

Handwriting development, competency, and intervention

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Failure to attain handwriting competency during the school-age years often has far-reaching negative effects on both academic success and self-esteem. This complex occupational task has many underlying component skills that may interfere with handwriting performance. Fine motor control, bilateral and visual-motor integration, motor planning, in-hand manipulation, proprioception, visual perception, sustained attention, and sensory awareness of the fingers are some of the component skills identified. Poor handwriting may be related to intrinsic factors, which refer to the child's actual handwriting capabilities, or extrinsic factors which are related to environmental or biomechanical components, or both. It is important that handwriting performance be evaluated using a valid, reliable, standardized tool combined with informal classroom observation and teacher consultation. Studies of handwriting remediation suggest that intervention is effective. There is evidence to indicate that handwriting difficulties do not resolve without intervention and affect between 10 and 30% of school-aged children. Despite the widespread use of computers, legible handwriting remains an important life skill that deserves greater attention from educators and health practitioners.

*'People present themselves to the world through their handwriting and are inevitably judged by it. From our earliest school days, success and failure are often measured in terms of neat handwriting.'*¹

Why is handwriting important?

The development of writing ability is not only important in building a child's self-esteem, but is considered an essential ingredient for success in school.^{1,2} Children spend 31 to 60% of their school day performing handwriting and other fine motor tasks,³ and difficulty in this area can interfere with academic achievement. Illegible handwriting can create a barrier to accomplishing other higher-order skills such as spelling and story composition.⁴ Despite the use of computers, handwriting remains an important developmental skill for a child to master.¹ In our society, handwriting is both a means of communication and a necessary life skill, as in writing a letter or telephone message, completing an application form, or writing a cheque. Handwriting 'is still the most immediate form of graphic communication'.¹

The consequences of poor handwriting

Estimates of handwriting dysfunction in children range from 10 to 30%⁵ and the consequences for academic performance have been well documented.⁶ Simner⁷ found that form errors, defined as additions, deletions, or misalignments, in kindergarten children predicted later academic abilities in reading and handwriting. Sandler et al.⁶ found that children with writing disorders had a tendency towards lower mathematics achievement, low verbal IQ, and increased attentional difficulties compared with controls. The reason underlying a child's writing difficulty may often be unclear as elements of the writing process are closely interwoven, e.g. difficulty in spelling can contribute to difficulty in note-taking or expression of ideas.⁴ No other school task requires as much synchronization as handwriting.⁸ It is clear writing difficulties can overshadow a child's capabilities in other areas, making

success at school less easily attainable.

Children with handwriting problems typically have difficulty keeping up with the volume of written work required during the elementary school years, which may impede academic progress and lead to lowered self-esteem and behavioural problems.⁹ In fact, it is common for these children to be mislabeled as noncompliant, lazy, or lacking motivation, which causes further frustration and disappointment.⁶ Handwriting is often judged and seen as a reflection of an individual's intelligence or capabilities as illustrated by several studies in which lower marks were consistently assigned to students with poor handwriting and higher marks given to those with legible handwriting despite similar content.^{10–12}

Handwriting development

The development of handwriting begins with early scribbling, which becomes more intentional with time.^{13,14} As the child develops, design patterns evolve into more precise shapes and then letters. Letter shapes can often be seen in children's drawings which can be viewed as an apprenticeship for writing.¹⁵ A child learns to print letters by first imitating geometric shapes beginning with vertical strokes (age 2y), followed by horizontal strokes (age 2y 6mo) and circles (age 3y). Imitation and then copying of a cross typically occurs at 4 years; copying a square occurs at 5, and a triangle at 5 years 6 months.¹⁶ The ability to copy geometric forms, particularly the oblique cross, is seen as an indication of writing readiness in the young child, as it requires crossing the body midline and has been implicated as the root of many reversal problems.^{16,17} This is supported in a study by Weil and Amundson¹⁸ in which 60 typically developing kindergarten children were examined for printing ability and performance on the Developmental Test of Visual–Motor Integration (VMI). Findings indicated that children who were able to copy the first nine VMI forms, including the oblique cross, were able to copy significantly more letters than those who could not copy the first nine forms. Marr and Cermak¹⁹ concluded that the VMI could not be supported as a tool for identifying kindergarten children at risk for handwriting difficulties. In this study of 101 children, VMI scores, including the oblique cross, did not predict handwriting success as a group in grade one; however, VMI scores were significantly associated with handwriting for females. The effect of sex is an important consideration in handwriting development. Studies of older children, ages 7 and up, have demonstrated a significantly lower quality of writing and slower speed in males compared with females.^{20,21}

Handwriting studies of typically developing children in grades one to five (ages 6–11y typically), have found the quality of handwriting develops quickly during grade one (ages 6–7y typically) and reaches a plateau by grade two (age 7–8y typically). Further development is seen by grade three (ages 8–9y typically), in that handwriting becomes automatic, organized, and is available as a tool to facilitate the development of ideas.^{22,23} Speed of writing develops in a somewhat linear fashion throughout primary school, and overall development of handwriting continues during the middle school years.

What constitutes poor handwriting?

The two most important elements in handwriting performance are legibility and speed. Difficulties with letter formation, spacing, size, slant, and/or alignment may affect handwriting legibility.^{4,24} However, Amundson and Weil²⁵ maintain that

below-standard performance in letter formation, and size in particular, can greatly reduce handwriting 'readability'.²⁵ A handwriting sample may be readable even though poor alignment interferes with its appearance. Speed is also an important aspect of handwriting ability if a child is to cope with classroom demands, and speed is variable depending on context, instruction given, and whether the child is copying, taking dictation, or free writing.²⁴ It is, therefore, important to consider these factors when comparing children's handwriting speeds.

Handwriting performance components

Handwriting is a complex perceptual–motor skill encompassing a blend of visual–motor coordination abilities, motor planning, cognitive, and perceptual skills, as well as tactile and kinesthetic sensitivities.²⁶ It is important to identify handwriting performance components as a means of targeting effective intervention strategies.²⁵ The motor and perceptual components related to handwriting performance may include fine motor control (in-hand manipulation, bilateral integration, and motor planning), visual–motor integration, visual perception, kinesthesia, sensory modalities, and sustained attention.^{27,28}

Lack of fine motor control is implicated in common writing errors in studies of children in grade one (ages 6–7y) and include incorrect size/placement of letters and relationship of parts.²⁹ Exner³⁰ refers to isolation, grading, and timing of movements as the three aspects of fine motor control that affect handwriting ability. Inadequate pencil grasp may result in children who have difficulty isolating and grading finger/hand movements. These children often use compensatory strategies (i.e. locking fingers into extension, fisting into flexion to stabilize their pencils). Laboured, slow, jerky writing or rapid, haphazard writing is usually a sign of difficulty with timing of movements affecting the rhythm and flow of handwriting.³⁰ Hamstra-Bletz and Blote³¹ concluded that problems of dysgraphic writers relate to a lack of fine motor control in the execution of motor programmes. Children with developmental coordination disorder (DCD), characterized by motor coordination substantially below that expected for their age, which is unattributed to a medical condition, represent one subgroup likely to exhibit handwriting difficulty.³² Although the motor performance previously described^{30,31} is frequently seen in children with DCD, it has also been documented in children without this diagnosis.

In-hand manipulation is included in fine motor control and is the process of adjusting objects within the hand after grasp.³⁰ After grasping a pencil, it must be shifted, which is defined as the linear movement of the tool by the fingers, in order to adjust it for writing. Translation, a type of in-hand manipulation task, is the ability to move an object from the fingers to palm or palm to finger pads,³⁰ as in pushing the fingers toward or away from the pencil's point during handwriting.³³ Rotation, another in-hand manipulation task, involves movement of the pencil around an axis and is essential for turning the pencil from grasp position to placement for writing or erasing.³⁰

Bilateral integration, the ability to perform symmetrical and asymmetrical movements of the body during an activity,³⁰ and motor planning are also important elements of fine motor control affecting handwriting. Handwriting consists mainly of asymmetrical movements as the child must stabilize

the paper with the non-preferred hand while holding the pencil with the preferred hand. Children with bilateral integration difficulties may be unable to dissociate symmetrical and asymmetrical movements of the upper extremity required in handwriting.²⁷ Motor planning influences the child's ability to plan, sequence, and execute letter forms and ordering of letters in words.²⁷ The ability to motor plan is particularly important when children first learn to write, as it is implicated in their ability to perform novel or unfamiliar movements. Tseng and Murray³⁴ examined the relation between perceptual-motor abilities and handwriting legibility. They found motor planning was the best and only predictor of legibility in poor handwriters.

Visual-motor integration is an important variable in handwriting performance, particularly when copying or transposing from text to cursive or manuscript writing.²⁸ Amundson²⁷ defines visual-motor integration as the ability to coordinate visual information with a motor response, allowing the child to reproduce letters and numbers for written school assignments. Several studies have found visual-motor integration to be one of the most significant predictors of handwriting performance, with strong correlations documented between visual-motor integration and writing legibility.^{18,26,34} Although several studies have found a correlation between handwriting and visual perception,³⁵ the relation remains unclear. Visual closure is an area of visual perception in which the child identifies which letters have been formed completely, whereas position in space influences a child's spacing between letters and words and within writing lines.²⁵ Form constancy perception enables the child to discriminate between similar letters or words (for example b/d, was/saw) and may also impact on handwriting;²⁵ whereas poor visual memory for letter sequences has been documented in children with difficulty in handwriting/copying tasks.^{36,37} However, as Tseng and Cermak³⁸ concluded, further research is needed to examine more closely the role visual perception plays in handwriting.

The ability to discriminate position of body parts as well as amplitude and direction of their movements without visual or auditory cues is referred to as kinesthesia or proprioception.³⁹ Proprioception/kinesthesia also plays a role in handwriting performance by influencing pencil grip, the amount of pressure applied to the writing tool, and the ability to write within boundaries while also providing directionality information during letter formation.^{27,28,33,40} However, studies of handwriting incorporating this component have produced conflicting results, pointing to the difficulty in measuring pure proprioceptive/kinesthetic function.²⁸

Sensory awareness of the fingers may also have an impact on handwriting performance. However, much of the research examining this relationship has involved motor-impaired children. One study found a significant association between poor tactile awareness and a handwriting execution/coordination error pattern in children with mild motor impairment.⁴¹ Similarly, children in grade one (ages 6–7y) born preterm demonstrated decreased sensory awareness of individual fingers and lower handwriting legibility scores compared with term peers.⁴² A study of low productivity in 26 school-aged children found half showed evidence of finger agnosia, identified in tasks involving imitative finger movement/differentiation.⁸ Furthermore, all children with finger agnosia were found to have difficulty with pencil control. During handwriting performance, tactile/proprioceptive inputs provide information regarding grasp of the writing tool, eraser, paper, and surface.²⁵ A less mature pencil grip was associated with decreased proprioceptive-kinesthetic finger awareness in a study of grade one children (ages 6–7y) with handwriting difficulties.⁴⁰ Impaired sensory awareness of the fingers may require more intense visual monitoring of written output, causing increased fatigue and limiting the automaticity and hence level of handwriting performance that can be achieved.^{38,40}

Sustained attention is also necessary to enable the child to

Table I: Summary of handwriting remediation studies

<i>Handwriting remediation studies</i>	<i>Mean age, y:m</i>	<i>Participants</i>	<i>Number of treatments; frequency</i>	<i>Duration (minutes)</i>	<i>Treatment type</i>
Berninger et al. ⁴⁸ (n=144)	6:8	ID	24; twice per wk	20	HI
Case-Smith ⁵⁶ (n=29)	7–10	TD, ID	weekly; 7mo	30	OTS
Graham ⁴⁹ (n=38)	6:11	TD, ID	27; three times per wk	15	HI PAI
Harris and Livesey ⁵⁹ (n=30)	5:10	ID	6; daily	15	KT
NC two groups of n=15	7:1				HP
Jones and Christensen ⁵⁷ (n=19)	7:2	ID	40; daily	10	HI
Jongmans et al. ⁶¹ study 1 (n=7)	8:7	ID	18; twice per wk, 3mo	30	HI ^b
study 2 (n=24) attended sp ed school	10:5		18; twice per wk, 6mo	30	HI ^b
Lockhart and Law ⁶⁶ (n=4) NC	9–11	ID	5; bi-weekly	60	Multi-sensory
Peterson and Nelson ⁶⁷ (n=59)	7:1	ED	20; twice per wk, 10 wks	30	+ Eclectic ^c
Roberts and Samuels ⁶² (n=36)	10:10	ID	7; not reported	40	HI
NC three groups of n=12					
Smits-Engelsman et al. ⁵⁸ (n=12)	8:4	ID	18; 3mo	Not reported	Physio and motor learning
^a Sudsawad et al. ⁶⁰ (n=45)	6:11	ID	6; daily	30	KT HP
three groups of n=15					

^aNo improvement on standardized handwriting assessment, but improvement reported by classroom teacher; ^btask-oriented self-instruction method; ^coccupational framework including biomechanical, sensorimotor, and teaching-learning strategies. ID, identified difficulty; HI, handwriting instruction; TD, typically developing; OTS, occupational therapy services; PAI, phonological awareness instruction; KT, kinesthetic training; NC, no controls; HP, handwriting practice; sp ed, special education; ED, economically disadvantaged; +, therapist individualized intervention based on student's needs; physio, physiotherapy.

effectively perform a handwriting task for an extended period.²⁷ A lowered attention span can limit practice of handwriting which can lead to poor mastery of letter formation. There is evidence suggesting that children with attention-deficit-hyperactivity disorder (ADHD) may exhibit handwriting difficulty, characterized by inconsistent letter sizes and shapes;⁴³ approximately 50% of children with ADHD have fine motor coordination problems.^{44,45} In a study by Schoemaker et al.,⁴⁶ decreased accuracy in figure copying was documented in children with ADHD who did not have coordination problems. However, the sample size for this study was small ($n=16$) and handwriting itself was not evaluated using a standardized measure. It may be that the root causes of handwriting difficulty are multifactorial and not easily associated with any one clinical population.

Extrinsic factors affecting handwriting performance

Factors that may affect handwriting performance in children may be intrinsic, stemming from the child's actual performance capabilities (discussed in the previous section) or extrinsic, relating to environmental/biomechanical issues. Extrinsic factors include sitting position, chair/desk height, writing instrument used, type of paper used and its placement on the desk, environmental lighting and noise, blackboard distance when copying, and volume of handwriting the child is expected to complete. Ideally, a child should be seated with feet flat on the floor, hips and low back supported against the chair back, knees flexed to approximately 90° and elbows slightly flexed with forearms resting comfortably on the desk surface.⁴⁷ Desk or chair height that is too low will encourage slouching forward and conversely, when chair and desk height are too high and/or feet are unsupported, written output may be compromised. It is important to evaluate biomechanical factors when addressing handwriting difficulties in typically developing children and children with disabilities.

As there are no standardized methods of teaching handwriting in schools, another extrinsic factor influencing handwriting is the type and duration of instruction the child has received. There is research indicating that, for some children, providing supplementary handwriting instruction can improve accuracy and fluency of handwriting performance.^{48,49}

Handwriting remediation: does it work?

Most studies of handwriting remediation provide evidence to support its effectiveness despite varying duration, frequency, and treatment approaches applied (see Table I). However, it is important that careful evaluation of a child's handwriting performance be carried out before remediation using both formal and informal methods (i.e. classroom observation, teacher consultation).^{17,25} The instrument chosen should best match the child's area of handwriting difficulty so as to facilitate the implementation of an effective treatment strategy.⁵⁰ A quantitative scoring system is critical in identifying the problem areas to be targeted during remediation, in monitoring a child's progress after intervention, and in communicating the results more clearly.⁵¹ In a cross-Canada survey of occupational therapists, formal handwriting assessments were rarely used, possibly reflecting a lack of availability at the time of a valid and reliable handwriting evaluation tool.⁵² More recently, several standardized instruments evaluating different areas of handwriting performance have become available.⁵³ In selecting an evaluation tool, it is important that the clinician is aware of the

psychometric properties of the instrument, keeping in mind its strengths and limitations.^{50,53,54}

The handwriting treatment approaches documented in the literature include perceptual-motor, visual-motor, motor control, individualized interventions/exercises, and supplementary handwriting instruction. However, there are few controlled studies that have examined specific treatment approaches to handwriting intervention using a large sample size. A survey of 50 pediatric occupational therapists found 90% favoured an eclectic approach in treating handwriting problems, irrespective of experience or work setting.⁵² An eclectic approach is also advocated in the handwriting literature;⁵⁵ with greater effectiveness expected when a combination of techniques are used to improve handwriting performance.²⁷ Some studies have reported that supplementary instruction enhanced both handwriting performance and story writing ability, whereas others reported improvement in component skills (i.e. visual-motor control, in-hand manipulation) after treatment.^{49,56,57} Studies that re-evaluated handwriting proficiency 3, 6, and/or 9 months post-treatment found children demonstrated improved compositional fluency and wrote more accurately than controls.^{49,58} The kinesthetic training approach in treating handwriting difficulties was shown to be effective by Harris and Livesey⁵⁹ but disputed by a later study.⁶⁰ Several studies have investigated the effect of supplementary handwriting instruction using varying types of handwriting practice based on an educational and/or motor learning model.^{48,49,57,61,62}

Most studies of handwriting intervention report an improvement in the legibility of children's handwriting, but no significant changes in speed. The 'readability' of a handwriting sample is considered more important than speed, with a trade-off between speed and legibility noted. The automatic production of alphabet letters is important in the early stages of learning to write⁶³ and the child's inability to acquire this automaticity will adversely affect their speed. The achievement of automaticity in alphabet-writing is a lower-order skill that may be affected by three neuropsychological variables: the child's letter retrieval ability from visual memory; their visual-motor integration skills; and soft signs seen in imitative finger movements, finger differentiation, or opposition.⁶³ In older children who have mastered lower-order writing, cognitive or linguistic difficulties should be explored as these are important in higher-order writing skills needed in planning/revising.⁶³ Indeed, remediation may need to focus on both lower-order and higher-order skills in some cases. The use of bypass strategies (i.e. keyboarding, decreasing volume of written work required, photocopied worksheets to reduce copying, oral test taking) may be recommended when children cannot keep up with the volume of classroom work.⁵⁵ Keyboarding requires specific prerequisite skills⁶⁴ and evaluation/training must be provided before choosing this as a feasible bypass strategy. Individualized evaluation is necessary, taking into account age and cognitive level, to determine whether alternative methods of test taking would be beneficial for the child, such as oral testing or keyboarding.

The idea of providing supplementary handwriting instruction as the first line of defense in remediating handwriting difficulties, as suggested by several authors, appears to have merit. However, there will likely be a subset of children in whom handwriting difficulties will persist. More evidence-based studies examining which treatment approaches are

effective on particular populations would be beneficial. Handwriting difficulties do not disappear without intervention.^{31,64} It is clear that further research is warranted, examining specific and eclectic approaches to treatment.

Conclusion

Handwriting competency is not only important for academic success at school age, but is a critical skill throughout adulthood. This complex occupational task has many underlying component skills that may interfere with handwriting performance. Although handwriting difficulties may be the result of intrinsic factors such as poor component skills, extrinsic considerations such as academic environment and biomechanics must not be overlooked. It is especially important that health practitioners and educators appreciate the far-reaching academic and psychosocial consequences of poor handwriting. This immediate form of communication continues to be an essential skill both inside and outside the classroom, despite the widespread use of technological devices. Therefore, greater consideration should be given to children's handwriting competency in assessing typically developing and high-risk populations.

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SOCIETY FOR RESEARCH INTO HYDROCEPHALUS AND SPINA BIFIDA

51st Annual Scientific Meeting June 27th – 30th 2007

**Venue: Kopfklinik, Neuenheimer Feld 400, Univ. of Heidelberg, Heidelberg, Germany
at the invitation of Professor A Unterberg and Dr A Aschoff**

Research papers are sought on hydrocephalus and spina bifida, including urology, orthopaedics, genetics and neural development, and psychosocial issues.

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