also show reduced accuracy. In the few studies that report on typing technique, they indicate that those with developmental disorders use similar hand/finger patterns for typing but suggest there is greater reliance on visual feedback for placement of the fingers compared to TD peers. In the one study that considered student preferences, most reported a preference for typing over handwriting in students with learning disorder.

Conclusions

From a progressively earlier age, typing has now become an important skill to aid progress in education, the workplace, and everyday life settings. For students with DCD and SLD, typing is often recommended as a useful accommodation [28••]. Although typing may offer advantages over handwriting, the model presented above shows the complex range of language, cognitive, perceptual, and motor components, which must be regulated by attentional systems for the performance of typing tasks.

Although typing skill generally has been well studied, this review highlights the paucity of research related to DCD and SLD. We found only 11 relevant studies published within the last 7 years and also included two studies published earlier, although the likely changes in context and typing skills over time must be acknowledged. Taken together, the 13 studies (published between 2008 and 2024) cover a range of developmental disorders, although diagnosed and assessed in different ways. Furthermore, the work spans different age groups, languages, countries, and educational systems. The set of studies also varies in the way in which typing skill has been assessed, using various writing tasks and different measures.

Despite the above differences and potentially complicating issues, there is consistency in the findings across the reviewed studies. Overall, they indicate that in both the younger and older groups with developmental disorders, when typing, the writing is slower and often less accurate than when handwriting. In only one study with younger participants was there a reported advantage of typing over handwriting [18]. There is also consistency across this work showing that typing skill in those with developmental disorders is less well developed compared to TD peers. Individuals with developmental disorders are reported to have slower, less accurate typing, and they rely more on visual monitoring of the hands compared to same-age peers. Given the complex nature of typing performance outlined in Fig. 1, it is hardly surprising that students with DCD and SLD perform more poorly than peers. Depending on the nature and extent of their difficulty, they may struggle with the different components of typing. Co-occurring disorders, which are common in these groups, may also make typing more challenging.

Despite the reports of overall poorer performance, when asked about their own typing skill, some students with learning disorders report that typing is faster and easier than handwriting [20•]. Furthermore, in the one study where students rated pain levels [28••], these were lower (or about the same) when typing compared to handwriting. Although not the focus of this review, in the three studies that evaluated typing intervention programmes, these were reported as effective, leading to increased skill in those with developmental disorders, both at younger [14] and older [25, 26] ages.

Although we report some general consistencies in the findings, it is important to note the variation within studies. Some report individual differences in their results within groups [14, 19] and others report differences between diagnostic groups [18, 27]. This variation reinforces the importance of consideration of individual needs, particularly in practical settings. Rosenberg-Adler and Weintraub [28••] present a useful example of a protocol for simulating different writing accommodations (extra time and/or typing) for those with handwriting difficulties. This helps to select the most appropriate support for an individual student. Others have recommended that, to aid decision-making regarding accommodations and intervention, it is important not only to assess typing and handwriting skill but also to consider the broader needs of the individual and the context in which they are working [6, 30].

This review illustrates the range of tasks used in typing research. Some studies use only one task, while others include more than one, which in some cases are part of a

test battery designed for typing in Spanish [31], Hebrew [32], or Arabic [33]. Khoury-Shaheen and Weintraub [34] suggest that a 'uniform' test could be used across languages, but they only promote dictation and copying tasks. A wider range of tasks than this might be useful, as tasks with varying demands give a broader understanding of typing performance.

Future Directions

It is clear that further research is needed to increase understanding of typing skill both within and across different developmental disorders. A combination of methods will help examine the three important aspects of typing identified in this review—the product, process, and student perceptions. A particular challenge for research in this area will be the continued rapid speed of developments both in technology (computer hardware and software) and whether and how typing is taught in schools.

Further work is needed to develop assessment tools that will help practitioners identify and support those with typing difficulties. In contrast to some tools used in research, practical assessments need to be easy to administer and interpret. Test norms need to be up to date, local, and relevant or adapted to the appropriate written language.

Improved knowledge about the nature of typing skill in those with developmental disorders will aid awareness and understanding of their difficulties. The development of assessment tools suitable for different ages and languages will aid identification, the implementation of accommodations, and design of appropriate interventions. This will help support those with difficulties to achieve their potential in writing.

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Compliance with Ethical Standards

Competing interests The authors declare no competing interests.

Conflict of Interest Anna L. Barnett declares that she receives royalties from the publisher, Pearson Clinical, on the sales of handwriting assessment tools. Nichola Stuart declares no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- •• Of major importance

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