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Predictors of Handwriting in Adolescents and Adults with Down Syndrome

Eloïse Moy, Carole Tardif and Raphaele Tsao

Centre for Research in Psychology of Cognition, Language and Emotion, Aix-Marseille Université, Aix-en-Provence, France

ABSTRACT

Handwriting is a skill that is constantly used in schools and in the workplace – two environments that are targeted in French legislation passed in 2005 on the integration of people with disabilities. The aim of the present study was to determine the predictive factors for handwriting speed and quality in adolescents and adults with Down syndrome (DS), looking at chronological and developmental age, pen grasp and perceptual-motor processing, which are known to contribute to both the speed and quality of handwriting. Results yielded by simple linear and curvilinear analyses revealed that handwriting speed and quality are related to chronological age, developmental age and perceptual-motor processing. Moreover, multiple linear regressions showed that handwriting quality can be predicted by fine motor coordination. We discuss the influence of different factors on handwriting acquisition in individuals with DS, and the implications in terms of intervention programmes.

KEYWORDS

BHK test; Down syndrome; fine motricity; handwriting; NEPSY I; predictors; quality; speed

Introduction

Handwriting is a graphomotor tool that enables individuals to communicate and transcribe their thoughts and experiences (Ziviani & Wallen, 2006). Since the deinstitutionalisation movement began in the 1970s, many countries, including ones in Europe (2007 United Nations Convention on the Rights of Persons with Disabilities, UNCRPD) and North America (1990 Americans with Disabilities Act; 1982 Canadian Charter of Rights and Freedoms), have implemented a series of educational policies aimed at promoting the social and occupational integration of people with disabilities. This integration requires a wide range of social and cognitive skills, to which handwriting can be key. Handwriting ability therefore represents one of the prerequisites for achieving integration and participating fully in the community, both of which are important to people with disabilities.

Handwriting: Development and Predictors

Handwriting relies on coordination between the cognitive and linguistic mechanisms recruited in text production (semantics, syntax and orthography) and various

CONTACT Eloïse Moy eloise.moy@etu.univ-amu.fr

perceptual-motor processes dedicated to the programming and execution of movements (graphomotricity). In the present study, we focused on the motor function of handwriting, investigating the way in which movements are generated in order to form letter sequences. The development of handwriting occurs as a result not only of academic training but also of the maturing of the motor system, which allows children to execute the fine movements required to form letters (Auzias & de Ajuriaguerra, 1986). In typically developing children, the quality and speed of their handwriting improves rapidly between the ages of six and eight years (Karlsdottir & Stefansson, 2002). By around 10 years, their movements are more fluent and the writing on the page is more harmonious, owing to a combination of retroactive control, based on the massive use of sensory information (Chartrel & Vinter, 2004; Meulenbroek & Van Galen, 1988), and proactive control, reflecting the emergence of internal motor programming (Zesiger, Deonna, & Mayor, 2000).

There are many interindividual differences in the development and learning of handwriting, and researchers have put forward a whole set of competing factors to explain them, one of these being sex. Among both children and adults, women write faster and more legibly than men (Berwick & Winickoff, 1996; Hellinckx, Roeyers, & Van Waelvelde, 2013; Schneider, Murray, Shadduck, & Meyers, 2006). Handedness has not been found to cause any differences in handwriting between right-handed and left-handed adults, be it for speed (Auzias, 1970; Ziviani & Elkins, 1984), legibility (Groff, 1964) or the kinematic characteristics of handwriting movements (Meulenbroek & Van Galen, 1989). However, compared with their right-handed peers, left-handed children have a tendency to adopt an intermediate pen grasp, oscillating between an inverted and a non-inverted grasp (Athènes & Guiard, 1990). There is considerable variability in pen grasps, depending on the task, as Braswell, Rosengren, and Pierroutsakos (2007) showed with kindergarten children, particularly during a free drawing task. These authors found that three- to four-year olds who exhibited particular variability in pen grasp produced poorer quality shapes in a copying task. Grasp configurations differ from one individual to another, as well as from one task to another, and this could have an impact on handwriting performance. For instance, in Stevens' study (2008), 51% of adults wrote with a dynamic tripod grip and 20% with a lateral tripod. Compared with a lateral grasp, a dynamic tripod or quadrupod allowed adults to write faster during a three-min handwriting task.

Above and beyond age, sex and pen grasp, fine motor development plays an important part in handwriting acquisition. Fine motor coordination relates to the finger dexterity that allows for the separation and coordination of the fingers of one hand. Several studies have highlighted close correlations between finger dexterity and handwriting quality (Cornhill & Case-Smith, 1996; Van Hoorn, Maathuis, Peters, & Hadders-Algra, 2010). In Weintraub and Graham's study (2000), finger dexterity was found to be predictive of handwriting performance in 10-year olds. Handwriting develops in parallel with fine motor coordination, which improves noticeably between 9 and 12 years (Dorfberger, Adi-Japha, & Karni, 2009). To our knowledge, Feder et al.'s (2005) study is the only one where finger dexterity has been identified as a predictive factor for handwriting speed.

Like the motor control of fingers, visual perception has also been explored by researchers. However, very few studies have explored the links between visual perception and handwriting quality, and these have yielded contradictory results. Whereas Volman, van Schendel, and Jongmans (2006) and Feder et al. (2005) both uncovered significant relationships, other studies have failed to do so, be it among poor or proficient handwriters (Kaiser, Albaret, &

Doudin, 2009; Maeland, 1992; Malloy-Miller, Polatajko, & Anstett, 1995). It is worth pointing out that the former looked at children who had been born prematurely or had a coordination disorder.

Several studies have also sought to highlight links between handwriting quality and visuomotor integration, which is defined as the coordination of visual perception and finger and hand movements, essentially measured via the copying of geometric figures (Beery, Buktenica, & Beery, 2003). Whereas every study conducted among young children (aged four–seven years on average) has reported a link (Cornhill & Case-Smith, 1996; Daly, Kelley, & Krauss, 2003; Marr, Windsor, & Cermak, 2001), longitudinal studies suggest that this relationship dwindles with age (Kaiser et al., 2009; Karlsdottir & Stefansson, 2002). Regarding handwriting speed, results are also divergent, and vary according to the children's profile. Visuomotor performances are assumed solely to predict the results of slow writers (Tseng & Chow, 2000) and children in special educational needs (SEN) classes (Williams, Zolten, Rickert, Spence, & Ashcraft, 1993). Studies with unselected children have failed to find a relationship (Karlsdottir & Stefansson, 2002; Volman et al., 2006; Weintraub & Graham, 2000).

Behavioural Phenotype of Down Syndrome

Down syndrome (DS) is defined by the World Health Organization (1993) as a chromosomal abnormality caused by aneuploidy. Although the incidence of DS remains relatively stable (1 birth in 650–1,000) (Bittles, Bower, Hussain, & Glasson, 2007), the prevalence of DS has been on the increase, mainly owing to improved life expectancy. At the present time, there are estimated to be 350,000 individuals with DS in the United States, 30,000 in the United Kingdom and 32,000 in Spain (Rondal, 2010). Numerous studies have highlighted a behavioural phenotype, specific to DS. Visuomotor integration and social adaptation are relatively well preserved (Carlier & Ayoun, 2007; Dykens, Hodapp, & Finucane, 2000; Fidler, 2005; Hodapp, DesJardin, & Ricci, 2003), but cognitive and language deficits have been observed in many areas. Furthermore, available data point to considerable variability in cognitive development profiles (Carr & Carr, 1995; Couzens, Cuskelly, & Jobling, 2004; Tsao & Kindelberger, 2009). DS is also associated with deficits in the development of both gross and fine motor skills. Children with DS exhibit delayed acquisition of basic motor skills, such as postural control (Tudella, Pereira, Basso, & Savelsbergh, 2011), walking, reaching and grasping (Palisano et al., 2001). The movements of children with DS are also slower in terms of reaction and execution times, compared with those of typically developing children (Savelsbergh, van der Kamp, Ledebt, & Planinsek, 2000). The more precise a movement has to be, the slower it is (Hodges, Cunningham, Lyons, Kerr, & Elliott, 1995; Wuang, Wang, Huang, & Su, 2008).

Handwriting in DS

Very few handwriting studies have focused on the population with DS, although some research has produced evidence that the majority of people with DS are able to write familiar words by the age of 10 years (Trenholm & Mirenda, 2006; Vaginay, 1995). When Tsao, Fartoukh, and Barbier (2011) carried out a comparison between adults with DS and typical adults matched for chronological age (CA), using the standardised French version of the Concise Assessment Method for Children's Handwriting (BHK test; Charles, Soppelsa, & Albaret, 2003), they found that the adults with DS performed more poorly than controls on handwriting speed and quality. Regarding letter shape, the adults with DS produced taller letters, more often than not misshapen, and in unsteady writing. As for spatial arrangement, word spacing and alignment were insufficient. Analyses based on the participants' developmental age (DA) failed to reveal any significant differences. In a second study, Tsao, Velay, Barbier, and Gombert (2012) focused on movement kinematics in order to examine handwriting processes more closely. Three groups (DS, typically developing children matched on DA and typically developing adults matched on CA) had to copy frequent and simple letters, and familiar words on a graphic tablet. Compared with the CA group, the participants with DS wrote more slowly (pause durations, stroke durations and overall movement duration). By contrast, analyses did not reveal any significant difference between the adults with DS and children matched on DA on any of the temporal measures. These results confirmed those of the previous study on the speed and quality of production. The handwriting movements produced in the writing tasks by participants with DS were relatively similar to those produced by typically developing children matched on DA. These findings were, in turn, recently confirmed by Varuzza, De Rose, Vicari, and Menghini (2015).

The aim of the present study was to determine the predictive factors for handwriting speed and quality in adolescents and adults with DS, rather than compare the productions of people with DS with those of a control population. Simple and multiple linear analyses would allow us to assess the influence of factors such as CA and DA, as well as the perceptual-motor processing that contributes to handwriting speed and quality (fine motor control, visual perception and visual–motor integration), and the way the pen is held (pen grasp). The objectives of this study were to: (1) define the diversity of factors that influence handwriting and their interactions in a population with atypical development and (2) determine whether these factors have a differing impact on two handwriting parameters (quality and speed). The data we collected would inform the programmes designed to promote handwriting acquisition among individuals with DS.

Method

Participants

Data were collected from 23 individuals with DS aged 10–40.5 years (12 men and 11 women). Of these 23 participants, 20 were right-handed and 3 were left-handed. They were recruited via services that provide care for persons with DS and are affiliated with the Trisomie 21 France federation. It should be noted that none of the participants showed signs of early dementia. Prior to assessment, a letter of consent setting out the purpose of the study and describing its procedures was sent to all participants with DS, as well as to their legal guardians, in accordance with the code of conduct of the American Psychological Association (APA, 2012). This letter of consent, together with the research project, was approved by the university's institutional review board. Only those adults who had given their written informed consent took part in the study.

Measures

We administered the BHK to each participant to estimate their handwriting speed and quality. This test consists in copying out a text of increasing difficulty for 5 min (or more, if the participant has not finished writing the first five lines). To obtain an overall score of handwriting quality, we summed 13 criteria for poor quality: large letter size, left margin widening, poor word alignment, insufficient word spacing, acute turns in connecting letters or letter joins too long (chaotic writing), irregularities in joining strokes, collision of letters, inconsistent letter size, incorrect relative height of letters, letter distortion, ambiguous letter forms, correction of letter forms and unsteady writing. A score of 1 was allocated when the handwriting met one of these criteria, and a score of 0 when it did not, such that the lower the score, the better the quality of the handwriting. Handwriting speed was measured by counting the number of characters (letters or punctuation signs) written during the 5 min. During the assessment, the examiner noted which hand was used (right or left) and the type of pen grasp (immature, intermediate or mature). The coding was performed by the same experimenter throughout, with no prior training. This French adaption of the BHK had previously been validated with a calibration population comprising 837 children aged 6–11 years. Interrater reliability was high (.71–.89), as was test–retest reliability (80–92%). Although this scale has not been validated with populations with intellectual disabilities such as DS, several studies have reported it to be sensitive to the presence of handwriting problems (Hamstra-Bletz & Blote, 1993; Smits-Engelsman, Niemeijer, & van Galen, 2001). The DA of each participant was assessed by means of Raven's Coloured Progressive Matrices (CPM; Raven, Raven, & Court, 1998), a set of non-verbal intelligence tests eliciting analogical and inductive-logical reasoning. We chose to use Raven's matrices because they are more suitable for individuals with intellectual disabilities, in terms of material, test duration and level of difficulty. Perceptual and motor functions were assessed with four subtests (fine motor coordination, visual attention, visuomotor integration and visuomotor precision) of the Developmental Neuropsychological Assessment (NEPSY I; Korkman, Kirk, & Kemp, 2003). The fine motor coordination subtest was used to assess fine motor coordination via the ability to imitate hand or finger positions from a model. We used the visual attention subtest to assess the speed and precision of attention maintenance: participants had to find visual stimuli on a drawing board. The visuomotor integration subtest served to assess graphomotor skills via the reproduction of a set of geometric figures. Finally, the visuomotor precision subtest was administered to estimate the speed of fine motor movements and the precision of oculomotor coordination by inviting participants to draw lines inside tracks.

Data Analysis

The raw scores on the BHK test and the four NEPSY I subscores were standardised. For the simple and multiple regressions, quantitative variables were centred and scaled. To assess the relationship between each quantitative factor (CA, DA, fine motor coordination, visual attention, visuomotor integration and visuomotor precision) and handwriting speed and quality, we ran Pearson's linear correlations. Simple linear regressions were carried out to measure the impact on handwriting performances of the participants' CA or DA, components of perceptual-motor processing (fine motor coordination, visual attention, visuomotor integration and visuomotor precision) and categorical variables (sex and pen grasp). In order to determine which factors were predictors, we ran multiple linear regressions on handwriting speed and the overall quality score. The relationship between speed and quality was ascertained with a simple linear regression. All analyses were conducted with R software Version 3.1.0 (R Development Core Team, Vienna, Austria). In order to study a homogenous group, one participant was removed from the sample because his handwriting speed was more than two standard deviations above the group mean for handwriting speed.

Results

Descriptive analyses of means and standard deviations of handwriting speed and quality, and all the quantitative variables (CA, DA, fine motor coordination, visual attention, visuomotor integration and visuomotor precision) are set out in Table 1. Of the 23 participants, 8 had an intermediate pen grasp and 15 a mature grasp with a dynamic tripod.

Pearson Correlations between Handwriting Speed, Handwriting Quality and Quantitative Variables

We tested the correlations between handwriting speed, handwriting quality and each of the quantitative variables (Table 2). Results revealed correlations between handwriting quality and CA, DA, fine motor coordination, visuomotor integration and precision. Handwriting speed was correlated with DA, fine motor coordination and visuomotor integration. Finally, handwriting quality and handwriting speed were co-dependent variables.

Predictors of Handwriting Quality

To look for linear and curvilinear changes in the quality score with CA or DA, we ran simple linear regressions based on a model that included either a variable or its second-order polynomial function. The relationship between the overall handwriting quality score and DA was found to follow both a linear ($\beta = -.618$, $p < .01$) and a curvilinear function ($R^2 = .537$, $p < .001$). An analysis of variance between the two models confirmed that a greater

Table 1. Descriptive statistics for handwriting quality and speed, developmental and chronological age, and performance on the four subtests of NEPSY I.

	M	SD
Handwriting quality	25.91	13.04
Handwriting speed	91.55	40.77
Chronological age	19.98	7.89
Developmental age	5.83	1.50
Fine motor coordination	3.43	1.77
Visual attention	2.52	2.26
Visuomotor integration	3.65	2.82
Visuomotor precision	3.70	3.10

Table 2. Pearson correlations between handwriting quality, speed and quantitative variables.

	HQ	HS	CA	DA	FMC	VA	VMI	VMP
Handwriting quality (HQ)	1							
Handwriting speed (HS)	−.67***	1						
Chronological age (CA)	−.44*	.21	1					
Developmental age (DA)	−.62**	.55**	.27	1				
Fine motor coordination (FMC)	−.79***	.55**	.47*	.67***	1			
Visual attention (VA)	−.31	.37	.38	.20	.33	1		
Visuomotor integration (VMI)	−.65**	.49*	.39	.71***	.85***	.19	1	
Visuomotor precision (VMP)	−.53*	.27	.54**	.61**	.69***	.06	.80***	1

*$p < .05$; **$p < .01$; ***$p < .001$.

proportion of the variance was explained by the curvilinear model ($F(1, 19) = 8.141, p < .05$). The variance of the quality score was also explained by CA in a curvilinear model ($R^2 = .446$, $p < .01$), though not by a linear one ($p = .088$). Regression analyses (detailed in Table 3) were run to determine the one-way influence of the different factors on the handwriting quality score. Simple linear regressions revealed a linear dependence between this score and scores on three of the four NEPSY I subtests (fine motor coordination: $\beta = -.792$, $p < .001$; visuomotor integration: $\beta = -.646$, $p < .001$; and visuomotor precision: $\beta = -.525$, $p < .05$). There was no significant relationship between the overall handwriting quality score and visual attention ($p = .147$), sex ($p = .195$) or pen grasp ($p = .188$).

We ran a multiple regression to ascertain the best predictors of the handwriting quality score out of CA, DA, sex, pen grasp, fine motor coordination, visual attention, visuomotor integration and visuomotor precision. Results are set out in Table 4. Taken together, the factors included in this model accounted for 73% of the variance in handwriting quality ($R^2 = .731$, $p < .01$). To find out which factors were the best predictors of the quality score, we ran a stepwise model selection based on the Akaike information criterion (AIC). Of all the factors, fine motor coordination (AIC = 17.73) was the best predictor of handwriting quality ($R^2 = .627$, $p < .001$).

Predictors of Handwriting Speed

Simple linear and curvilinear regressions were used to highlight changes in handwriting speed with CA or DA. The relationship between handwriting speed and DA followed both a linear ($\beta = .537$, $p < .01$) and a curvilinear ($R^2 = .391$, $p < .01$) function, with no significant

Table 3. Simple linear regressions of handwriting quality.

	β	SE	p
Age characteristics			
Chronological age	−.363	.203	.088
Developmental age	−.618	.171	.002**
Categorical variables			
Sex	.549	.410	.195
Pen grasp	−.585	.429	.188
Perceptual-motor processing			
Fine motor coordination	−.792	.133	.001***
Visual attention	−.312	.207	.147
Visuomotor integration	−.646	.167	.001***
Visuomotor precision	−.525	.186	.010*

*$p < .05$; **$p < .01$; ***$p < .001$.

Table 4. Multiple linear regression of handwriting quality on eight predictors.

Model	Variables	R	R^2	Adjusted R^2	F value
1	CA, DA, S, PG, FMC, VA, VMI, VMP	.675	.731	.565	4.409**
2	CA, DA, S, PG, FMC, VA, VMI	.651	.730	.596	5.419**
3	CA, DA, S, PG, FMC, VMI	.629	.730	.622	6.766**
4	CA, DA, S, FMC, VMI	.625	.715	.626	8.045***
5	DA, S, FMC, VMI	.630	.693	.621	9.597***
6	DA, S, FMC	.634	.671	.616	12.22***
7	S, FMC	.632	.655	.618	18.02***
8	FMC	.640	.627	.609	33.69***

Notes: CA: chronological age; DA: developmental age; S: sex; PG: pen grasp; FMC: fine motor coordination; VA: visual attention; VMI: visuomotor integration; and VMP: visuomotor precision.
**$p < .01$; ***$p < .001$.

Table 5. Simple linear regressions of handwriting speed.

	β	SE	p
Age characteristics			
Chronological age	.243	.251	.346
Developmental age	.537	.183	.008**
Categorical variables			
Sex	−.418	.427	.339
Pen grasp	.882	.409	.043*
Perceptual-motor processing			
Fine motor coordination	.540	.182	.008*
Visual attention	.360	.205	.095
Visuomotor integration	.475	.191	.022*
Visuomotor precision	.266	.214	.229

*$p < .05$; **$p < .01$.

difference between the two models ($F(1, 19) = 2.776$, $p = .112$). A curvilinear model also explained the relationship between handwriting speed and CA ($R^2 = .331$, $p < .05$). No linear function was found for the relationship between handwriting speed and CA ($p = .346$). We determined the influence of the factors on handwriting speed with simple regression analyses (reported in Table 5). There was a significant linear relationship between two of the four NEPSY subtests and handwriting speed (fine motor coordination: $\beta = .540$, $p < .01$; visuomotor integration: $\beta = .475$, $p < .05$). Simple linear regressions failed to reveal a linear dependence between handwriting speed and the other two subtests, namely: visual attention ($p = .095$) and visuomotor precision ($p = .229$). As with the overall handwriting quality score, the categorical variable sex ($p = .339$) had no significant impact on handwriting speed, but a linear function did emerge between handwriting speed and pen grasp ($\beta = .882$, $p < .05$). We also ran a multiple regression to identify the most predictive factors for handwriting speed. Taken together, the factors we studied did not explain the variance in handwriting speed ($p = .165$).

Relationship between Handwriting Speed and Quality

Simple linear regressions revealed that handwriting speed was both a linear ($\beta = -.682$, $p < .001$) and a curvilinear ($R^2 = .477$, $p < .01$) function of handwriting quality, with no difference between the two models ($F(1, 19) = 1.200$, $p = .287$). More specifically, simple linear regressions indicated that the scores for poor word alignment ($\beta = -.394$, $p < .05$), irregularities in joining strokes ($\beta = -.442$, $p < .05$), collision of letters ($\beta = -.454$, $p < .05$), incorrect relative height of letters ($\beta = -.557$, $p < .01$), letter distortion ($\beta = -.528$, $p < .01$) and ambiguous letter forms ($\beta = -.627$, $p < .001$) linearly decreased when handwriting speed increased. By the same token, handwriting quality was both a linear ($\beta = -.651$, $p < .001$) and a curvilinear ($R^2 = .445$, $p < .01$) function of handwriting speed. An analysis of variance did not reveal any significant difference between the two models ($F(1, 19) = .037$, $p = .850$). A multiple linear regression model showed that none of the 13 criteria for quality were explanatory variables for handwriting speed ($p = .144$).

Discussion

Theoretical Implications

The aim of the present study was to analyse the impact of a set of factors on handwriting among a population of adolescents and adults with DS. Initial analyses highlighted significant correlations between the participants' CA and several handwriting parameters. More specifically, data indicated that overall handwriting quality, as assessed with the BHK's copy task, improved linearly with the participants' CA. Although some studies have highlighted difficulties with letter formation and spatial arrangement, in comparison with CA-matched controls (Tsao et al., 2011, 2012), our study showed that the handwriting quality of individuals with DS can improve with CA. This improvement can probably be attributed to the maturation of the perceptual-motor system in the course of development, as well as to participants' life experiences. Repeated exposure to writing tasks over a number of years may foster the learning and mastery of the graphomotor movements required for handwriting. Correlational analyses also highlighted significant relations between the level of development (DA) and handwriting performances, in terms of both speed and quality. These data underscore the role of cognitive skills in the acquisition of handwriting among individuals with DS, just as studies have done for typically developing children. Furthermore, our study highlighted the relationship between perceptual-motor abilities and handwriting performances. Results showed that finger dexterity, assessed here via the imitation of hand movements, and visuomotor integration and precision, measured via the copying of geometric figures and the drawing of lines between two tracks, were linked to both handwriting speed and quality in our population with DS. These results correspond to findings in the literature for typically developing children (Cornhill & Case-Smith, 1996; Marr et al., 2001; Van Hoorn et al., 2010). Visuomotor integration and precision rely on the visual control of movement and the anticipation of changes in direction, and are therefore often defined as letter-writing prerequisites. Regarding the role of visuospatial processes, however, our study failed to uncover any correlation between visual attention and either the speed or quality of handwriting. Thus, although finger dexterity and visuomotor integration and precision are related to handwriting performances, visuoperceptual processing has no significant link, as already demonstrated by Maeland (1992) and Malloy-Miller et al. (1995) in unselected samples of children. We can assume that motor and visuomotor controls are more important than visual control alone, when it comes to performing the graphomotor movements required in a handwriting task. The results of the simple linear analyses converged with those of the correlational analyses, except for the relationship between CA and overall handwriting quality. This may be because the link between these variables was found to be curvilinear, but not linear, with lower BHK scores for participants below and above the 16–25 years age group. In line with results for the typical population (Berwick & Winickoff, 1996; Hellinckx et al., 2013; Schneider et al., 2006), our analyses confirmed that sex and handwriting quality are unrelated. They did, however, highlight the influence of pen grasp on speed, thus confirming the results reported by Stevens (2008), who found that a dynamic tripod or quadrupod allowed adults to write faster. It is interesting to note the similarity between the relationships we found between the endogenous factors and handwriting in our population with DS and those reported in the literature for typically developing populations. Our study therefore converges with the few studies that have so far explored handwriting in persons with DS (Tsao et al., 2011, 2012; Varuzza et al., 2015), which concluded that the stages of handwriting acquisition are simply delayed in persons with DS, and there is no specific deficit. Furthermore, by running multiple regression analyses, we were able to investigate the predictive value of perceptual-motor skills. Of all the factors we studied, fine motor coordination emerged as the best predictor of handwriting quality. This factor explained 63% of the variance in handwriting quality. Finger dexterity, which relies on fine, precise and dissociated movements of the fingers, appears to have a considerable impact on the ability to produce the fine movements required in a writing task. Our results suggest that a rehabilitation programme focusing on improving finger dexterity and visuomotor integration could promote handwriting acquisition in children and adults with DS. Caution nonetheless needs to be exercised when generalising our findings, owing to the small size of our sample. The original results yielded by this initial study indicate that it would be well worth pursuing this line of research, focusing on methods for teaching handwriting in order to support the schooling and integration of children and adults with DS as effectively as possible.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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