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SHORT REPORT

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Handwriting difficulties in children with dyslexia: Poorer legibility in dictation and alphabet tasks, slowness in the alphabet task

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Several studies have shown that children with dyslexia (DYS), in addition to their reading and spelling deficits, encounter handwriting difficulties that are still poorly understood in terms of their nature and origin. The present study aimed to better understand the handwriting difficulties of children with DYS by comparing their handwriting quality and speed in two tasks, a dictation task and an alphabet task, which required fewer spelling skills than the dictation task. Twenty-nine French-speaking children ($M_{age} = 9.5$ years) participated in the study, including 18 children with DYS and nine typically developing (TD) children matched on chronological age. The children performed control tasks, a dictation task with words varying in graphic and orthographic complexity and an alphabet writing task. Accuracy, handwriting quality (legibility), and fluency (speed, writing and pause time) were carefully measured using a digital tablet. GLMM analysis and *t* tests showed that children with DYS made more aesthetic errors (handwriting quality) in both the dictation and alphabet task than TD children. They also wrote more slowly than TD children in the alphabet task (speed, pause time). These findings suggest that children with DYS present handwriting difficulties, even in a simple alphabet task. In dictation, they seem to favour speed at the expense of handwriting quality.

KEYWORDS
alphabet Task, dictation Task, dyslexia, handwriting, handwriting quality and speed

Practitioner Points

- Children with dyslexia present poorer handwriting quality in both dictation and alphabet tasks: they made more aesthetic errors.
- The handwriting speed of children with dyslexia was slower in the alphabet task: they wrote more slowly and made longer pauses.

1 | INTRODUCTION

Writing is a complex activity involving many processes that a child must learn to use simultaneously (Lambert & Espéret, 2002). It represents a challenge at the beginning of a child's schooling. To write, children must learn to control handwriting (graphomotor gesture) and master spelling, which should be automated in parallel. During this complex activity, lower-level motor perceptual processes (motor planning and execution) and higher-level cognitive processes (spelling) interact continuously (Purcell et al., 2011; Van, 1991). The parallel management of these two processes is further complicated for children with dyslexia (DYS). Indeed, it is well known that these children face difficulties in spelling (Angelelli et al., 2010), at the sublexical, lexical and grammatical levels (DSM-5, American Psychiatric Association, 2013; Egan & Pring, 2004; Gosse & Van Reybroeck, 2020; Van Reybroeck, 2020). In the meantime, there is growing evidence that children with DYS also demonstrate handwriting difficulties. According to Di Brina et al. (2018), at least 50% of children with DYS show handwriting difficulties. In the literature, handwriting is often assessed through two aspects: fluency (speed or pauses) and quality of writing, which refers to the legibility of handwriting. Regarding fluency, Berninger et al. (2008) showed that DYS children write more slowly, whereas Sumner et al. (2013) demonstrated that they make more pauses while writing at the same speed. Regarding quality (legibility), Martlew (1992), on the other hand, observed poorer legibility among these children. In sum, difficulties have been observed either in fluency or in the quality of handwriting (legibility), but no clear insight has been provided. Although the existence of a spelling disorder in children with DYS has been largely studied in the literature, the nature and origin of their handwriting difficulties are still debated. The present experiment investigated the handwriting difficulties of children with DYS by comparing their performance in two tasks: an alphabet writing task and a dictation task. Several hypotheses have been put forward in the literature concerning the handwriting difficulties of children with DYS. The main question that emerges is whether they face difficulties in handwriting as a consequence of their difficulties in spelling or whether they have additional difficulties in graphomotor gesture as such (for a synthesis, Van Reybroeck & Gosse, 2023).

1.1 | Handwriting difficulties in DYS as a consequence of their spelling skills

On the one hand, since spelling and handwriting interact, difficulty in spelling may impact the handwriting process (Gosse et al., 2022). Studies have shown that the spelling difficulties experienced by children with DYS limit their handwriting production (Berninger et al., 2008), impacting the fluency and duration of movements and the quality and quantity of written words (Kandel et al., 2017). Sumner et al. (2013) showed longer writing times in children with DYS because they paused more during their productions. On alphabet letter writing and text writing tasks, their

handwriting speed was comparable to that of children of the same age. However, a significant difference was found in the number of pauses: children with DYS had longer and more regular pauses than typically developing (TD) age-matched children. Sumner et al. (2013) suggested that pauses in text composition were related to spelling difficulties and the high cognitive load required to write text. Later, Sumner et al. (2014) proposed a different task of copying sentences that did not involve the cognitive resources required to write a text. The results showed a comparable speed of execution between children with and without DYS, but children with DYS made more pauses within words. Suárez-Coalla et al. (2020) also demonstrated the influence of spelling deficits in DYS on handwriting processes. They proposed a sentence dictation task in which the last word varied in lexical frequency and orthographic consistency. They observed that children with DYS paused longer than control children when writing the article preceding a low-frequency noun and when writing the first syllable of a low-frequency noun. They presented evidence showcasing how spelling deficits affect handwriting fluency in children with DYS.

1.2 | Difficulties in graphomotor gesture

On the other hand, according to Nicolson and Fawcett (1990), the poor handwriting of children with DYS could be explained by additional motor difficulties. According to their theoretical framework, these motor difficulties may arise from a more general cerebellar deficit affecting motor automation, planning and coordination (Nicolson & Fawcett, 1990). These difficulties could lead to poorer motor coordination, which could explain the handwriting difficulties experienced by these children. Indeed, motor difficulties could make handwriting slower (Rose, 2009). However, although motor difficulties are sometimes found in children with DYS, only a small percentage of these children have such difficulties (Iversen et al., 2005; Ramus, 2003), and they are not as marked as in children with developmental coordination disorder (Di Brina et al., 2018). Gosse and Van Reybroeck (2020) and Van Reybroeck (2020) investigated the impact of the graphic and orthographic complexity of words in a word dictation task to evaluate the hypothesised presence of a handwriting deficit in children with DYS. The study's novelty was that it compared words that contained difficult-to-write segments and words with easy-to-write segments while controlling for spelling difficulty. Although the results showed no difference in handwriting quality as a whole (i.e., group comparison), 9-year-old children with DYS appeared to be more impacted by the graphic complexity of words than TD children matched for chronological age (9 years old) or spelling level (7 years old). Indeed, children with DYS had poorer handwriting legibility when the words contained segments that were more difficult to handwrite. These findings suggested that handwriting legibility problems in children with DYS arise when graphomotor costs are increased, without being related to spelling deficits. Alamargot et al. (2020) also provided evidence for a deficit in handwriting by asking children with DYS to write the alphabet and their first names, which required less spelling knowledge than dictation task. They found that compared with TD children, children with DYS made more short pauses in both tasks, while they produced more illegible letters. A recent neuroimaging study (Gosse & Van Reybroeck, 2020; Van Reybroeck, 2020) provided further evidence of graphomotor difficulties in children with DYS based on task-fMRI data. During handwriting, children with DYS exhibited significantly lower activation in the writing network than their peers. Specifically, they observed dysfunction in areas dedicated to handwriting (and not in the regions involved in general motor activity) situated in the right cerebellar lobule VI. These regions are recognised for their essential role in motor control for complex finger movements.

In summary, the literature provides arguments for difficulties in handwriting as a consequence of spelling deficits, as well as for graphomotor difficulties. However, there is a lack of experimental support for understanding handwriting deficits in children with DYS. To the best of our knowledge, no study has ever evaluated the writing skills of children with DYS by assessing their handwriting quality (legibility) and fluency (speed, pauses and writing time), comparing an alphabet writing task and a dictation task involving different spelling processes, to allow a more comprehensible understanding of their actual difficulties.

The main objective of this experiment was to better understand the nature and the origin of handwriting difficulties in children with DYS by examining their performance in two contrasting tasks: an alphabet writing task, which required few spelling skills, and a dictation task, which required more spelling skills. In the dictation task, words were

either graphically simple or graphically complex to handwrite and either orthographically simple or orthographically complex (cf. Gosse & Van Reybroeck, 2020; Van Reybroeck, 2020). Children completed both tasks on a digital tablet that provided information on handwriting speed and pauses. Handwriting quality was evaluated based on graphic criteria. Children with DYS were compared with TD children matched on chronological age. Our research question was the following: Do children with DYS have handwriting difficulties (quality and/or speed) to the same extent in alphabet and dictation tasks compared with TD children? According to the hypothesis of difficulties in handwriting related to spelling deficits (Sumner et al., 2013), we expected children with DYS to show more handwriting difficulties in the dictation task than in the alphabet task. According to the hypothesis of handwriting deficits (Alamargot et al., 2020; Van Reybroeck, 2020), we expected children with DYS to show handwriting difficulties (quality and speed) in both the dictation and alphabet tasks compared with TD children.

2 | METHOD

2.1 | Participants

The experiment was carried out with respect to the ethical standards of the Declaration of Helsinki and was approved by the Ethics Committee of the University Hospital of Anonymous (number Anonymous). Participants were from six French-speaking primary schools in Anonymous with a middle socioeconomic status. Parent meetings were organised in these schools to explain the project. Parents and their children participating in the study completed a written informed consent. Inclusion (native French-speaking, aged between 7 and 10 years old) and exclusion criteria (sensory deficit, history of brain damage, learning disability other than DYS such as developmental coordination disorder or developmental language disorder) were determined before data collection. Twenty-seven primary school children participated in the experiment, which was interrupted by the COVID-19 pandemic in March 2020 ($M_{age} = 9.5$ years, SD = 1.25, 18 boys). Eighteen children with DYS diagnosed by a speech and language therapist and nine TD children were included. All children with DYS performed below two standard deviations on at least one of the reading or spelling standardised tasks in this experiment. As shown in Table 1, there were no differences between the groups in nonverbal intelligence (WISC-IV, Wechsler, 2005), vocabulary (Peabody, Dunn et al., 1993), handwriting speed or manual dexterity (Box and Blocks test, Mathiowetz et al., 1985). However, children with DYS showed poorer performance on the reading and spelling tasks (BALE; Jacquier-Roux et al., 2010), as well as poorer handwriting quality (BHK [Concise evaluation scale for children handwriting]; Charles et al., 2004), than the TD children.

2.2 | Materials and procedure

The data were collected by three experimenters in the children's schools. Speed and time measures for the dictation and alphabet tasks (created for the study) were recorded through a digital tablet, a digital pen (Wacom Intuos Pro Medium and Wacom Inking Pen), and a computer, and data were extracted using a handwriting analysis tool (Gosse et al., 2018). In the word dictation task, 10 words were irregular, 20 words were regular. To better understand the influence of handwriting, words were selected based on their graphic complexity index (Gosse et al., 2018), which measures difficult-to-write segments such as angles in letters. The graphic complexity index indicates whether words contain graphically complex or simple to handwrite segments. Based on an algorithm, Gosse et al. (2018) have determined the different types of graphic segments included in letters, such as angles, turnbacks, and curves in X or Y. Their experiment then identified the graphic segments that caused aesthetic errors and slowdowns in second grade children. On this basis, the graphic complexity index indicates whether words contain complex segments to handwrite, such as angles, which lead to reduced fluency. In the present experiment, half of the words ($n = 15$) were graphically complex to write (index above 19.4, percentile 75), and the other half ($n = 15$) were graphically simple to write (index below 15.6, percentile 25).

TABLE 1 Characteristics of the participants on cognitive and literacy tasks.

	Dyslexia (DYS)		Typically developing (TD)				
	N = 18		*N* = 9				
	(13 boys)		(5 boys)		Group comparison		
Measures	*M*	SD	*M*	SD	*t*	*p*	Equivalence
Age in years	9.61	1.24	9.46	1.34	0.977	0.338	DYS = TD
Receptive vocabulary	1.14	0.62	1.33	1.11	−0.448	0.665	DYS = TD
Nonverbal reasoning	0.25	0.66	0.29	0.71	−0.138	0.891	DYS = TD
Word reading accuracy							
Raw (/120)	84.61	16.06	100.56	14.58	−2.503	0.019	DYS < TD
Standardised	−1.35	1.08	−0.05	0.63	−3.155	0.004	DYS < TD
Word reading speed							
Raw (in seconds)	214.44	106.36	150.89	54.13	1.676	0.106	DYS = TD
Standardised	−0.55	0.96	0.44	0.46	−2.742	0.011	DYS < TD
Word spelling							
Raw (/50)	27.71	9.99	40.38	9.42	−2.917	0.009	DYS < TD
Standardised	−2.35	1.42	−0.03	0.71	−4.603	0.000	DYS < TD
Handwriting quality							
Raw[a]	14.78	6.18	8.22	3.99	2.881	0.008	DYS < TD
Standardised	0.78	1.77	−0.88	0.96	2.491	0.020	DYS < TD
Handwriting speed							
Raw	195.00	69.87	216.56	75.25	−0.737	0.468	DYS = TD
Standardised	−0.22	0.81	0.13	0.75	−1.065	0.297	DYS = TD
Manual dexterity							
Raw	54.59	8.61	55.88	8.18	−0.354	0.727	DYS = TD
Standardised	−0.09	1.36	0.18	1.13	−0.505	0.618	DYS = TD

[a]For handwriting legibility, high raw score indicates poor handwriting.

2.3 | Measures

2.3.1 | Spelling in the word dictation task

Children received one point when the word was spelled correctly and 0 points when the word was misspelled.

2.3.2 | Knowledge of the alphabet

In the alphabet task, children were asked to write the letters of the alphabet in order in cursive writing. This task required accessing the letters' allographs in memory and retrieving the alphabetical sequence of the letters. The score was determined based on the order and accuracy of the letters, measured by deducting one point for the omission, substitution, or permutation of letters (inspired by Berninger et al., 2008; Graham et al., 2000; Sumner et al., 2013).

2.3.3 | Handwriting quality in dictation and alphabet tasks

Regarding the dictation task, handwriting quality was evaluated by five graphic criteria inspired by the BHK scale (Charles et al., 2004), rated in terms of correct (zero points) or incorrect in the case of the presence of graphic abnormalities (one point; Gosse et al., 2018). A word with a score of 0 represented good handwriting quality, while a score of 1 to 5 represented poor handwriting quality. The five criteria were as follows: (1) distortion of a letter: the letter was distorted from its usual production; (2) inconsistent letter size: variations in the relative height of small letters; (3) inconsistent relative height: incorrect relative height of small letters to tall letters; (4) letter correction: the letter was retouched or rewritten; and (5) poor alignment of letters. Percentages of agreement among the three scorers revealed high agreement (intraclass correlation: $r = 0.821$, $p < 0.001$).

For the alphabet task, handwriting quality was assessed by calculating the number of correctly traced letters. The final score corresponded to the proportion of correctly traced letters divided by the knowledge score. A high score indicated good performance.

2.3.4 | Handwriting fluency in dictation and alphabet tasks

Word production times, measured in milliseconds, were extracted from the tablets. The tablets provided three times: writing speed, writing time and pause time. Writing speed referred to the distance covered while the pen was on the sheet of paper (cm/s). A low value indicated slow handwriting, while a high value indicated fast handwriting. Writing time referred to the time spent writing the words, while pause time referred to pauses inside the words or in air phases (i.e., pen lifts).

2.4 | Data analysis

Statistical analyses were run using SPSS Statistics 25. Preliminary analyses revealed no distributional problems for the alphabet task (all Sk <3 and Ku < 10; Kline, 2016), while for the dictation task, writing time and pause times were transformed (LN transformation) to meet the normality assumption of parametric procedures. Descriptive statistics are presented in Table 2. Correlations between the measures are provided in Tables 3 and 4 for each group (DYS, TD). Generalised linear mixed models (GLMMs) for the dictation task and t tests for the alphabet task were used to answer our research question. GLMM analyses were run to consider the variability induced by children and that induced by the Items. The *t*-tests were run for all alphabet task dependent variables with Group (DYS, TD) as a factor. GLMM analyses were run for all dictation task dependent variables with Group (DYS, TD), Word graphic complexity (simple and complex) and word orthographic complexity (regular and irregular) entered as fixed factors. One random factor was included in the model for participants, allowing us to consider the interdependence between our observations due to repeated measures.

3 | RESULTS

3.1 | Correlations

As can be seen in Table 3, there is a robust correlation in TD children between spelling accuracy and writing speed, as well as between handwriting quality and speed and between handwriting quality and spelling accuracy. The alphabet task is not correlated with manual dexterity.

TABLE 2 Descriptive statistics of the dependent variables by group and by condition.

	Dyslexia (DYS)								Typically developing (TD)							
	GC simple		GC complex		OC simple		OC complex		GC simple		GC complex		OC simple		OC complex	
Task	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Dictation task																
Spelling	0.44	0.08	0.43	0.08	0.60	0.08	0.28	0.07	0.78	0.08	0.83	0.07	0.91	0.04	0.64	0.12
Handwriting quality	1.02	0.12	1.31	0.12	1.14	0.11	1.19	0.12	0.43	0.17	1.02	0.17	0.69	0.16	0.75	0.17
Writing speed	1.64	0.12	1.59	0.12	1.60	0.12	1.64	0.12	1.72	0.16	1.68	0.16	1.66	0.16	1.75	0.16
Writing time	4.08	0.25	4.95	0.25	4.38	2.05	4.86	2.69	3.74	0.36	4.82	0.36	4.27	1.42	4.31	1.53
Pause time	1.34	0.13	1.11	0.13	1.06	1.46	1.58	2.15	1.11	0.18	1.03	0.18	0.92	0.92	1.36	2.23

	DYS		TD	
	M	SD	*M*	SD
Alphabet task				
Knowledge of alphabet	24.56	3.01	25.89	0.33
Handwriting quality	0.80	0.19	0.93	0.08
Writing speed	1.22	0.30	1.60	0.47
Writing time	38.98	10.60	32.71	10.56
Pause time	65.40	43.20	32.94	14.49

Abbreviations: GC, graphic complexity; OC, orthographic complexity.

TABLE 3 Correlations between measures among children with dyslexia.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Manual dexterity (box and blocks)	–												
2. Handwriting quality (BHK)	−036	–											
3. Handwriting speed (BHK)	0.106	0.069	–										
4. Spelling accuracy (BALE)	−0.008	−0.308	0.785**	–									
5. Dictation task: spelling accuracy	0.029	−0.025	0.750**	0.949**	–								
6. Dictation task: handwriting quality	−0.021	0.574*	−0.467	−0.833**	−0.371	–							
7. Dictation task: writing speed	−0.228	0.537*	0.31	0.014	−0.023	0.111	–						
8. Dictation task: writing time	−0.254	−0.179	−0.603**	−0.455	−0.328	0.226	−0.499*	–					
9. Dictation task: pause time	−0.008	0.191	−0.558*	−0.540*	−0.327	0.531*	−0.144	0.470*	–				
10. Alphabet task: knowledge of the alphabet	−0.157	−0.486*	0.094	0.453	0.301	−0.396	−0.612**	0.232	−0.345	–			
11. Alphabet task: handwriting quality	−0.042	−0.315	0.337	0.395	0.24	−0.603**	−0.199	0.046	−0.258	0.609**	–		
12. Alphabet task: writing speed	−0.098	0.44	−0.097	−0.028	−0.20	0.029	0.381	0.054	0.125	−0.063	0.235	–	
13. Alphabet task: writing time	0.148	−0.36	−0.189	−0.427	−0.24	0.121	−0.276	0.416	0.242	0.026	0.036	−0.502*	–
14. Dictation task: pause time	0.16	0.086	−0.599**	−0.670**	−506*	0.222	−0.141	0.532*	0.561*	−0.406	−0.157	0.147	0.36

Note: For the interpretation of the correlations involving handwriting quality scores (BHK and dictation task): a higher score refers to a higher number of graphical errors.
*$p < 0.05$; **$p < 0.01$.

TABLE 4 Correlations between measures among typically developing (TD) children.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Manual dexterity (box and blocks)	–												
2. Handwriting quality (BHK)	−0.036	–											
3. Handwriting speed (BHK)	0.447	−0.325	–										
4. Spelling accuracy (BALE)	0.149	−0.418	0.841**	–									
5. Dictation task: spelling accuracy	0.063	−0.307	0.791*	0.960**	–								
6. Dictation task: handwriting quality	−0.368	0.375	−0.930**	−0.884**	−0.846**	–							
7. Dictation task: speed	0.696	0.052	0.296	−0.174	−0.192	−0.023	–						
8. Dictation task: writing time	−0.373	0.372	−0.403	0.023	−0.016	0.117	−0.790*	–					
9. Dictation task: pause time	0.047	0.404	−0.233	−0.218	−0.159	0.036	−0.448	0.754*	–				
10. Alphabet task: knowledge of the alphabet	0.093	0.397	0.521	0.531	0.694*	−0.584	−0.152	0.254	0.27	–			
11. Alphabet task: handwriting quality	0.019	−0.574	−0.124	0.393	0.213	−0.088	−0.264	0.156	−0.085	−0.149	–		
12. Alphabet task: speed	0.68	−0.515	0.677*	0.575	0.566	−0.548	0.536	−0.683*	−0.568	0.16	0.327	–	
13. Alphabet task: writing time	−0.205	0.575	−0.388	−0.509	−0.538	0.286	−0.067	0.419	0.446	−0.014	−0.362	−0.761*	–
14. Dictation task: pause time	−0.357	0.143	−0.63	−0.533	−0.646	0.472	−0.315	0.527	0.371	−0.525	0.008	−0.788*	0.730*

Note: For the interpretation of the correlations involving handwriting quality scores (BHK and dictation task): a higher score refers to a higher number of graphical errors.
*$p < 0.05$; **$p < 0.01$.

In children with DYS (see Table 4), a robust negative correlation exists between handwriting quality (dictation) and spelling accuracy. The better the handwriting quality (lower score), the better the spelling accuracy. Spelling accuracy (in both dictation task and BALE) is also strongly correlated with writing speed. The pause time in the alphabet and dictation tasks was negatively correlated with spelling accuracy (BALE). The alphabet task was not correlated with manual dexterity.

3.2 | Dictation task

Regarding the spelling score in the dictation task, the 2 × 2 × 2 GLMM analysis with Group [DYS, TD], graphic complexity [simple, complex], and orthographic complexity [regular, irregular] demonstrated a significant effect of Group ($p = 0.003$) The children with DYS ($M = 0.43$, SD = 0.07) produced more spelling mistakes than the TD children ($M = 0.81$, SD = 0.07). An effect of orthographic complexity was also demonstrated ($p < 0.001$, Table 5). Regular words ($M = 0.80$, SD = 0.05) were written more accurately than irregular words ($M = 0.45$, SD = 0.08). The analysis did not demonstrate any other significant effect, or interaction (see Table 5). Regarding handwriting quality, the analysis demonstrated a significant effect of Group ($p = 0.021$). The children with DYS ($M = 1.17$, SD = 0.11) produced more aesthetic errors than the TD children ($M = 0.72$, SD = 0.16). The analysis also showed a significant effect of Graphic complexity ($p < 0.001$). Children in both groups made more aesthetic errors on graphically complex words ($M = 1.17$, SD = 0.10) than graphically simple words ($M = 0.72$, SD = 0.10). An interaction between group and graphic complexity was also demonstrated ($p = 0.040$). Post-hoc analyses showed that children with DYS ($M = 1.02$, SD = 0.12) had a lower quality of handwriting for graphically simple words than TD children ($M = 0.43$, SD = 1.17) ($p = 0.004$). Regarding speed (cm/s), the 2 × 2 × 2 GLMM analysis did not demonstrate any significant effect of group, graphic complexity, orthographic complexity or interaction. Regarding writing time, the 2 × 2 × 2 GLMM analysis revealed a significant effect of the graphic complexity of words ($p < 0.001$), meaning that graphically complex words were written more slowly ($M = 0.66$, SD = 0.02) than graphically simple words ($M = 0.56$, SD = 0.02). The effects of group and orthographic complexity were not significant.

Regarding pause time, the analysis did not demonstrate any significant effect of group or graphic complexity, or interaction. However, an effect of orthographic complexity was demonstrated ($p < 0.001$). Pause times were longer for irregular words ($M = 1.45$, SD = 0.12) than for regular words ($M = 0.99$, SD = 0.10).

3.3 | Alphabet task

Regarding knowledge of the alphabet, the *t*-test did not reveal a significant effect of Group, showing that both groups had similar knowledge of the alphabet letters (see Table 6).

Regarding handwriting quality in the alphabet task, the analysis demonstrated a significant effect of Group ($p = 0.020$), meaning that the children with DYS ($M = 0.79$, SD = 0.19) made more aesthetic errors than the TD children ($M = 0.93$, SD = 0.81).

Regarding writing speed (cm/s), the analysis revealed a significant effect of Group ($p = 0.018$). The children with DYS ($M = 1.22$, SD = 0.30) wrote letters more slowly than the TD children ($M = 1.60$, SD = 0.47).

Regarding writing time, the analysis did not show any significant effect of Group.

Regarding pause time, the t test revealed a significant effect of Group ($p < 0.01$), meaning that the thinking times of the children with DYS ($M = 65.41$, SD = 43.21) were longer than those of the TD children ($M = 32.94$, SD = 14.50).

TABLE 5 Results for the generalised linear mixed models analyses in the dictation task.

	Spelling accuracy					Handwriting quality					Writing speed				
Fixed effects	***df1***	***df2***	***F***	***p***	***ηp2***	***df1***	***df2***	***F***	***p***	***ηp2***	***df1***	***df2***	***F***	***p***	***ηp2***
Group	1	801	8.867	0.003	0.247	1	802	5.320	0.021	0.137	1	802	0.160	0.689	
Graphic complexity	1	801	0.489	0.485		1	802	39.658	<0.001	0.138	1	802	2.329	0.127	
Orthographic complexity	1	801	54.607	<0.001	0.196	1	802	0.600	0.439		1	802	3.683	0.055	
Group × graphic complexity	1	801	0.765	0.383		1	802	4.228	0.040	0.011	1	802	0.026	0.873	
Group × orthographic complexity	1	801	1.008	0.316		1	802	0.007	0.935		1	802	0.922	0.337	
Orthographic complexity × graphic complexity	1	801	0.050	0.823		1	802	0.037	0.848		1	802	0.005	0.943	
Group × orthographic complexity × graphic complexity	1	801	0.671	0.413		1	802	3.352	0.067		1	802	0.108	0.743	
	Writing time					**Pause time**									
Group	1	802	0.111	0.739		1	781	0.014	0.905						
Graphic complexity	1	802	79.518	<0.001	0.173	1	781	0.431	0.512						
Orthographic complexity	1	802	1.949	0.163		1	781	13.956	<0.001	0.125					
Group × graphic complexity	1	802	1.065	0.302		1	781	0.301	0.583						
Group × orthographic complexity	1	802	2.199	0.139		1	781	0.397	0.529						
Orthographic complexity × graphic complexity	1	802	0.690	0.406		1	781	1.229	0.268						
Group × orthographic complexity × graphic complexity	1	802	0.479	0.489		1	781	1.396	0.238						

Note: For effect sizes, the partial eta squared *ηp2* were calculated within repeated measures ANOVAs.

TABLE 6 Results for *t*-test analyses in the alphabet task.

	t(25)	*p*	Group comparison
Knowledge of alphabet	−1.854	0.080	DYS = TD
Handwriting quality	−2.486	<0.05	DYS < TD; $d = 0.89$
Writing speed	−2.542	<0.05	DYS < TD; $d = 0.96$
Writing time	1.451	0.159	DYS = TD
Pauses time	2.880	<0.01	DYS < TD; $d = 1$

Note: Cohen's *d* are reported for effect sizes of significant differences between groups.
Abbreviations: DYS, dyslexia; TD, typically developing.

4 | DISCUSSION

The present experiment aimed to further understand handwriting difficulties in children with DYS. For this purpose, children with DYS and TD children performed dictation and alphabet tasks, and their spelling, handwriting quality, and handwriting speed were analysed. Our research question was whether children with DYS had handwriting difficulties to the same extent in dictation or alphabet tasks compared with TD children, with the latter requiring fewer spelling skills than the dictation task.

In the context of the hypothesis of handwriting difficulties, we expected children with DYS to show lower handwriting scores than TD children in both the dictation and alphabet tasks. Our findings mainly support this hypothesis. Indeed, for handwriting quality, children with DYS made more aesthetic errors in both the words from the dictation task and the alphabet letters compared with TD children. The effect size was larger for the alphabet task (Cohen's $d = 0.96$) than the dictation task (Cohen's $d = 0.11$). Regarding handwriting fluency, children with DYS also wrote more slowly in the alphabet task, with a substantial effect size. Our results align with those of Alamargot et al. (2020), who also showed difficulties in handwriting quality and speed in an alphabet task. The difficulties in the alphabet task were surprising, as it was a fairly simple task that the children learned in the first grade, at least 2 years earlier (i.e., the included children were at least in Grade 3).

Thus, regarding handwriting quality, children with DYS had more difficulty tracing the alphabet letters accurately, and they made more aesthetic errors on graphically simple words than TD children. This seems to indicate that their basic graphic motor patterns of letters are somewhat underspecified, which is consistent with the idea of handwriting difficulties in DYS. This raises the question of the possible causes of these handwriting difficulties. A first explanation would be that these difficulties are independent of their spelling impairment. One argument in favour of this would be that DYS children did not make more handwriting errors when words were irregular than when they were regular. A second explanation is that children with DYS may be subject to a Matthew effect because they avoid writing situations, preventing them for developing their handwriting skills like other children. A similar explanation would be that, given the cognitive overload at the start of learning to write (McCutchen, 2006), their spelling difficulties require a great deal of cognitive resources, which would hinder the proper automation of graphic motor patterns at the same time.

Regarding handwriting fluency, children with DYS wrote more slowly and made longer pauses in the alphabet task and not in dictation task, which could be interpreted as an argument in favour of handwriting difficulties separate from the spelling deficit. Indeed, their writing time for isolated letters was slower, even though this task required few spelling skills. This alphabet task correlated with handwriting quality and speed (not with manual dexterity) but also with spelling accuracy. However, one might think that the longer pauses could be related to difficulties in retrieving the sequences of letters (potentially related to children's phonological disorders, Snowling, 2000), although the letter sequence accuracy scores did not differ between the children. The longer pauses could be related to a lack of automatic retrieval of the sequence of letters.

In summary, the children with DYS showed lower handwriting quality in both the alphabet and dictation tasks, whereas they showed slower handwriting only in the alphabet task. Children with DYS had the same writing times (speed of execution, pauses) as TD children in the dictation task. These results agree with those of Sumner et al. (2013), who observed similar execution times in text writing and sentence copying tasks. Why do children with DYS write words at the same speed as TD children, even though they perform slower in the alphabet task? It is possible that when writing words, children compensate by trying to write faster to keep up with the writing pace of their classmates. They have created graphic-motor patterns that allow them to write words quickly or automatically, even if these patterns may be inaccurate or distorted. This is likely the case in reading, where children with DYS compensate for their difficulties by reading faster at the expense of quality because they make reading errors (Perfetti et al., 1979). Regarding writing, it can be hypothesised that the children also favour speed over handwriting quality.

One last difference between Sumner et al.'s (2013) results and ours is that they observed longer pauses between words in sentence and text writing tasks, while our results did not show longer pauses in word dictation. However, we proposed an isolated word dictation task in which we do not measure the pause times between words, only the pause times within words. It would be interesting to measure pauses between words in a future experiment.

This study presents some limitations that should guide future research. First, the sample size was reduced due to the closure of schools following the COVID-19 pandemic. A future study with a larger sample size would enable us to better characterise the difficulties of children with DYS, potentially by identifying subgroups of children. A second limitation concerns the comparison group of TD children. Indeed, it would have been interesting to propose a third group of TD children matched in written language skills. This group comparison composed of younger children could help identify if handwriting difficulties in DYS could be attributed to a Matthew effect due to lack of writing practice.

5 | CONCLUSION

In sum, our experiment demonstrated that children with DYS had poorer handwriting quality in both the alphabet and dictation tasks, while their graphomotor gesture were slower in the alphabet task than those of TD children. Considering that the alphabet task required fewer spelling skills, these results provide a new argument for handwriting difficulties in children with DYS, in addition to the spelling deficit. These results convey relevant implications regarding handwriting support that could be offered in therapies.

AUTHOR CONTRIBUTIONS

Marie Van Reybroeck and Claire Gosse contributed to the study's conception and design. Elise Van Heuverswyn and Claire Gosse performed material preparation and data collection. Marie Van Reybroeck conducted analysis. Elise Van Heuverwyn and Marie Van Reybroeck wrote the first draft of the manuscript. All authors reviewed and edited previous versions of the manuscript and read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author.

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