To the many children who have taught me

The Relationship between Poor Handwriting and Written Composition in Children with a Developmental Coordination Disorder

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Nec manus, nisi intellectus, sibi permissus multum valent; instrumentis auxilibus res perficitur.

Neither the hand nor the intellect, on its own, yields much power; only through tools imbued with culture is this accomplished.

(Francis Bacon)

Abstract

Handwriting difficulties are well documented in children with Developmental Coordination Disorder (DCD). Whether, and how, these difficulties affect the content of the work such children produce is less clear. The aim of this thesis was to explore the relationship between poor handwriting and the quality of written expression in these children, using different methodologies.

Four studies are reported. In the first, a group of 10-11 year-old children whose teachers regarded their writing difficulties as "unexpected" were compared with matched controls. Objective measurement showed that they had at least average intelligence, could read and spell adequately and did not differ from the control group in their ability to produce stories orally. Consequently, the poor *hand-* and *story writing* revealed in the study could not be explained in terms of poor intellect or general language or literacy problems. However, all met criteria for the diagnosis of DCD. The second study confirmed that the physical act of handwriting supported the ability to compose a story in typically developing children but conferred no such advantage if handwriting and movement difficulties were present. When children from Study 1 were followed up after five years, those whose handwriting had not improved continued to have difficulty with written composition.

Having shown that poor handwriting can affect the conceptual side of writing, the final study set out to determine which particular aspects of handwriting difficulty might constrain the cognitive resources available for composition. To this end, the effect of increasing motor and orthographic complexity on the spatial, temporal and force aspects of handwriting was explored in a series of writing tasks varying in content, length and difficulty. Consistent with the capacity theory tested, results showed that variations in motor *and* orthographic complexity affected writing performance in all children, but those with DCD and poor handwriting were affected more.

Declaration and Word Count

All the empirical studies reported in this thesis were planned, executed and analysed by the candidate. The candidate also confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Word count: 82,424 words.

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Next, my thanks go to all the children and young people who participated in the four studies and to their families for their interest and cooperation.

Finally, I want to thank my husband and sons for their encouragement and my friends for their patience.

Glossary of Terms

Allograph A letter or combination of letters that can represent one phoneme, e.g. 'f' and 'gh' can represent the phoneme /f/ (in 'fish' and 'cough'). Also, different forms of the same letter, e.g. 'G', 'g', '*g*' or 'g'.

Di-graph A group of two letters representing one phoneme, e.g. 'th' or 'ar' (in 'the' or 'car').

Grapheme The graphic representation of a phoneme, i.e. a letter or combination of letters.

Morpheme The smallest meaningful linguistic unit that cannot be divided, e.g. 'man' or '-ed' (as in 'walked').

Morphology The study of the structure of word forms or morphemes.

Orthography A spelling system; also the study of written language and spelling.

Phoneme The smallest unit of sound in language that be used to make a meaningful distinction.

Phonology The study of the sound system of language.

Semantics The study of the meaning of language.

Syllable The unit of organization for a sequence of speech sounds, e.g. the word 'tablet' comprises two syllables: 'tab' and 'let'.

Syntax The study of the principles whereby words of other elements are combined to form grammatical sentences.

Tri-graph A group of three letters representing one phoneme, e.g. 'ing' or 'igh' (in 'sing' or 'sigh').

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Chapter 1

Introduction and overview of the thesis

1.1 Introduction

Literacy skills are vital to success in modern society. They are central to learning in school and they influence a person's subsequent passage through life. Literacy is not purely an educational issue: it comprises essential skills which allow people to participate fully in society and to contribute to the economy (National Commission on Writing, 2005).

The concept of literacy encompasses not only the ability to decode and interpret text as in *reading* but also to communicate thought, through language, in symbolic form as in *writing.* Logically, these two aspects of literacy should be considered equally important; in reality, education systems in many countries seem to place less emphasis on writing than on reading, resulting in a disparity of success between the two in the primary years and beyond.

Achievement tests show that not all young people master adequate writing skills (see below) and failure can be attributed to a number of different factors. However, it is commonly noted that certain specific populations of children struggle to write and this thesis focuses on one such group, as is illustrated in the case study below.

1.2 A case study

The lines of writing shown in Figure 1.1 were written by a boy named Sam aged 11 years.

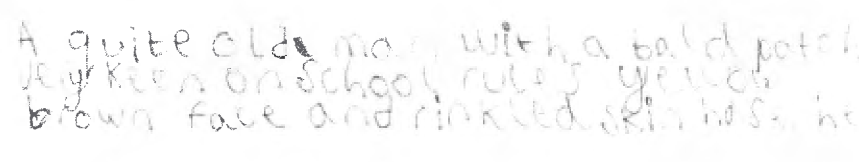

Figure 1.1 'My teacher' by Sam aged 11 years

Sam attends a mainstream primary school in North London and is described by his teachers as an intelligent boy with considerable difficulty writing. As part of their concern they note that he is poorly coordinated and has struggled to master fluent handwriting and spelling. Formal assessment confirmed him to be of gifted ability with a measured verbal IQ of 143, orally competent and a good reader. He is also seen to be sociable and from a supportive home; in short, not the kind of child expected to have difficulty with written expression.

The task set for Sam (illustrated) was to write about a person known to him, taking thirty minutes. This description of his teacher is his total output and clearly the work does not reflect the intellect of its author. Apart from the fact that only three lines of writing have been produced in the allotted time and that the handwriting is ill formed, Sam is not writing in full sentences, he has produced few ideas and these are sparsely expressed. Also, despite scoring near ceiling scores for vocabulary on the formal IQ test, Sam's choice of words is limited. In contrast, when asked to describe his teacher orally he produced the following response:

> "Mr. Hanson is quite an old man with not much hair. He has a bald patch on the top and his head is shiny like a beacon. He has brown skin and a wrinkled face and he wears his glasses on a string round his neck.
>
> He is very conventional and likes us to obey the school rules. If you do something wrong he gets very angry and starts shouting like a maniac. He is particularly keen on us being neat and tidy and makes us tuck our shirts in. He teaches Geography and gives us lots of homework which is often quite long and boring. He is very unpopular and no one relishes being in his class."

For comparison, Figure 1.2 shows part of the piece written by Sam's classmate on the same task.

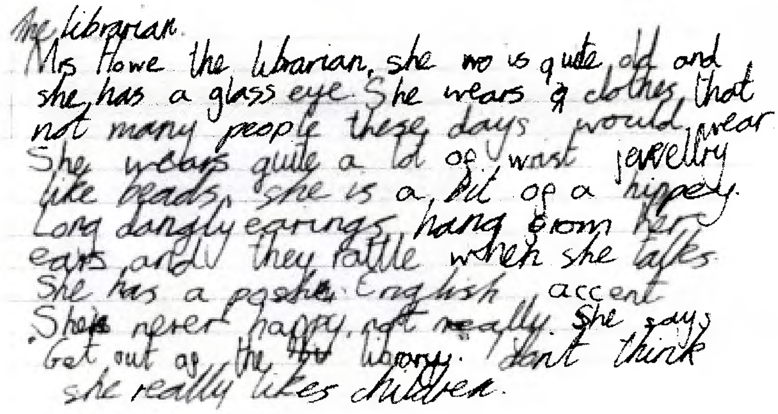

Figure 1.2 Writing sample from Sam's classmate on the same task

This boy, of similar age and ability to Sam, has produced a great deal more text and it contains some interesting ideas. Additionally, his handwriting is fluent and confidently produced, if a little untidy. The teacher notes that this piece is in line with class expectation which Sam's is not.

A case such as Sam's raises a number of questions:

1. Why does a boy with a high intellect and good oral language skills fail to express himself in writing at an age-appropriate level?
2. Is there an association between (a) Sam's poor handwriting and (b) the "thinness" of the written content produced?
3. Does the physical act of handwriting affect the written content by making excess demands on limited cognitive resources and overloading them or diverting them away from the process of composing?

Some of the reasons why Sam and others like him have difficulty expressing themselves in writing will be explored in this thesis but before considering this problem in any detail, it may be useful to consider the place of writing currently within our culture.

1.3 Handwriting, writing and educational attainment in the 21st century

In the UK, levels of achievement in literacy are monitored by means of national exams in core subjects at two key points: at 11 years of age and again at 16. At 11, at the top of primary school (the end of Key Stage 2), children are tested in English and Maths using Standard Attainment Tests known as SATs. English is sub-divided into reading and writing, with separate marks awarded for each. Recent results show that excellent standards were achieved in reading at this stage with 87% of girls and 80% of boys reaching the required level (DfE, 2011), and this success is supported by a wide body of research. Success in writing, however, lags behind. Key Stage 2 SATs results for writing (which include handwriting) during the same period show that only 75% children reach the required standard at 11 years of age, (81% girls and 68% boys). This figure has increased only slightly over the last decade (www.DfE.education.gov.uk/statistics)[1], confirming that there is still some way to go before all children enter secondary school as competent writers.

From a different perspective, The National Literacy Trust's annual literacy survey for 2011 produced interesting findings on young people's attitudes towards writing. For example, 14% of young people said they do not enjoy writing at all; 24.6% said they never write outside the classroom and 13.8% agreed they would be embarrassed if friends saw them write (National Literacy Trust, 2012). This suggests there are real issues to be addressed in written literacy for the growing generation. Importantly also, a gender gap in writing has been consistently reported since 1994 with girls outperforming boys throughout the primary years (e.g. Berninger & Swanson, 1994; Stainthorp & Rauf, 2009). The disparity in competence between reading and writing, particularly for boys, continues to be a concern for educators.

Poor standards of writing are not just a UK phenomenon. In the United States at a summit convened in January 2012 to share cross-disciplinary research into the place of handwriting in the 21st century, it was estimated that 25-33% of US school students struggle to handwrite (Conti, 2012). Thus it would appear that in two major cultures in the developed world, standards of writing do not match those of other aspects of literacy.

Writing serves many functions including the recording and storing of information, the organisation and transmission of ideas, the expression of thoughts and feelings and as a tool for remembering and learning (Grabowski, 2005; Graham, 2009; Torrance & Galbraith, 2006;). Writing, or more specifically *symbolic expression*, can be accomplished through various means: through handwriting, through keyboard use or through the use of voice-activated software. All are available to the current generation. However, despite computer-based technology becoming a critical part of every child's life, handwriting is thought to confer benefits over keyboarding for certain writing tasks. For example, a study by Connelly, Gee and Walsh (2007), found that at aged 10-11, children's compositional quality was superior in handwritten scripts as opposed to keyboarded scripts, with keyboarded scripts developing up to two years later than handwritten. Anthony, Yang and Koedinger (2007) found effects of handwriting on speed of learning in maths when students were allowed to choose whether to use handwritten or typed mode for their output. Handwriting resulted in similar learning gains to typing but in much less time. Additionally, the students seemed to experience a higher degree of transfer in handwriting than in typing, based on performance during training. Berninger, Abbott, Augsberger

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[1] Changes in 2012 from external testing to teacher assessment in writing make comparisons between this year and former years unreliable.

and Garcia (2009) asked 100 children aged 7-8, 9-10 and 11-12, to write an essay using first pen and paper and then keyboard, and found that at all ages the children wrote longer essays which contained longer sentences and were produced faster when using pen and paper. In some of these studies, it was difficult to determine whether the degree of practice in handwriting and typing was properly controlled so it may have been that familiarity with the mode of production played a role in the outcome. Also, order of task performance was not taken into consideration. Nevertheless, the breadth of data across ages and tasks does suggest that handwriting may confer an advantage.

The benefits of handwriting apply not only to children. It is often reported by adult professional authors (e.g. John Le Carre, Julia Donaldson, Philip Hensher) that handwriting helps to stimulate the flow of creative ideas, many of them choosing to handwrite their early drafts for this very reason (The National Handwriting Association: www.nha-handwriting.org.uk). One possible explanation of this phenomenon is offered by Berninger and her colleagues (2009) who suggest that the formation of letters by hand strengthens the memory of a word in a way that typing the same letter sequence does not. In turn, this increases the general fluency of written production. It is possible, of course, that this phenomenon is true only for those who were taught first to write by hand before learning to type but no evidence to date suggests that handwriting is becoming any less useful as a means of written expression.

Despite these benefits, many people question whether writing by hand is still an essential skill as alternative technology becomes increasingly available (e.g. BBC Radio 4 October 2012; The Times newspaper, March 2012). Only recently, calls have come from the official body of school inspectors in the UK to allow increased use of computers for examining school children. However, the case for ceasing to promote handwriting is still not convincing, as the evidence presented at the US summit (2012) demonstrates. In addition, a recent study conducted in the UK of undergraduate students' writing preferences found that 90% chose to handwrite for exams rather than to use a keyboard (Mogey et al, 2008) and an earlier attempt to replace handwritten exams with computers met with a number of impediments, both practically and ideologically (Mogey, Cowan, Paterson, & Purcell, 2008). It would seem, therefore, that more research is needed into the relative merits of the two different writing modes before handwriting is consigned to the past, and it still appears to be the preferred mode of transcription for many people in many contexts.

One final argument for continuing to promote handwriting is a very practical one. While computers are present in most of today's classrooms, few, if any, schools use keyboarding as their primary mode of teaching writing. Thus, handwriting currently plays a key role in education as the medium through which a young person's knowledge, understanding and ability are measured, both in school and at tertiary level (Browne, 1999). Assessment tests at all stages, both in the UK and around the developing world, are required to be performed in handwritten form, with exceptions only for those with severe handwriting difficulties. Even at tertiary level and beyond, handwriting is still vital, as most university students and young professionals are required to sit handwritten examinations as part of the successful completion of their degrees and professional exams despite course assignments being accepted in typed form. Although some difficulties exist with regard to using exam performance as the sole measure of attainment (Smith, 2005), considerable weight is currently attached to these results, making it critical that the mode of expression students employ in these assessments is taught and practised in schools if they are to succeed.

1.4 Handwriting difficulties and their impact on academic attainment

As attainment tests show, not all children learn to master the skills required for writing by the time they reach secondary school. Concerns over failure to master a skill which is still so important across all cultures has led to a resurgence of research into the field, particularly in populations where writing difficulties are common, e.g. as in children with developmental disorders such as Dyslexia (Connelly, Campbell, MacLean, & Barnes, 2006), Specific Language Impairment (Dockrell, 2009), Attention Deficit Disorder (Racine, Majnemer, Shevell, & Snider, 2013) and Learning Disabilities (Graham, 1990). However, there is one group of children whose failure to write competently is especially noticeable but hard to explain - children of high verbal ability who read well and whose only visible problem is one of poor motor coordination.

As a teacher supporting children with poor motor coordination in mainstream schools, I have found that those in this group often fail to express themselves adequately in writing. Most often they are referred for *hand*writing help, as it is this difficulty which teachers focus on. Certainly my own observations confirm that handwriting difficulties frequently accompany other motor difficulties and these may vary in their precise nature. For some children the letters and joining strokes are wrongly formed and the handwriting tends to feature spatial or directional errors suggesting a difficulty linking perception and action. For others, the handwriting is simply untidy or difficult to read, suggesting a more isolated problem of motor control. For another group, writing is produced slowly and requires undue effort, whilst discomfort and fatigue are also frequently reported (Case-Smith & Weintraub, 2002). It is also true that problems can be experienced in any one or in several of these areas.

However, despite handwriting being the primary cause for concern in many children referred, it appears that the motor production of text is only part of the frustration felt. Teachers report that, as well as scripts being poorly presented, the content of the written work is below standard, with assignments lacking depth and breadth and being poorly structured, even in the intellectually able. They note that written compositions seem somewhat "thin" when compared with what the child can produce when speaking, and not only do these children write less than the rest of the class, but their use of language and the way ideas are expressed in writing can also be severely compromised (as in the example at the start of this chapter).

Many of these writing difficulties are surprising in that they can occur in able children who are articulate and demonstrate no problems in other areas of literacy, particularly reading, where most appear to be proficient. Their skill in speaking and reading contrasts with their inability to perform at the same level when writing work down. This association between poor handwriting and weak composition went unrecognised for many years. However, the phenomenon has now gained recognition in the research community where the relationship between handwriting and the higher order processes involved in producing well-structured compositions is being studied both in the general population of school children and in university students (e.g. Alamargot & Fayol, 2009; Berninger, et al., 1997; Christensen, 2009; Connelly & Hurst, 2001; Galbraith, van Waes & Torrance, 2007; McCutchen, 1996; Olive, Alves, Castro, & Branco, 2009; Stainthorp & Rauf, 2009). Despite this, the particular issues which poorly coordinated children experience with written expression beyond handwriting have not been studied to date and this thesis aims to address this gap in knowledge.

1.5 Handwriting difficulties and Developmental Coordination Disorder

Because handwriting represents the *physical* expression of language on paper, an act which demands high levels of motor control, handwriting difficulties are especially common among children who have generalised problems with motor coordination, often identified as having Developmental Coordination Disorder (DCD) (Barnett & Henderson, 2005; Mandich, Miller, & Polatakjo, 2003; Miller, Missiuna, Macnab, Malloy-Miller, & Polatajko, 2001; Zoia, Barnett, Wilson, & Hill, 2006). The need for the smooth execution of a structured sequence of highly complex and coordinated fine movements, working under precise spatial and temporal constraints, makes handwriting a complex and highly skilled activity, difficult to acquire even for the typically developing child (Thomassen & Teulings, 1983). Since this is the case, in this thesis children who meet the criteria for DCD are the major concern. For them, handwriting difficulties are so common that *"a difficulty with handwriting"* is listed among the diagnostic criteria for identifying the condition (DSM-IV, APA, 1994, 2000). A direct association between handwriting difficulties and underachievement in school is often suggested in the literature (e.g. Dellen, van Vaessen, & Schoemaker, 1990; Gubbay, 1975; Losse, et al, 1991; Sprinkle & Hammond, 1997) but although there is evidence from teacher reports to link them, no one has tested this association empirically or studied it in any depth. Possible problems with handwriting are worth studying in their own right, but research into writing difficulties which extend into the qualitative aspects of written composition need also to be explored in this group, hence the studies undertaken as part of this research.

1.6 Plan of the thesis

1.6.1 Literature reviews - theoretical background to the research chapters 2 - 5

Prior to planning the empirical work contained in this thesis, three separate bodies of literature were consulted: the first related to the writing process in general, with particular reference to theories of writing; second, the literature relating more specifically to *hand*writing, and third, the literature on Developmental Coordination Disorder.

The review begins in Chapter 2, which offers a definition of "written expression" or "writing" and follows with a look at the nature of the writing process in general (a topic developed more fully in Chapter 3). Expression in written and oral modes is compared and the relationship between them as well as their developmental trajectories is explored. Finally, current knowledge of the development of handwriting and spelling is discussed and research into the relationship between these two components considered. The chapter also deals with definition and description of difficulties of written expression, with particular emphasis on research into deficits in handwriting development. The evidence of writing difficulties within specific populations is also reviewed at this point.

Chapter 3 examines models and theories of writing in some detail. Taking a historical perspective, early models, which influenced current thinking, are first outlined. Next, information-processing models, taken from neuro-cognitive psychology, are examined with a view to understanding how linguistic units are translated into letters and words on the page. This is followed by a description of the most recent model describing the developmental trajectories of novice and improving writers as well as the most enduring model of handwriting itself. Finally, models and theories of how limited cognitive capacity impacts on the execution of writing are critically evaluated. Particularly important at this stage is a discussion of the concepts of fluency and automaticity in the writing process and their possible relevance to deficiencies in written production.

Chapter 4 examines Developmental Coordination Disorder (DCD) in detail with particular reference to the relationship between handwriting and this motor disorder. What is known about the nature and prevalence of the condition is reviewed and issues surrounding the definition and diagnosis of DCD are discussed. Evidence of educational under-achievement in children so described is examined with particular reference to writing. The incidence of co-occurrence of DCD with other developmental disorders is also addressed.

Chapter 5 addresses questions relating to the design and methodology of the four empirical studies, which follow. First, the theoretical background to the research is set out and then the studies are set in context. The aims of each study are introduced and issues surrounding recruitment of participants, choice of standardised tests, structuring of experimental tasks and data collection and analysis are discussed. This marks the end of the theoretical part of the thesis.

1.6.2 Empirical work - chapters 6 - 9

The second half of the thesis describes the empirical work undertaken in search of answers to the research questions outlined in Chapter 5. A series of four studies are described, each of which explores the written expression of poorly coordinated children with handwriting difficulties in a slightly different way.

Study 1, reported in Chapter 6, is an exploratory study which examines the profiles and types of handwriting difficulty experienced by children at the top of the primary school who have been identified by their teachers as having "unexpected" writing problems. Their performance in writing on a narrative task is compared first with their performance on the same task in oral mode and then with the performance in both modes of age-, gender- and ability-matched controls. The results of this study raise questions about the influence on the translation of ideas into linguistic units of the mode in which they are expressed, and the possible effects of order when using the same task for both modes. For this reason, Study 2, reported in Chapter 7, examines whether, when a task is performed in both modes, the order in which they are performed influences the outcome. Of particular concern in this study is whether children identified as having Developmental Coordination Disorder (DCD) respond differently to this manipulation from typically developing children, again matched for gender, ability and age.

Few studies have been undertaken to describe the long-term educational outcomes of poorly coordinated adolescents and none have looked specifically at written composition. Longitudinal data for children with DCD (e.g. Losse et al., 1991; Cantell, Smyth, & Ahonen, 2003) show that general motor problems tend to persist beyond the primary school and that academic grades often remain poor. Although some of these studies mention that handwriting is an on-going problem, none provides any detail on either the nature of the difficulty or the direct consequences. To fill this gap, Study 3, reported in Chapter 8, was undertaken as a five-year longitudinal follow up of the children who were tested in Study 1. In order to discover whether the writing difficulties identified in the primary school are still evident after puberty and if so, in what form, children were tested on the same or similar age appropriate measures as were used in Study 1. Also, it examines whether the developmental patterns observed across the sexes differ in the target DCD group from their typically developing controls.

Although the findings of the first three studies provided valuable data on the nature of handwriting difficulties in children with DCD and their effect on written composition, their design did not permit the testing of specific theories which might tell us more about how exactly a perceptuo-motor deficit might lead to a problem with the composition of a story a child was asked to write. For the final study in this thesis, therefore, a completely different approach was taken with the specific objective of employing a theory, known as "capacity theory", to generate and test specific hypotheses relating the physical act of handwriting to the more cognitive-linguistic aspects of writing. Described in Chapter 9, Study 4 is designed to yield evidence of possible effort in the handwriting of children with DCD, consistent with the proposition that the excess demand involved in the handwriting process of non-proficient writers borrows from limited resources needed for composing. Here, the handwritten performance on certain specifically designed tasks is examined, using computer software to analyse dynamic and spatial aspects of the writing of children with and without DCD, testing also the impact of exceptional spelling on handwriting fluency. The results of this final study are presented in the light of the findings of the earlier studies.

In conclusion, Chapter 10 summarises the findings of all the studies and discusses the implications for schools in supporting children's writing skills, especially in those with specific impairments. The theoretical and practical contributions which this research can make will be outlined and possible areas for future research will be identified.

Chapter 2

Written Expression:

Its nature, development and relationship with oral expression

2.1 Introduction

The terms "written expression" and "writing" relate to a lasting visual representation of language through symbols on the page. Their definitions in the Oxford English Dictionary suggest that the terms can be used interchangeably (OED, 1989) and as this seems be the case in the literature, it will be adopted for this thesis. The concept of written expression or writing can be regarded both as the *product* of expressed thoughts and ideas in written form, and also the *process,* or sum of sub-processes, by which the product is achieved. The latter is dynamic, the former a completed act.

Writing is often mistakenly regarded as a unitary, homogenous activity, that of translating conversation into symbols (Torrance, 2007). However, the process of expressing thoughts in written form is a complex one, involving a number of different linguistic, cognitive, perceptual and motor sub-processes, all of which have to be coordinated to produce meaningful and coherent written text (Christensen, 2009; Hart-Paulson, & Moats, 2010, pp. 70-80). It includes having a central plan about what to write, collecting and retrieving relevant information from memory, organising the specific ideas to be communicated, translating those ideas first into language then into linguistic units (words, phrases, sentences and paragraphs) and then transcribing those units, motorically, on to the page. Finally, the text will need to be revised and edited to form a cohesive whole (Kellogg, 1994). The way in which these different component skills are performed or orchestrated is the topic of continuing research (e.g. Alamargot, & Fayol, 2009; Olive et al., 2009).

The various language-specific processes involved in translating ideas into written form include lexical knowledge, semantic coding, phonological coding and the monitoring of syntactic structures (Bain, 1991; Berninger, 1994; Levine, 1987) as well as knowledge of orthographic conventions and the constraints of each particular writing system (Kandel, 2010). Current views of how this is achieved are discussed in detail in Chapter 3 through looking at models and theories of writing. However, at this point, it might be useful to begin by considering how our ability to learn to express ourselves orally develops and interacts with the later acquisition of writing.

2.2 The development of oral and written language

It is generally accepted that the four language systems, listening, speaking, reading and writing, share a common core (Berninger, 2000; Shanahan, 2006; Vygotsky, 1978) with writing being the last to be mastered (Johnson & Myklebust, 1967). Berninger's description of the four systems as "language by ear, mouth, eye and hand" reflects this commonality. She suggests that as the child matures, the different systems develop, not in discrete sequential stages but rather in parallel and overlapping waves, the mastery of each developing along a continuous trajectory whilst influenced by the other forms of language (Berninger, 2000). Understanding how the different language systems develop and interrelate is important in shaping our understanding of how a writer's performance is influenced by competence in the other systems, particularly with the oral language system where the "inner voice" plays a part in preparation for what is to be written down (Chenoweth & Hayes, 2001).

In all cultures speaking develops before writing. Indeed, not all of the world's languages have a written form (Lewis, 2009) so there would appear to be nothing natural about being able to write (Peregoy & Boyle, 1997, p. 2). In languages where writing does exist, children become fluent in the spoken form before learning to write and it is widely believed that competence in the oral domain facilitates the acquisition of writing (Garton & Pratt, 1998). A young child begins to develop speech towards the end of the first year, by mimicking vowel and consonant sounds around four months and producing single words from around ten months (Dworetzky, 1993; Vihman, 1993). At this age, writing has not yet begun to emerge. Cognitive skills are not developed to a high enough degree to allow the child to understand the concept of symbolic representation, nor will he have the perceptual ability to discriminate and assimilate letter shapes or have the fine motor control of hand and fingers required to manipulate a writing implement. However, in the following four to five years, some major and rapid developments will take place.

The spoken language of the child increases several-fold and typically he will have established a vocabulary of around 2,000 words by five years of age as well as having mastered the main components of grammar (Hulit & Howard, 2002). During this same period some rudimentary writing skills will begin to develop. The child will attempt to make marks on different surfaces with an array of implements and may well be able to achieve these on paper using crayons or jumbo pencils. Marks will at first emerge as drawings or pictorial representations rather than symbols but they enable the child to experience a nascent form of writing through producing lines and strokes to which he attaches meaning. Also, in a more formal way, he may learn to print letters by imitating, first vertical strokes (at about 2 years), followed by horizontal strokes (2.5 years) and circles (3 years). At 4 years of age the typically developing child can copy a cross, followed by a square (5 years) and a triangle (5.5 years) (Beery & Buktenica, 1989). At this stage, however, most children will be unaware of the exact relationship between the spoken word and the forms on paper. This highly specific association has to be made explicit as part of writing teaching, but the typically developing child will have observed adults around him using writing to convey meaning and will copy those actions in play.

From five years of age onwards, the increase in vocabulary and semantic complexity in oral language continues at a fast pace throughout the primary years and beyond into adulthood unless the process is impaired or interrupted (Mackie & Dockrell, 2004). In contrast, the ability to write does not develop automatically. It has to be modelled and explained, and the detailed components of handwriting, such as the way in which specific symbols or groups of symbols represent the sounds, words and sentences which comprise writing, systematically taught. Handwriting studies of typically developing children show that where this is done, handwriting quality develops quickly between 6-7 years, reaching a plateau at 8-9 years (Blote & Hamstra-Bletz, 1991; Karlsdottir & Stefansson, 2002). Speed of handwriting appears to increase in a linear fashion throughout the primary school and continues during the middle school years (Barnett, Henderson, Scheib, & Schulz, 2007; Feder & Majnemer, 2007).

It would seem logical to assume that oral language underpins written language (Fletcher, 2009; Harrell, 1957; O'Donnell, Griffin & Norris, 1967) and that the process of converting thoughts into oral language is a pre-requisite of being able to write them down, as suggested above (Juel, 1988). In general, the literature supports this idea. The extent and complexity of written language is strongly influenced by that of oral language and research shows a clear and consistent relationship between measured verbal intelligence (as evidence of oral competence) and writing, leading to an assumption that both forms of language draw on a common set of cognitive abilities (Shanahan, 2006). However, there is also some evidence to suggest that the developmental trajectory followed by the two modes differs. With regard to length for example, typically, in the early to middle primary years, more words are produced when the child speaks than when he writes. This difference then disappears as the child matures, usually assumed to be as a result of increased mastery of handwriting and spelling, and this changes the relationship between the two forms of language by the secondary years (Bereiter & Scardamalia, 1987; Loban, 1976; O'Donnell et al., 1967; Olive & Kellogg, 2002). Similarly, in compositional terms, younger children's spoken stories have been found to be of higher quality than those which they write down. However, the superiority of oral over written mode in composing disappears, first, as verbal working memory expands with age and second, as other sub-processes become more automated (Bereiter & Scardamalia, 1987; Berninger, Fuller & Whitaker, 1996; McCutchen, 1987).

In addition to length and quality of output, other more specific developmental differences between modes have been reported in the literature. For example, cohesion of compositional content has been found to develop in oral language before being reflected in writing (Cox, Shanahan, & Sulzby, 1990) and morphology and the knowledge of linguistic structures appears first in oral, then later in written language (Carlisle, 1996). In all of the above studies it was found that most morphological errors identified in writing could be explained by similar errors in the speech of the individual. Interestingly, however, in a study of learners with linguistic deficits, Naucler and Magnusson (2002) found that if children had experienced problems acquiring oral language, writing suffered even after the oral expression had been remediated. This suggests that the dependence of written expression upon oral competence is fundamental and that the foundations for writing are laid down very early on in the child's development.

To date, studies which provide comparable data on oral and written language in children suggest that in a typically developing population, young children finds it easier to express themselves orally than in written form. However, around the age of 10-11 years of age, the superiority of oral over written disappears and the amount of text produced and the quality of content between oral and written modes of expression appear to be roughly equal (Bereiter & Scardamalia, 1987; Olive & Kellogg, 2002; McCutchen, 2006). During early adolescence the balance seems to change again, with written language overtaking oral as the superior mode. At this stage, not only are written narratives longer, but they contain more ideas, more complex structures and are expressed in a wider vocabulary (Applebee, 2000; Berman & Verhoeven, 2002). Also, older children write more coherently than they speak (Cox, Shanahan, & Tinzman, 1991; McCutchen, 1986, 1987; Wright & Rosenberg, 1993). However, further developments in the more accomplished writer may lead to a later levelling out of the previous mode differences altogether. Myhill (2009), for example, has noted that styles and structures of language, developed through writing during the learning process, may, in turn, influence how spoken language is constructed. Conventions over the way language is structured in writing when delivering narrative, for example, spill over into oral storytelling, supported by increased memory capacity, with the result that more sophisticated linguistic structures and complex compositional strategies can be utilised. This is yet more evidence of the cross-modal interplay proposed by Berninger (2000).

While the general trends reported in these studies may be correct, it's important to note that most of the data in these studies are cross-sectional rather than longitudinal and many employ tasks that are not directly comparable (e.g. the much quoted study of Loban, 1976). As a result, interpretation of the findings with regard to specific ages should be treated with some caution. In the studies reported in this thesis, care is taken to ensure the children taking part and the tasks employed are comparable.

2.3 Different sub-processes within writing

As was discussed earlier, the writing process encompasses everything that happens between the conception of an idea to the marks on the paper and involves a number of cognitive mechanisms, only some of which are addressed in this thesis. Broadly speaking these processes, which vary a great deal depending on whose theory one is considering, are divided into two groups: those which address the content of what is written and those which relate to how that content is delivered. Some authors refer to those which relate to composition as "higher-order" processes and those to transcription, such as handwriting and spelling as "lower-order", but this terminology is often used by those who fail to acknowledge the complexity of the perceptual and motor processes involved in transcription. Without accepting this hierarchical view, each of these aspects of writing will be dealt with separately below.

2.3.1 Composition

Literary composition refers to "the putting together or assembling of parts into words" (Shorter Oxford Dictionary, 2007). The term describes the way thoughts and ideas are encapsulated in language to be communicated. Good composition involves the crafting of words to convey meaning in the particular way the author intends and is highly demanding of intellectual resources. Researchers have modelled the processes involved in composing for over thirty years and Chapter 3 of this thesis is devoted to a discussion of these models and theories, as well as a review of the relevant studies which pertain to them. Thus, the aim at this point is purely to demonstrate the complex and demanding nature of the act of composing in order to show how easily these mechanisms can be disrupted if subjected to interference. Also, although it is beyond the scope of this thesis, it should be recognised that composing is not only a cognitive and linguistic activity but a social and cultural one, drawing content from the cultural context in which the author writes and structuring it to best appeal to the intended audience. Thus, when asking children to tell or write a story, as is done in the studies that follow, their cultural background and the purpose of the tasks may well influence the resulting narratives.

2.3.2 Transcription

Historically, greater status has been assigned to the compositional rather that the transcription aspects of writing, yet increasing evidence shows that composition is not independent of the manner in which composed thoughts are transferred to the page. Both handwriting and spelling are critical to the whole writing process and unless they are achieved smoothly and with minimum effort, the content of what is written can be negatively affected (Bourdin & Fayol, 2000; McCutchen, 2006; Olive et al., 2009; Torrance & Galbraith, 2006). Where transcription skills are efficient, composition may be positively affected, some authors even suggesting that fluent handwriting stimulates creative thinking more than keyboarding does (Berninger Abbott, Augsberger & Garcia 2009). In what follows, the process of handwriting is dealt with in greater detail and reference is also made to the contribution which spelling makes to the smooth transference of words on the page.

2.3.2.1 Handwriting as a crucial component of transcription

Using graphic symbols to represent meaning is very old. Since the discovery of tablets bearing hieroglyphs in Mesopotamia or cave paintings in France, man has used symbols to communicate with others. It is believed by many that writing is the very skill which differentiates humans from lower animal forms and some also argue that the development of writing has led to the development of civilisation itself (MacGregor, 2010). However, writing is not a skill which is instinctive or develops naturally like other motor skills, such as running or throwing an object, or even drawing; it is a skill which has to be taught, and this includes the formation of the individual symbols as well as the spatial and directional conventions specific to each writing system (Barnett & Henderson, 2005). Young children instinctively make marks, but without guidance those marks will not develop into a sophisticated written symbolic expression of language.

Additionally, handwriting is not purely a motor skill, although it greatly depends on good motor coordination. Cognitive, linguistic and perceptual skills are also involved, especially during the acquisition phase. Knowledge of written conventions and the linguistic constraints of each particular orthography require important cognitive input (Apel, Wolter & Masterton, 2006) and understanding the significance of, as well as being able to "see" and reproduce, the accurate spatial organisation of letters and words on the page are dependent upon keen visual perceptual skills (Chu, 2000). Evidence to support the view that there is more to handwriting than purely motor competence can be found in the data provided by the Detailed Assessment of Speed of Handwriting (DASH) (Barnett et al., 2007). This comprehensive test assesses children's handwriting speed across five separate tasks, four involving alphabetic script (at either letter or word level) and one purely graphic task where the child is required to repeat a letter-like form as accurately as possible. The results across the UK from the four alphabetic tasks were substantially inter-correlated (.50 - .81 for this age group: the reliability estimate for the total scores being similarly high at .87), but the results of the fifth, graphic non-alphabetic task, show that this is only modestly correlated with the other tasks at each age (.05 - .45), suggesting that tasks which require alphabet letter writing involve greater levels of processing than the task which depends purely on fine-motor control.

2.3.2.2 Handwriting's link with spelling

An additional source of data suggests that transcription is more complex than the physical reproduction of strings of symbols. Recent research into written spelling has shown that, in the writing of alphabetic script, the processing of orthographic codes comes into play. At the most basic level this involves the translation of phonemes (sounds) to graphemes (symbols) using knowledge of general spelling rules and patterns, but it also involves factors such as the implicit appreciation of orthotactic (positional) constraints on the sequences of graphemes, i.e. whether graphemes are allowed in certain positions in the word, and also the probability of the occurrence of various combinations of graphemes within words (Apel et al., 2006; Kandel, 2010). This clearly links the production of handwriting with processing relating to spelling and suggests that writing cannot be studied without orthographic factors being considered (see below for greater detail). It is this integration of orthographic coding with the fine-motor skills required for writing, or "*orthographic-motor integration*", which makes handwriting unique (Berninger, 1994; Berninger, Yates & Lester, 1991; Christensen, 2004; 2005).

2.3.2.3 How handwriting develops

As was mentioned earlier in this chapter, handwriting develops comparatively late in a child's acquisition of language and noticeably after the onset of speaking, which incidentally also requires a very high degree of motor coordination. Despite the fact that the use of the hand is not directly linked to the expression of thought for some time, all children seem instinctively programmed to use the hand as an instrument of communication, starting with pointing and gesticulating, and then engaging in clapping and singing games with actions. While all of these activities converge to set the child up for communicating through writing, gesturing, signing and mark making need to be transformed, with teaching, into the more formal writing of symbolic language. It is widely accepted that children as young as three years of age attempt to play at writing if they have observed adults doing so, thus developing an understanding of the concept of symbolisation and the physical representation of meaning (DfE, 2008). Scribbling is a pre-cursor of letter formation with toddlers learning to imitate lines and shapes (Feder & Majnemer, 2007) and drawings are used to tell stories. By the age of four years they may be ready to form regular letter shapes and by the age of five will be able to copy and reproduce most letter forms with a writing implement if taught (Henderson & Pehoski, 2006; Jarman, 1979). It has been found that the skill in writing letters from the age of four years is related to letter knowledge and children who participate frequently in adult-child writing activities that include a deliberate focus on print have better alphabet knowledge relative to those who may spend time on other activities like shared reading (Aram & Levin, 2004). Although size and alignment will be variable during the early primary years, the child is well able to understand and learn to form and join letters into words during this period so that the subsequent focus can be on refinement of execution (Sassoon, 2003).

A fairly detailed study of the development of handwriting provides useful data on when children first acquire different components of writing. Graham, Berninger, Weintraub & Schafer (1998) assessed 900 American school pupils from grades 1-9 (ages 6-16). Their findings on three different tasks, copying, narrative writing and essay writing, suggest that once letter forms have been established, the improvement in accuracy is concentrated around the intermediate grades, whilst the speed of handwriting increases steadily from one grade to the next. Although the pace of development tends to be uneven during the intermediate grades it levels off in Grade 9 (age 15-16) as speed begins to approximate adult levels. This study also notes developmental differences in gender and handedness, girls writing faster than boys in Grades 1, 6, and 7 and right-handers being able to write faster than left-handers, though there was no difference in the legibility of their written work in the different groups. More recent studies have replicated these findings (e.g. Stainthorp & Rauf, 2009).

There are cultural differences round the world in the way in which handwriting is taught, the writing style which is expected and age at which formal teaching is introduced. Although in the UK, the National Curriculum demands that direct teaching of handwriting commences at five years of age, that letters are joined at six years and cursive writing expected from seven years onward (DfE, 2001), in other European countries, and also in the US, formal teaching of handwriting is delayed by up to two years whilst the focus is on activities to enhance "readiness" for writing. Some practitioners contend that damage may be caused if formal teaching is given too early by enforcing a pen-hold on a child whose fine-motor control is not well enough developed to respond appropriately (e.g. Benbow, 1995) whilst others guard against leaving teaching too late, running the risk of children establishing erroneous letter formation through lack of guidance which has to be corrected later (e.g. Sassoon, 2003) and this debate is on-going.

The essence of successful handwriting is seven-fold: it should be legible, neat, comfortable, fluent, fast, able to be performed with the minimum of conscious effort and to be sustained over time if the tasks demands. In the UK, these goals are largely set out in the National Literacy Strategy (DfEE, 2001), though there has been criticism from experts in the field (the NHA) that too much focus rests on neatness of presentation rather than the teaching of speed and automaticity. Even in the recent revisions to the Primary Literacy Strategy (DfE, 2012), the research evidence on the importance of speed is not really reflected. Although it is recommended that in Year 4 children are encouraged to increase speed and accuracy in typing, there is no mention of speed with regard to handwriting, the emphasis being on adaptiveness at Year 5 and "developing a consistent and personal legible style" in Year 6. In contrast, the earlier mentioned summit on handwriting in the USA has produced guidelines which include writing at speed under the heading "Core subjects, etc".

Where these goals are achieved, handwriting develops as a functional tool for recording and storing language. Because the purpose of handwriting is to communicate with other people or to record ideas to be read by others, the primary goal in learning to write is legibility – being able to consistently produce letters which are recognisable. However, a study into the effect of specific aspects of legibility found that regularity of the handwriting to some extent mitigated effects of inaccurate construction of letterforms (Velay, et al., 2010). These authors suggest that if letter deformations are consistent, the reader accommodates these invariants, making the particular style more legible with time. They argue that it is lack of consistency which contributes most to illegibility not necessarily an irregular letterform. Whatever the detail, legibility is a basic requirement of handwriting. Difficulties in mastering legible handwriting have been shown to contribute to underachievement at school at least in part because of the negative effects which illegibility has on the perceptions of those who grade the work. A meta-analysis of 35 studies in which influence of presentational effects on readers' or scorer's judgments about written text was evaluated, a negative effect of illegibility on judgment of the quality of knowledge content was found in 89% of the studies (Graham, Harris, & Hebert, 2011). In these studies, using a text-modification paradigm, grades for scripts written by illegible hand-writers were given a higher grade rating when resubmitted having been copied by good hand-writers - sometimes by as much as 25%.

In addition to handwriting being readable, it also needs to be easy or comfortable to perform. This way it can be sustained over time if a task so demands. Writing which lacks comfort can cause lasting strain with detrimental results (Benbow, 1995; Sassoon, 2003; Tiburtius, 2003). Another feature of handwriting is that in scripts such as English, the pen needs to *flow* across the page and for this reason the development of cursive script is usually encouraged in schools. This is in contrast to scripts which are based upon pictograms, such as many of the Asian languages, where flow is not so much an issue. In the English script, joining the individual letters in the correct way is thought to enable the writer to produce writing more smoothly and with increased fluency, despite hard evidence on this being scant. Indeed, such studies that have tested the relative speeds of joined versus un-joined strokes show no speed advantage in writing cursively (Graham, Weintraub, & Berningrer, 1998; Hildreth, 1945), though this finding seems not to have influenced teacher attitude or practice. However, whether script is joined or un-joined, the development of handwriting fluency is vital if increased writing speed is to be accomplished at a later stage. Along with legibility, speed is the cornerstone of functional handwriting (Amundson, 1995). Barnett and Henderson (2005) also suggest that the ability to write at speed and to sustain fast writing over time is necessary for students to cope with the demands of the busy curriculum. Indeed, several studies have shown that lack of handwriting speed is more detrimental to accomplishing high quality written work than poor accuracy (Jones & Christensen 1999; Stoodley & Stein, 2006).

Over time, with practice and experience, the skill of handwriting becomes firmly established and gradually the movements involved in performing the letters, words and sentences require less conscious thought: the handwriting becomes more fluent and more automatic. However, the concepts of both *fluency* and *automaticity*, frequently referred to, need some de-constructing. To take fluency first, it would seem that much confusion arises in the use of this term. When used to describe handwriting it is often used interchangeably with the term "cursive" or an assumption is made relating to its association with writing speed. More specifically, the word "fluent" means "flowing", suggesting an ease and consistency of movement, particularly important in the writing of a script such as English which needs to move across the page. It is sometimes overlooked that flowing movements can be achieved both when the pen is *on* and when it is *off* the page. Misconceptions over the need for handwriting style to be continuously cursive in order for handwriting to be fluent and fast are demonstrated in the (few) studies which find no difference in speed between joined and un-joined strokes (Hildreth, 1945). Generally speaking, what the term seems to imply in many studies is some degree of smooth, easy performance of the handwriting strokes which can be effortlessly adapted, if necessary, to faster delivery through release of pressure on the page (Tiburtius, 2003). Fluency is also referred to in the literature to describe ease of written composition (e.g. "compositional fluency": Connelly, Gee & Walsh, 2007; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). In these studies, the term refers to the ability to commit text smoothly and easily on to the page and seems to involve both linguistic and orthographic competence.

The need to develop automaticity in handwriting is also a recurring theme in the writing literature since lack of automaticity has been found to have a serious negative impact on children's ability to express ideas in text (Christensen, 2005; De La Paz & Graham, 1995). Automaticity has been defined as "the execution of cognitive tasks quickly, accurately, efficiently, and without the need for attention to be allocated to the task" (La Berge & Samuels, 1974). When applied to transcription, it is often used to mean that words can be transferred on to the page quickly and without the need to think about either how a word is spelt or how the letters are formed. Automation of handwriting and spelling is something which is expected to be highly developed by the age of ten or eleven years in typically developing children (Berninger, Mizokawa & Bragg, 1991; Levine, 1987; O'Hare, 1999; Ziviani & Elkins, 1984), and Berninger, Fuller and Whitaker (1996) suggest that for children up to this age the focus of concern is still the establishment of fluent translation processes. However, this goal may in fact take longer than expected to achieve. For instance, Nagy et al. (2003) found that ten year olds were still learning to coordinate orthographic, phonological and morphological cues in written words, and Graham et al. (1997) found that transcription skills (handwriting and spelling) contributed substantially to ratings of compositional fluency and compositional quality *throughout* the elementary grades, not just at primary level. In their study, handwriting accounted for 66 percent of the variance in measures of "compositional fluency" in the primary grades but still 41 percent in intermediate grades. Spelling accounted for 25 percent of the compositional quality in primary grades and 42 percent in intermediate grades. Thus, the evidence suggests that handwriting may not become automatic as early as previously thought. In fact, the notion that handwriting could ever become *fully* automatic is open to question. For example, even when the writer has established an internal motor programme for the formation of individual letters, accurate reproduction of those letters in relation to lines and spatial constraints requires a degree of visual monitoring (Thomassen & Teulings, 1983). Often called online processing, it has parallels with operating controls of a car while focusing attention on an unfamiliar road.

Additionally, because handwriting conveys spelt words on to the page, where orthographic patterns vary, not only will the process of *letter* selection require conscious thought but also the process of the selection of the specific *movement sequence.* This means that if one is looking to establish what is meant by automated handwriting, different levels of production need to be distinguished. For example, simple repetitions of single strokes or letters may be able to be reproduced, once learned, without conscious effort, such a looped 'e' or a series of 'e's, (*eeee*) (Marquardt & Mai, 1994). However, not all letterforms are so simple and most contain a series of different strokes, requiring the writer to stem the flow of the pen at certain points and change direction, sometimes more than once. Even so, more complex letterforms can be learned and produced with little effort, though the learning may take longer. However, the writer still has to adapt to the production of a range of different letter combinations to be selected and executed for spelling, making it impossible to claim that this process can ever be fully automated. This is not to say that partial automation cannot be achieved, and this has been shown to have a positive impact in speeding up the process of handwriting (e.g. Berninger, Cartwright, Yates, Swanson & Abbott, 1994), but it should be recognised that some effort will always be required to produce controlled, legible handwritten text which is correctly spelt in a full writing environment. Evidence of the "speed-accuracy" trade-off, a well-recognised phenomenon from the motor learning literature in which handwriting accuracy deteriorates as the writer increases speed (Schmidt & Lee, 2005), is testament to this. It may be that in some instances, the terms "fluency" and "automaticity of production" are used too loosely and it is important in the context of this thesis that the degree to which focus must be ascribed to handwriting and to minimise constraints on composition is clearly defined.

2.3.2.4 Handwriting and its relationship with other components of literacy

The relationship between handwriting and reading is not at all clear. A recent experimental study into the influence of handwriting on the acquisition of reading, presented at the US Handwriting Summit in 2012 suggests that writing of letters enhances perception of letterforms for reading during the early stages of skill acquisition (James, 2012). However, beyond this stage, despite poor handwriting often being reported in young people described as dyslexic (e.g. Connelly, Campbell, MacLean, & Barnes, 2006), there seems little research evidence to back this up. One possible explanation is that the term "dyslexia" is subjected to varying interpretations, and general understanding of the parameters of the disorder is inconsistent.

More numerous than studies which report deficits in common, are those which report dissociations between the different components of literacy. For example, Honeycutt (2002) looked at eleven US 5th grade students (ages 11-12 year) who were identified as good readers but poor writers, based on state-required assessment tests at fourth grade. Using interview and focus group techniques, profiles of reading and writing strategies were identified and compared between modes. It was concluded that these students were unable to generalise and apply concepts recognised in texts they read to those they composed. This and other studies focus on how the positive cognitive strategies that good readers employ during reading can be encouraged to improve general writing performance.

Regarding spelling, it was not the original intention in this thesis to focus on spelling per se but a review of the research on the nature of writing suggests that the relationship between handwriting and written spelling cannot be ignored, given that handwriting, by its very nature, is a production tool for transcribing spelt words. Further investigation of this relationship shows that spelling's role, particularly with regard to handwriting speed, is fundamental (Bourdin & Fayol, 2000; Fayol, Zorman, & Le'te', 2009). For example, there is increasing evidence that the flow of handwriting may be interrupted at points in words where irregular or unexpected orthographic units are encountered (Kandel & Valdois, 2006). Furthermore, despite much of the earlier research into handwriting and spelling being conducted at single letter level (Gottlieb et al., 1989) or at single stroke level (Van Galen, 1990) where the focus is on handwriting accuracy, more detailed research into the relationship between spelling and motor modules demonstrates that knowledge of spelling patterns plays a vital part in the production of handwritten text, not only influencing handwritten production but in turn being influenced by it (e.g. Kandel & Valois, 2006; Kandel, et al., 2009; Kandel & Spinelli, 2010; Kandel, 2010). More specifically, Kandel cautions against conceptualising spelling as mere linear strings of letters. She suggests that orthographic representations are complex multi-dimensional structures that code information that goes beyond the word and the letter (Kandel, 2010, p. 10). Poor understanding of orthographic constraints or weak internal representations of orthographic units can impede handwriting fluency. This research demonstrates how important it is when studying handwriting that orthography is taken into consideration, and, as Kandel herself observes (2010, p. 11), there is little known about how orthographic representations affect the production of writing movements. In this thesis, therefore, it is now recognised that it is vital to look at written spelling's impact on the production of handwriting and examine the way in which these two transcription components interact during the writing process (see Chapter 3).

2.4 Summary

Written expression can be conceptualised as a physically generated symbolic representation of language. The term relates both to the process of writing and also the product. Written and oral expression share a common language base but, although there is a consistent relationship between the two modes, the developmental pathways are not identical, oral mode being superior to written in the primary years, with written catching up in typical development as the child enters secondary school. A further phase where writing is the dominant mode develops in adolescence with the balance between modes being level in adulthood. At every stage, each mode influences the development of the other and the relationship between them is complex.

Ideally, handwriting should be legible, easy, neat, fast and sustainable. The terms "fluent" and "automatic" are often used with some confusion, and it is suggested that a closer definition of these concepts is needed to clarify what is meant by the use of the terms.

The three components of literacy, reading, spelling and writing, develop along different trajectories and at different rates and although the relationship between the three appears to be logical and harmonious in typical development, common patterns of dissociation are frequently reported in the literature.

Having examined the research into the role of handwriting both on its own and as a component of literacy, we need to look more closely at the part it plays within the context of written expression and to do this the following chapter will look at writing models and theories.

Chapter 3

Models and Theories of Writing

3.1 Introduction

Whilst Chapter 2 described the development of, and relationship between, oral and written expression and looked more specifically at handwriting, this chapter now turns to the broader view of writing, examining models devised to explain the nature of the various processes involved and the relationships between them, thereby placing handwriting and composing in context.

The theoretical frameworks within which writing research has been conducted over the years can be interpreted from three main perspectives (see Alamargot & Fayol 2009; Galbraith & Torrance, 1999; Nystrand, 2006). The first views writing through the processes involved in producing, evaluating and organising thought, sometimes referred to as the 'cognitive-enunciative' approach. Here, writing is conceptualised as a unitary activity, albeit a complex one, and it describes the large-scale cognitive processes employed by the individual writer in creating composed text, processes that operate on a level above those of text production. Writing, from this perspective, is seen as a problem-solving activity and is concerned with the way the writer manages large processing components (thoughts) to achieve the communicative goals of a specific writing task (e.g. Hayes & Flower, 1980, 1986; Kellogg, 1987, 1988; Levy & Ransdell, 1996). The problem for the writer is seen as constantly having to monitor the relationship between the production of language and the intention of the task, using strategies which are very costly in terms of cognitive resources (Torrance & Galbraith, 2006).

The second framework describes processes involved with the translation of thoughts into language, usually referred to as the 'psycho-linguistic' approach. In contrast to the first approach, this framework draws heavily on the work of linguists who describe the functional architecture of writing systems. Based initially on Levelt's (1989) model of speaking, this approach was adapted by van Wijk and Sanders (1999) and encompasses both lexical and syntactical processing - semantic, orthographic, phonological. It also is unique in addressing processes relating to graphemic and motor components of text production (Berninger & Swanson, 1994). Because this approach is strongly inspired by models of oral language production, much of the processing described is common to both modes of verbal production (Alamargot & Fayol, 2009). Although the "cognitive-enunciative" and "psycholinguistic" frameworks are characterised by different paradigms, they both represent aspects of cognition and share the common conceptualization that writing is a composite activity which can only be understood if the component processes are first identified, but also studied with regard to the complex way in which they interact. This is important to this thesis which explores the possible relationship between two components– handwriting and composition – which, on the surface, might appear to have no direct connection.

The third theoretical framework, described by Prior (2006), is often labelled the 'social-cultural' approach. Within this, writing is studied from a communicative and cultural perspective, emphasising the importance of the social context in which writing takes place and showing how the audience is influential in shaping the text produced.

Whilst differentiating between these conceptualisations of writing has in the past been commonplace, there is growing evidence for acknowledging the inter-dependence of the three. For example, an increasing number of studies show that the way in which language is transcribed can influence the very generation of the language itself, as well as how it is structured (e.g. Galbraith, van Waes, & Torrance, 2007; Galbraith, 2009). This has led to a blurring of the hard distinctions between the first two frameworks above. Equally, it has also been demonstrated that the context of writing influences both composition (Flower & Hayes, 1981; Nystrand, 2006) and transcription (Alamargot, Dansac, Chesnet & Fayol, 2007), again crossing theoretical boundaries. Taking these findings into consideration, a more contemporary approach might be one in which some recognition of the different perspectives is retained but that a more inter-disciplinary interpretation better describes the fundamental nature of writing and the most influential factors within it.

Having said this, the social and cultural issues in writing will receive less focus than the cognitive or the psycholinguistic approaches in the core work of the thesis because of the nature of the research questions to be answered.

3.2 Early influences

3.2.1 Hayes and Flower's process model of writing

The writing model which still today appears influence thinking on the processes involved in written expression is that by Hayes and Flower (1980), shown in Figure 3.1. This was devised as a result of work analysing protocol transcripts and video evidence of adult students 'thinking aloud' whilst writing.

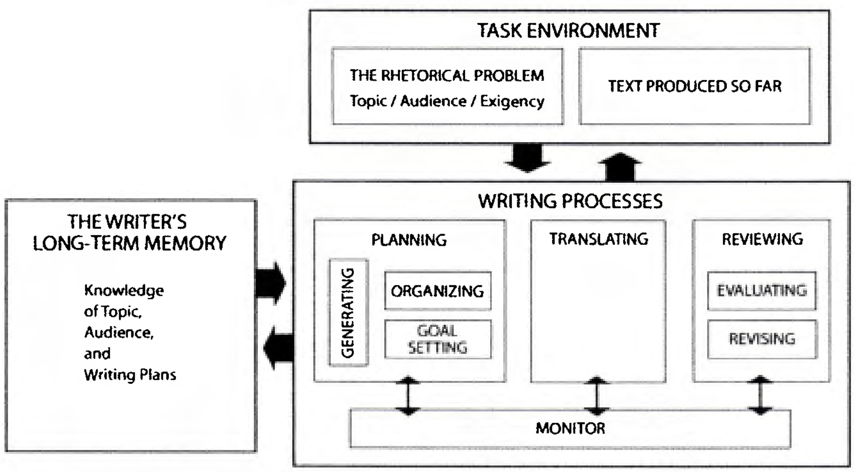

Figure 3.1 Hayes and Flower's process model of writing (1980)

As the model shows, the act of writing was viewed as involving three interacting components: the composing processor, the task environment and writer's long-term memory. The composing processor is presented as the core of the model and is specified in much the greatest detail than the other two. It contains three operational processes: *planning,* in which ideas are generated and organised according to set goals, *translating,* which involves the converting of those ideas into linguistic units which are turned into text, and *reviewing,* which requires the evaluating and editing of what is produced. What goes on in the composing processor, according to the authors, is influenced by various aspects of the task environment, such as the topic, the audience, and the social context in which the writer is performing, and also task constraints. At a rather different level of analysis, the model also highlights the importance of aspects of long-term memory as a source of content.

While this model was the first to identify the basic processes within writing, its limitations are considerable. Major criticisms included the absence of experimental evidence to support the theories upon which it was based and the reliability of using protocol analysis (subjective accounts of what people believed they were doing). In addition, the lack of recognition of the vital role of working memory in the processes was regarded as a major issue (Galbraith, 2009). It did, however, spawn some interesting experimental research which influenced later revisions to the original model. One important example of this came from Kellogg (1988), who measured the effect of different preparation strategies on the resulting content quality in two experiments. In the first he compared two different pre-writing strategies: (1) preparing a written outline, and (2) writing a rough draft. His results showed that the former led to texts of higher rated quality than the latter, suggesting that conservation of cognitive resources might improve outcomes. However, in the second experiment comparing the effects of a "mental" outline as opposed to a "written" one, he found no difference in text quality, leading him to conclude that both outlining strategies, mental and written, eased attentional overload by allowing the writer to focus processing time on the single process of translating ideas into text. His, along with Hayes and Flower's, was the first recognition of the idea of conflicting cognitive demand in writing, one upon which the core of this thesis hinges. Several subsequent studies by Kellogg developed this theme, also highlighting the role played by working memory (see below).

Following this work and others, Hayes and Flower (1986) revised and extended their early model, refining the basic processes and making several critical changes. First, they expanded on their previous ideas of writing as a dynamic process. While the early model included mostly uni-directional arrows which suggested a linear form of processing with only limited interaction between components, in the revised model which contains more bi-directional arrows, they introduced the idea that at least some of the component processes had to be dealt with *simultaneously*, visually representing the different components by boxes of similar size, with working memory at the centre. Writing was conceptualised as a problem-solving activity, and the idea of 'cognitive load' first described in 1980 was introduced into the model. They had already stated that :

> "The writer must exercise a number of skills and meet a number of demands – more or less all at once. As a dynamic process, writing is the act of dealing with an excessive number of simultaneous demands or constraints. Viewed this way, a writer in the act is a thinker on full-time cognitive overload" (Hayes & Flower, 1980, p. 33.)

Thus, the idea that having to juggle so many different elements during writing making heavy demand of memory and of executive functioning was clearly recognised.

A major criticism of the Hayes and Flower model, both in its original and in its revised form, arises from the fact that no attempt was made in this work to address what the process of translating, let alone transcribing, actually involved, that part of writing relating to how linguistically encapsulated ideas were converted into text. One commonly held explanation for this is that the authors assumed the fluency of both handwriting and spelling in the adults from whom the model was devised but it remains as a noticeable void in their conceptualisation.

3.2.2 An expansion of Kellogg's model recognising the role of working memory

One of the first researchers to model these changes was Kellogg (1994) whose extension to the model is shown in Figure 3.2 (Kellogg, 1996). Not only did he refine it to include more on translation, he also acknowledged the importance of multi-level processing, to build on the concept of writing as a dynamic activity in which different cognitive skills were invoked simultaneously (Kellogg, 1994). As a result of experiments to measure the processing time for planning, translating and reviewing in a letter writing task, for example, he proposed that prewriting planning and the revision of subsequent drafts could all be described as "phases of product development" rather than separate writing processes (Kellogg, 1994, p. 27). He observed that the composing processes, which Hayes and Flower identified as discrete entities, occur repeatedly through all phases of the writing, with planning declining across phases whilst revision increases.

The importance for this thesis of Kellogg's developments (1996) is that he acknowledges that *how writing is executed* needs to be embedded in any complete model and thus "Execution" is located sequentially between "Formulating" and "Monitoring" (see Figure 3.2). Recognising the role of working as well as long-term memory in written production from his experimental work, Kellogg drew up the theory that particular writing processes draw on different components of working memory (the "phonological loop" and the "visuo-spatial scratchpad") and devised his own model to demonstrate this.

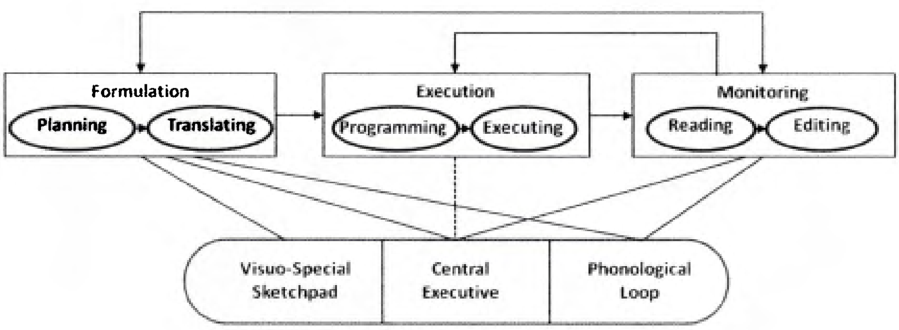

Figure 3.2 Kellogg's resources model of working memory (1996)

Interestingly, although Kellogg does indeed acknowledge the programming and executing of motor movements in his model, he suggests that neither involve the two types of memory he describes in detail (Kellogg, 1996; 1999). Also, there is no mention of another form of memory which plays a central role in motor execution of writing: kinaesthetic memory. Because Kellogg's focus was the role of memory in its different forms, it is strange that this model leaves the 'execution' box without any further elaboration, again making no provision to explain how the brain tells the hand what to do.

There is also reason to challenge the Kellogg proposal that memory is not involved in establishing motor patterns for transcription: the programming and the executing of movements. To take the first as an example: in order to establish a motor programme, the specific range and sequence of movements for smooth execution must be assimilated and stored whilst being converted by the neuro-muscular systems. In handwriting, this involves holding an accurate internal representation of the letterforms prior to their conversion into motor sequences (Hillis & Caramazza, 1986). Memory, both visual and kinaesthetic, is necessary for creating this mental picture. Once the programmes are established, the kinaesthetic memory becomes important for more automated recall whilst the dependence on visual memory declines. One could also argue that the phonological loop would be involved during handwriting, particularly during phoneme-grapheme conversion in the production of orthographic forms, i.e. spelling. Thus it would appear that in more than one area of writing, different aspects of memory are implicated, particularly with regard to fluent orthographic-motor integration.

Some signature research work in the field of graphonomics had been conducted prior to the formulation of Kellogg's model which looked (1) at the impact on handwriting of poor motor memory (e.g. Teulings, Thomassen & Van Galen, 1986), (2) its dissociation from phonetic memory (e.g. Nihei, 1986) and (3) into the allocation of attentional resources in handwriting control (Shek, Kao & Chan, 1986). For example, Meulenbroek and Van Galen's (1989) study suggests that a special status of allographs (letterforms) are represented in the novice writer's long-term motor memory. Also, following Van Galen's handwriting models (1991), described later on in this chapter (p. 56), the results of the study above points to increased processing capacity in working memory, enabling the preparation of a writing unit (a stroke or a letter) during the execution of the unit before. Despite this detailed and critical work, none of it is reflected in the Kellogg's conceptualisation. Although transcription is only fleetingly considered, there is a critical message to take from this research and that is that many of the processes required for efficient text generation and composing are dependent upon working memory in some form, leaving them vulnerable to disruption if either memory traces are disturbed or that capacity for memory is strained. (For a review of the evidence see Hayes, 2009, p. 31).

3.2.3 The 'Simple view of writing'

Since the time when Kellogg and Hayes and Flower independently proposed that working memory be included as a central component of writing, McCutchen (1994), and Swanson and Berninger (1994) tested ways in which it contributes to the development of written composition, suggesting that individual differences in short-term memory more influence transcription, and those in working memory more influence text generation. In order to represent the all-encompassing role which working memory plays, Berninger and colleagues devised a more recent model, the 'Simple View of Writing' (Berninger, Abbott, Abbott, Graham, & Richards, 2002; Berninger & Amtmann, 2003)

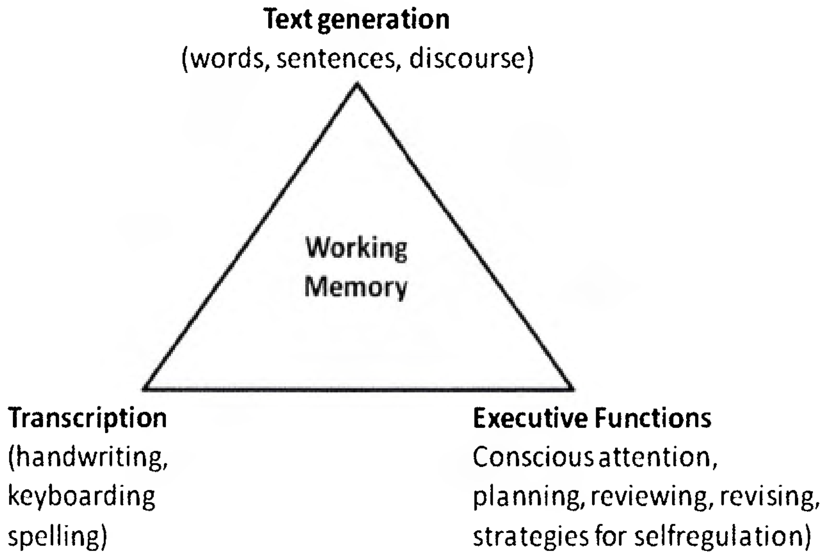

Figure 3.3 The 'Simple view of writing' extracted from (Berninger & Amtmann, 2003)

This model, shown in Figure 3.3, describes the relationship of the different component skills in developing writing in triangular form, placing transcription skills and executive functions at the two base corners of the triangle. This enables the goal of efficient generation of text, represented at the top, to be operational, all within the context of working memory. Represented this way, the model demonstrates how working memory impacts upon all these three components, not in a hierarchical structure but in a fully interactive and dynamic way. The model also gives transcription skills equal weight to text generation and executive functioning, the first model to do this. Thus, handwriting and spelling for the first time take their place on the writing stage as key players rather than 'added-on' processes.

3.3 The development of writing

Although the models described above go some way to explaining how skilled adults write, this has only partial application when studying children. Writing takes time to develop and the roles of different aspects of writing change as the writer matures. Two particular attempts to model the timing and the pathways of writing development provide critical background and are now examined. The first addresses the *content* of writing, the second the role of *transcription*.

3.3.1 Bereiter and Scardamalia's developmental model

Bereiter and Scardamalia (1987) were two of the first researchers to examine the differences between novice and skilled adults in specific aspects of written expression. By using a task in which participants were asked to say aloud the words as they wrote, they developed their knowledge-transforming model of 1987 (see Figure 3.4).

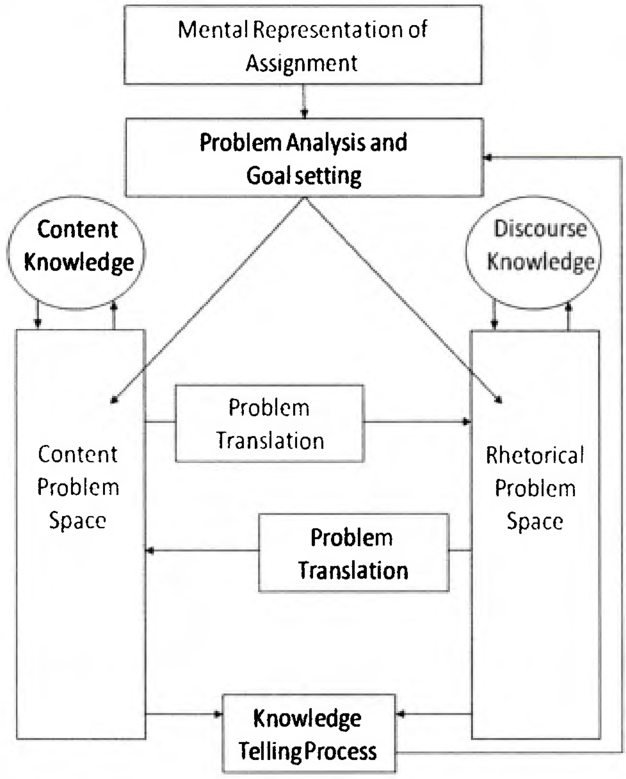

Figure 3.4 Bereiter and Scardamalia's knowledge-transforming model of writing (1987)

They suggest that the main difference between novice and skilled writers lies in the way they deal with the content of what they write. Their experimental work suggests that the text of young writers is characterised by a strategy the authors' term "knowledge telling", i.e. the relating of factual content, such as the recalling of events in the sequence in which they occur, content which is similar to oral delivery of the type commonly heard in the classroom. They note that the sequence of written events corresponds to the order in which they are retrieved from memory. In contrast to this simplistic expression of content, they suggest that more mature writers develop "knowledge transforming" strategies, which are more elaborate. This writing is characterised by the re-organisation of domain knowledge to comply not only with linguistic and procedural constraints, but to create content which fulfils the demands of a given task, i.e. invoking skills of planning, revising and editing, such as those described by Hayes and Flower.

According to these authors, adults, as opposed to novice writers, have the ability to use both simple and elaborate strategies, but they found that younger writers not only omit to use planning in their written output, but, when questioned, lack awareness of planning activities and are unable to recognise them in others (Bereiter & Scardamalia, 1987). Not all researchers agree with these findings. McCutchen, for example, suggests that children do engage in planning to some degree but that they may not be able to articulate their strategies in the way adults do, thus masking their planning strategies (McCutchen, 1988). She found that children differ from adults in the *nature* of their strategy and that they tend to use the writing assignment itself as a plan with planning occurring 'online', i.e. continuously during writing, and although the main focus for them is on generating content, protocols such as speaking aloud which is commonly observed during writing, act as contemporaneous planning. This is in direct contrast to the way that adults plan by using schemata developed in advance of writing (McCutchen, 2006).

There seems to be common agreement that with increasing age, children adopt the planning strategies more characteristic of adults, strategies which are highly demanding of cognitive resources. Knowledge transforming strategies have been observed in adolescents from around 14 years onwards (Bereiter & Scardamalia, 1987; Bereiter, Burtis, & Scardamalia, 1988) though whether the age at which these strategies develop are influenced by cognitive and environmental factors has not been questioned. For example, none of these studies address whether high verbal ability in children might affect either the onset of planning or the trajectory of its development. One could posit that the developmental pattern in gifted children, where precocious linguistic development might stimulate the early adoption of more adult protocols, would be different in children with more modest verbal ability. Similarly, the type or effectiveness of the teaching in specific schools might also affect outcomes. No research evidence has been found to support or refute either. What does seem clear from this model is that maturity influences writing style and that when testing children within a specific age band, the genre chosen must be appropriate.

3.3.2 Berninger and Swanson's developmental model

A major review of Hayes and Flower's original model was conducted by Berninger and Swanson (1994) in which they proposed modifications to explain the issues specific to early and developing writing. They devised an altogether more dynamic model of writing (see Figure 3.5) which is commonly quoted in the literature and has influenced the way in which the development of writing has subsequently been perceived. Importantly, transcription forms an integral part of this multi-directional process.

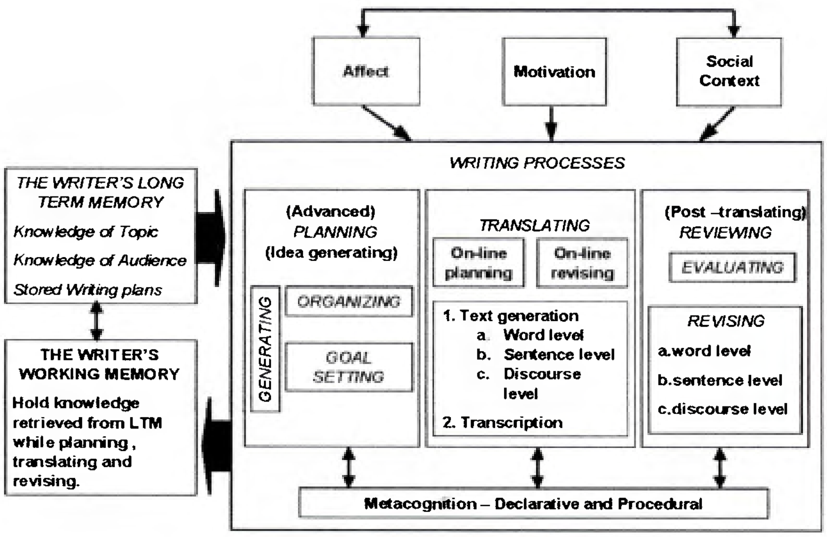

Figure 3.5 A modification of the Hayes-Flower model for beginning and developing writing (Berninger & Swanson, 1994)

Whilst maintaining the basic structure of the earlier model, Berninger and Swanson (1994) demonstrated, first, that the three cognitive processes, *planning, translating* and *reviewing*, represented by separate boxes by Hayes and Flower, might in fact operate concurrently and interact. They also found a developmental pathway in *planning, translating* and *revising*, processes which are not fully operative in beginning writing, but emerge systematically during the course of development, each on its own trajectory and at its own rate and this is something which more recent research has clarified. For example, Alamargot and Fayol (2009) suggest a clear developmental sequence in the acquisition of knowledge-transforming strategies based on Berninger's model. They suggest that *formulation*, in which text generation can only be accomplished once transcription skills are well developed, is followed by *revision*, which is initially confined to surface changes and only later to fundamental text refinements. Developmentally, *planning* emerges last.

Berninger and colleagues next focused on the translation process. Within it they distinguished *text generation* (in which a task schema directs the cognitive processes that generate pre-linguistic ideas and convert them into linguistic units) from *transcription* (the processes by which these units are delivered on to the page). They suggested that, whilst these two components may develop together, they may also develop at different rates. They observed two sub-types of dissociated development in their studies: one where *text generation* developed more quickly than *transcription*, with children being able to produce an oral account of a composition whilst unable to produce decipherable written text, and another, where the opposite was true, where children who were competent hand writers and spellers were unable to think of anything to write. One could also argue the existence of a third type of atypical development, and that is of children who are competent in oral language expression but who have problems both with generating and organising ideas *and* with transcription. For these children, it is not known whether impairment in these two quite separate components is coincidental or whether they are in some way related. As this profile characterises the children in the studies which follow in this thesis, this particular issue will be tested in Part 2.

The Berninger and Swanson (1994) work highlights a number of additional features which characterise developing writers which had not been demonstrated in earlier models. For example, they suggest that planning and reviewing have *temporal* and *spatial dimensions*. Like Kellogg (1994), they note, for example, a distinction between what they call *on-line* (or contemporaneous) *planning* which accompanies the writing act, and *pre-planning*, which takes place in advance of it, on-line planning seeming to emerge before pre-planning.

Another factor emerging from the Berninger and Swanson work is that gender differences in development affect the transcription component of translation more than that of text generation. Their empirical work showed that whilst boys outperformed girls in the primary grades in oral fluency, girls outperformed boys on written orthographic fluency, i.e. the ability to write words fast and smoothly. They found that gender effects for oral fluency disappeared between the ages of 8 - 12 but female superiority remained in orthographic and written compositional fluency well into adolescence. Again, nothing is reported on the point at which maturing boys catch up with girls in these different aspects of writing. Since the studies were conducted with whole class groups of mainstream pupils, no indication is given relating to individuals with specific writing difficulties. Other work, such as that by Graham, Weintraub and Berninger (1998), describes particular writing difficulties experienced by those with learning disabilities and has found a preponderance of boys in his samples. All these issues will be tested in the empirical work to follow.

3.4 From the general to the specific – models with a focus on written spelling

Around the time that Hayes and Flower produced their model of writing, a completely different line of enquiry was being pursued in a clinical context in the field of neuro-psychology. Hillis and Caramazza (1989) studied adults with acquired brain disorders who demonstrated problems with writing. The model which they constructed provides a useful framework not only on how written words are *spelled* but also on how spelled words are *written,* demonstrating how the two arms of transcription inter-relate. This model, described first in their 1986 paper and later in 1989, maps the pathway from the idea to the word written on the page in a cascade form (see Figure 3.7 below).

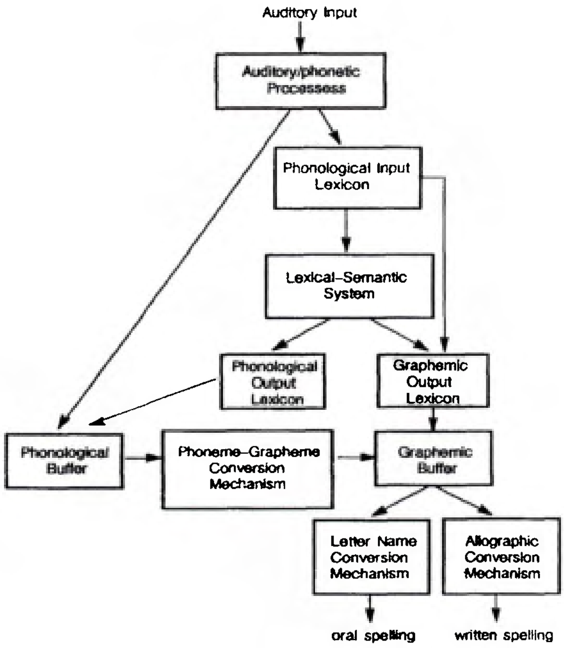

Figure 3.6 Schematic diagram of the spelling process (Hillis & Caramazza, 1986)

According to this model, at the start of the process, a spoken word it is taken in through auditory/phonetic processes (though could be generated from long-term memory) and is then transferred either via the word meaning (*lexical-semantic*) system through conversion procedures relating to spelled words (the *graphemic output lexicon*) or by means of sound-to-symbol (*phoneme-to-grapheme*), to the memory store (the *graphemic buffer*). From there (*allographic conversion*) allographs are defined as the physical variants corresponding to the same grapheme or letter. For example, the letter 'g' can be represented in several different ways, such as 'g', 'G', '*g*' or 'g'. The authors acknowledge that the writer has to select a specific letterform before executing it. However, no provision is made in the model for an allographic memory store between the graphemic buffer and the allographic conversion mechanism where a mental representation of the form is held whilst being converted into a motor trace. As it was devised to describe the process by which words were *spelled*, albeit in both oral and written modes of expression, the motor mechanisms for how spelt words were physically delivered were assumed. However, as a description of the processing involved in the final stages of transcription, downstream of the graphemic memory store, it provided a useful starting point.

A cascade structure of this type enables possible areas of breakdown in the writing process to be located. Tasks designed specifically to target each layer of processing, not only for spelling but also for handwriting, can be used to test the performance of an individual. Whilst caution must be taken when applying evidence gained from the acquired disorders of adults to explain developmental disorders in children (Karmiloff-Smith, 1997), this technique is one which can provide a useful testing platform.

Not only was the focus of Hillis and Caramazza's model on spelling rather than writing, it was also devised before keyboard use was universal. These two factors may have contributed to the fact that only two modes of delivery, speech and handwriting, were described downstream of the graphemic buffer. Looking to understand the comparative processing demands of different modes of transcription in the production of written allographs I conducted a small study as part of my Masters' degree which explored the spelling difficulties of 10 year-old boys with and without Developmental Coordination Disorder (DCD). Selective assessment using targeted spelling tests identified specific areas of weakness within the Hillis and Caramazza model and established that for all the children selected, processing was intact upstream of the graphemic buffer. A spelling list of 50 high frequency irregular words was dictated in each of three modes: oral, handwritten and typed at one-week intervals in the same order. I found that children without DCD made fewer spelling errors than those with the disorder. Those with DCD made significantly more errors in the handwritten mode than those without and also more than in either of the other two modes. Additionally, not only were fewer errors made in the oral and typed modes than in the handwritten, but also *the same words* were misspelt with identical errors across these two modes. The contrasting error pattern was interpreted as evidence that handwriting made *different* demands on cognitive resources than either of the other two modes. Also, the identical error pattern found in speaking and typing suggested that these two modes made similar demands. In these cases, children had simply to select relevant graphemes from an established letter store, either from an internal auditory alphabet store or from the letters on the keyboard to produce them. In contrast, handwriting required an additional level of processing to convert the letters from the letter store into movements because of the specific characteristics of each allograph.

Although it might seem presumptuous to use such a small and unpublished study to suggest a revision to the model, the results did point to the need for an extension to the Hillis and Caramazza model at the level of allograph selection to reflect this difference in demand. Because the term '*allograph selection*' used by Hillis and Caramazza in the model, appropriate for oral and typed text, did not accurately describe the processing required for handwriting (where the mental representation of the letter strings must first be conceptualised and then converted into motor patterns), a more suitable term, i.e. '*allograph generation*', was suggested to reflect the extra layers of processing which handwriting required.

The findings of this small study reflect the work of Ellis (1982, 1988) and Margolin (1984) who suggest that once a graphemic code has been determined, a bifurcation "should be assumed" between handwriting and other modes of output for letter strings (cited in Van Galen, 1991), all of which have a direct influence on the empirical work to follow in this thesis.

Caramazza and his colleagues later revised the 1985 model, focusing more directly on the levels of processing beyond the graphemic buffer. They inserted an additional layer, the "allographic store", where selected allographs are assigned size and shape for conversion into graphic-motor patterns before being executed via neuromuscular mechanisms as handwriting (Rapp & Caramazza, 1997). This later model draws a distinction below the central graphemic buffer between what the authors term the two "modality-specific" mechanisms, i.e. those dedicated to oral as opposed to written spelling. This emerged from reports of individual patients who had difficulty reproducing the written forms of words despite their oral spelling being relatively intact (Rapp & Caramazza, 1989), although, interestingly in the cases cited, the patients exhibited no generalised motor deficits. However, the development takes us one step nearer an explanation of handwriting processes by clearly recognising that in order to execute the movements required for written letters there must first be what the authors term 'an abstract motor plan', creating an 'internal' letter-form representation to be converted into movement. Earlier studies by both Ellis (1982, 1988) and Margolin (1984) suggest that the allographic specification of letter shapes, such as that in the abstract letter-form representation, is made in terms of visuo-spatial features followed by their conversion into the graphic motor pattern, where, according to Ellis (1988), one derives "the sequence of strokes necessary to create the allograph...it specifies the direction, relative size, position and order of strokes required to form the allograph" (p. 102). In order to test the distinction between stages dedicated to letter-shape assignment versus stroke specification for motor execution, Rapp and Caramazza devised a series of experiments to provide detailed information about the content of letterform representations, whether visuo-spatial or motorically based. They concluded that whilst these two separate forms of representation may be identifiable, there is much uncertainty regarding the allocation of visuo-spatial or motor features to the representations utilised. In relating this work to children with problems in the motor production of handwriting, it would be helpful if such an allocation could be achieved in terms of identifying a particular locus of difficulty (for the purposes of intervention).

The developments of the work described above provide a framework within which to place the motor aspects of producing the letterforms but, of course, it does not accommodate every aspect of the process. For that we need to examine theories which puts the understanding of the perceptual and motor aspects of writing at their core.

3.5 A focus on handwriting

Models of handwriting are few in number, probably because no single model can convey all the biophysical and psychological components involved. One of the most influential models that does exist is that of Van Galen (1991) whose "psychomotor model" proposes a hierarchical view of the generation of script (see Figure 3.8) and follows logically from the Caramazza conceptualisation. At the highest level it is suggested that writers store and activate spatial codes of letterforms. At the lower level, appropriate force-time impulses are generated, moderated by the real-time biophysical context of the task (Van Galen, 1991, p. 169).

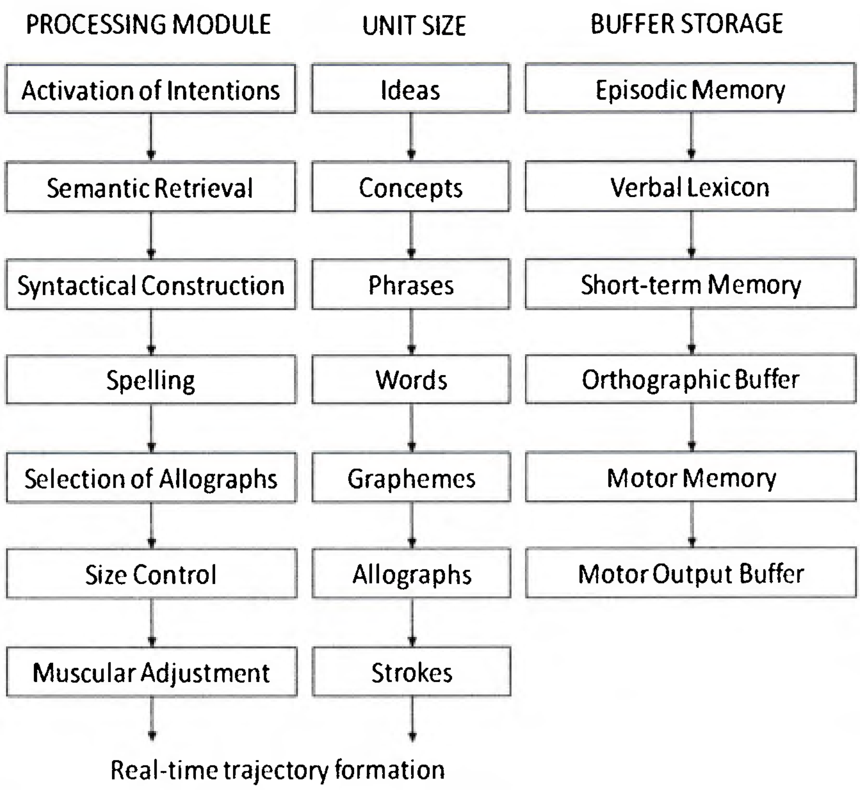

Figure 3.7 Van Galen's model of handwriting (1991)

This model is also structured in cascade form, the start-point here being different processing modules, each addressing specific features of the message, and the output from one forming the input for the next. From the top to the lower stages, processing units decrease in size and all modules engage in processing concurrently, the higher modules being further ahead in the overall process than the lower ones. The vertical structure of the model presents the hierarchy of the processing modules in one column, for the identity of the processing units addressed in the corresponding module in another and for the storage nodes that mediate in the communication between successive levels of the model in a third. In this way, provision is made for processing at each level and at each size of unit and uniquely serves to explain the role of motor processing below the spelling module. Within this model, the first four steps involve cognitive/linguistic processes whilst those involving motor processes lie downstream of these. According to the model, the selection of an allographic motor pattern is a two-step process: the current writing mode activating the long-term motor representation that should be applied in the second step of grapheme-to-allograph conversion. Van Galen concedes that the size of the unit of programming in handwriting is unclear and suggests, from earlier research, that the production units, whether they be at stroke level, letterform level, at bigram or word level, may in fact depend on the form of the output (Portier, Van Galen, & Meulenbroek, 1990; Teulings et al., 1986). He claims that his own results support the view that, in preparing the motor system for an upcoming handwriting response, complete letters seemed the most likely programming unit with which this is achieved, but this has been subsequently challenged by the work of Kandel and Spinelli (2010). In their detailed studies of mono- and bi-lingual children and adults they suggest that orthographic units *between* letter and word level have the greatest influence on handwriting fluency and thus upon smooth general production of text. This work will be described in greater detail at the end of this chapter but suffice here to say that where both these theories meet is in the proposal that programming of future orthographic codes appears to run concurrently with the motor execution of the one being written and this parallel processing enables the writer to produce letters at speed.

A limitation of the Van Galen model is that although it recognises that variable cognitive demands affect the motor execution of handwriting, it does not specify how the load effects operate. It accepts that the concept of limited resources is too simplistic but fails to answer how what is generally termed "psychological load" causes the increase in movement time as is consistently found. One possible explanation is that the recruitment of muscle force is contaminated with neuro-motor noise during disruption or stress by overload, leading to a less efficient recruitment process in the muscle system. This needs to be further researched.

3.6 The processing demands of writing

In the writing literature, the term "cognitive demand" is usually used to describe intellectual processing capacity and the way performance on different tasks taps into this facility, eliciting a response to a greater or lesser degree (e.g. McCutchen, 2006; Torrance, Waes & Galbraith, 2007). The response to the "demand" is described by some as conditioned by levels of attention, e.g. Kellogg, who suggest that discourse formulation and motor execution draw jointly on attentional resources (Kellogg, 1994, p. 31) and Sweller, who stated that "cognitive load" refers to the attentional demands required to perform intellectual tasks (Sweller, 1988). Others interpret it as a feature of organisation and have likened the skill of managing the various processes to that of conducting an orchestra (e.g. Brown, 2000) where different critical processes must be invoked simultaneously without damaging creativity, and this calls upon high-levels of executive skill. This is reflected in the Berninger and Amtmann model described above (p. 39).

The relevance of research into working memory for this thesis is that it shows it to have capacity limitations and if that capacity is overloaded by high demand, this will have an impact on all processes within the writing model even if they do not seem obviously related. In exploring cognitive limitations, Torrance and Galbraith (2006) propose that failings in working memory may have several possible causes. They argue, first, that limitations may arise from processing "bottlenecks", where processes which draw from the same pool of key resources make contemporaneous demands of them, thus "clogging up" the system. This would certainly be true to a certain degree of the processes involved in linguistic activity which are thought to share such key resources (Just & Carpenter, 1992). Alternatively, Torrance and Galbraith argue that disruption may arise from distraction or "crosstalk" among outputs, such is the case with dual-task interference studies which show that when two tasks are attempted in close temporal proximity, one or both are negatively affected (e.g. Pashler, 1994). A third argument relates to the transient nature of short-term memory and individual differences in the size of the memory store affecting the quantity of material which can be held at any one time (e.g. Baddeley's "phonological loop": Larsen & Baddeley, 2003). Whatever the cause, all the research in this field suggests that working memory represents either a vulnerable or a finite resource pool and demonstrates that the need to manage demand on resources when performing a complex skill such as writing is critical. This presents a strong argument for ensuring that mastering handwriting and spelling is essential if functional capacity is to be maximised. By way of support for this argument, several studies have shown that if the cognitive load of transcription is relieved, by, for example, allowing poor writers to use a keyboard (Connelly & Hurst, 2001) or by working to improve the handwriting fluency (Christensen, 2005), composition fluency is increased and the composition quality also improved. This places a high priority on automating handwriting in the developing child in order to allow composing to develop to the full potential.

3.7 Theories on idea generation

In the early models described in this chapter, the writing process was seen to begin with an idea which was generated from imagination or retrieved from long-term memory and then developed. This is consistent with the naive view of writing, identified by Torrance, which describes writing as "conversation written down" (Torrance, Waes, & Galbraith, 2007). This view suggests that everything to be written is somehow fixed, intact and waiting to be put on the page. However, more recent research by authors, such as Galbraith, challenges this notion. Evidence from his empirical work suggests that the way in which ideas are translated plays an active role in idea generation itself and that composing continues throughout the writing task, influenced by and as a direct result of the translating process (e.g. Galbraith, 1999). Working with undergraduates he demonstrated, through a series of experiments, that there were differences in idea generation between "high self-monitors" (who planned an essay before writing it) and "low self-monitors" (who wrote before they planned). The results showed differences in approach between the two groups, and he concluded that there were clear personal differences in approach. This is an altogether more dynamic view of idea production and demonstrates an interplay between the content to be delivered and manner of the delivery. The importance of this work for the development of smooth execution of the transcription skills, is that if production is difficult, it is liable to impact directly not only on the structuring of text but upon idea generation itself, something which might affect children's handwriting problems. Interesting also are his studies which suggest that the spatial component of working memory plays a crucial role in the development of new ideas (knowledge transforming) during outlining (Galbraith et al., 2005).

3.8 Ways to measure the relationship between translation and transcription

Although the work described above suggests one way in which poor handwriting skills can impact upon written composition, these studies fail to quantify the full impact of the handwriting impairment. In contrast, there are studies which attempt to measure the degree to which transcription deficits interact with higher order processes. A common method employed in research is to measure comparative periods of inactivity, or "pauses", during handwriting. It is generally acknowledged that written composition is characterised by a considerable amount of pausing – some suggest up to 60-70 % of total composition time (e.g. Alamargot et al., 2007). These pauses have commonly been assumed to be associated with periods of planning. For example, writers are observed to pause to think and plan how something will be written, and this is followed by periods of activity during which the ideas are then physically transcribed. In a review of the literature of the last 20 years on this topic, Alamargot identifies four assumptions on which writing researchers usually interpret these pauses and suggests that these are indeed relevant to the production of shorter, simpler texts which more closely resemble oral discourse but that in more complex compositions a greater degree of planning is required. The fourth of these suggests that by measuring the length and position of pauses it may be possible to quantify how demanding a writing task is. This is one technique which may be deployed in Study 4 to compare the degree of load experienced by children with and without DCD.

Olive and Kellogg (2002) suggest that in skilled writers the processes of translating and transcribing normally occur in parallel as long as a high degree of automatic production has been achieved in the latter. In practical terms this means that translating and some planning occur *during* the execution of automated handwriting and spelling. This "processing in parallel" produces a seemingly continuous flow of writing, pauses occurring only where new ideas need to be brought to mind. On this basis, some researchers have suggested that increased pause time can be evidence of a degree of difficulty with transcription (e.g. Olive et al., 2009). They argue that if transcription is not fully automatic and requires some conscious thought, then translating simultaneously with handwriting is too demanding. This situation results in *sequential* rather than *simultaneous* activity with the writer pausing to translate as well as generate ideas. Furthermore, it has been suggested that this can be measured by the frequency, position and duration of pauses. In order to test this theory Olive and colleagues conducted two experiments (see Chapter 9, p.232). They found that increasing the demand of planning had no effect on how writing processes were activated during pauses and execution periods, but the degree of automaticity of handwriting did. When handwriting was less "effortful", translating was activated mostly in parallel with motor execution, whereas revising and planning were activated mostly during pauses (Olive et al., 2009). This work offers strong evidence in support of ensuring handwriting takes the minimum of effort, but it still leaves unanswered the question of what comprises the effort. Some recent studies have studied the occurrence of parallel events based on the encoding of visual information using a graphic tablet and "Eye and Pen" software to monitor gaze during writing (Chesnet & Alamargot, 2005; Alamargot et al., 2009). Through a detailed analysis of the occurrence of the different types of parallel events these researchers concluded that writing pauses should be considered as the ultimate consequence of cognitive overload but recognises that cognitive capacity is not the only factor governing the occurrence of pauses.

In theory, pause length can be measured by electronic means. However, how a pause is defined and how it is quantified has to be decided. For example, as natural and essential pen-lifts occur in proficient writers during writing, how long does the pen have to off the page for it to be to be considered a pause? Generally, these parameters have to arbitrarily determined. If the results of different studies are to be compared, there needs to be a consensus among researchers about what constitutes a quantifiable "off-page" event? This issue may be further complicated when looking at different types of script. For example, how frequently the pen leaves the page and how much movement is performed in the air may be in part determined by the script style. In certain scripts where the style is fully cursive, "segments" of movement (when the pen is continuously on the page) can be measured. In contrast, in Chinese characters each stroke is represented by a discrete movement separated by an 'in air' stroke. But in English script, in the UK, where cursive script is not mandatory, pen-lift frequency is, to a large extent, determined by each individual writer. How then can this be quantified? All these factors have an impact on how each 'off-page' event is defined and measured. Furthermore, not all pauses may result in pen-lifts, as it is theoretically possible (though less likely) for a writer to pause whilst maintaining pen contact with the page. To interpret writing behaviours with any meaning, all these issues have to be considered.

A further problem for writing research is how to interpret what is happening on the part of the writer when the pen leaves the page. If lifting the pen to produce new letter strokes and pausing to "think" are natural features of writing, the challenge here, then, is to distinguish normal from excess levels of pausing? One attempt comes from researchers such as Chesnet and Alamargot, (2005) who looked at the position of 'off-page' events for evidence of intent. They found that although 75% of their defined pauses occurred at word boundaries (something which would seem entirely logical if pauses were for planning purposes), 25% occurred within words, suggesting that at least a quarter of them might result from grapho-motor or lexical constraints.

The development of different attempts to measure 'on paper' and 'in air' behaviour during writing provides some evidence which may shed light on the occurrence and duration of periods of stress. As such, it could be useful when comparing specific populations with skilled writers. So far, the research has all been conducted only with university under-graduates and it is not yet known how this relates to children's writing. In order to understand its relevance to children, and those with handwriting difficulties in particular, such findings need to be evaluated in context. Several researchers have highlighted the impact of task demand on writing performance. For example, Dockrell, in her work with speech and language impaired participants, demonstrated that for children with writing difficulties, it is the interaction between the specific difficulties experienced and the particular task demands which cause a breakdown (Dockrell, 2009). She reported that children with dyslexia performed more like age- and ability-matched controls than literacy-matched controls on a simple writing task but this changed for the worse when the task demands increased. This suggests that when assessing demand, the degree of automaticity which would be expected of a child of a particular age with what is known about gender differences for that age, what constraints to writing have so far been identified and the task environment in which the work is being performed all need to be considered.

3.9 The role of orthography in transcription

Van Galen (1991) defined spelling as the process through which elements of an utterance are substituted by their corresponding graphemic codes. This approach, that handwriting production involves orthographic representations of simple letter sequences, is illustrated in the 1991 model. There, it is suggested that processes involved in producing handwritten text assimilate information in a hierarchical and sequential fashion, that the spelling module activates whole words to be converted into motor patterns. More recently this view has been challenged. Kandel and Valdois (2005) observed French children in 1st -6th grades (6-12 years) writing in French, a language in which 75% of the words are morphologically complex (Rey-Debove, 1984) although the orthography is transparent. By this they mean that there are a number of complex orthographic clusters which are typical of the written language but that these are regular and consistent in their interpretation. When observing participants writing in this language, the authors first noted a slowing of the motor act of handwriting at points in words where more complex morphology occurred, and this they interpreted as evidence that the children were processing the language in units which fell *between* word and letter level, either at syllable level or in orthographic clusters. The longer and more complex the word, the greater was the need to break it down into smaller though logical units. Further work by these authors (Kandel & Valdois, 2006; Kandel & Valdois, 2006a; Kandel et al., 2006b; Kandel et al., 2009; Kandel & Soler, 2009), illuminated two important features of writing. First, that when a copying task involved words which increased in complexity, the child would select a unit to copy which was greater than a single letter but less than a whole word. Interestingly, the writing *movements* were influenced by the size and type of the chosen units. The second important feature was that the processes did not occur in a linear way, as suggested by the Van Galen model, but rather that parallel, online programming occurring throughout the writing of the words. Thus, the initial syllable was prepared in advance of the onset of the handwriting movement but that the second and subsequent syllables were prepared online during the writing of the first or previous ones, making the writing process smooth and continuous. This feature they found to be true at every age, irrespective of lexical status or item length (see also Kandel & Spinelli, 2010).

There are still questions which this research leaves unanswered. The critical one is an assumption made that the demand which the adopting of the orthographic codes places on the writer is to do with constructing the mental representation of the code. However, the extra demand of developing and automating these orthographic codes as *motor* programmes has not been considered and this is something which has direct relevance to children for whom the motor execution of the structures is challenging, i.e. those with DCD.

The relevance of these questions to children with DCD is multi-faceted. The first relates to the management of the burden of parallel processing on children whose motor execution is impaired. If orthographic complexity adds a further cognitive load on the writer, something which is found to slow down movement execution, having to write in English, a language with a most complex orthography, would be more demanding than writing in either French or Spanish. Additionally, the participants of the Kandel studies were not known to have any difficulty with the motor aspects of transcription, but if an increased load is placed on those with an already stressed motor system, the burden will be exponentially greater. The second issue relates again to the way in which mental representations of letters, parts of words or whole words are converted into motor patterns. Motor learning theory suggests that practice of motor sequences to be performed increases the quality of the performance. Thus, for a poorly coordinated child, writing in a language with a greater number of morphological complexities would lessen the frequency of repetition for the developing writer and might be a further factor in explaining a delay to the fluency with which words are converted into handwritten text or continued slowness to do so.

In order to explore these questions further, the additional demand on learning motor patterns for irregular and less familiar codes can be tested by structuring tasks with variable demand levels and evaluating motor, spatial and temporal patterns during execution of the material.

3.10 Summary

Historically, research into writing falls under three headings: cognitive-annunciative, psycho-linguistic and socio-cultural. A more cross-disciplinary approach best describes this current work. The writing process has been modelled in a number of ways to explain the inter-relationship of different components of writing, but writing models have been slow to explain the place of *hand*writing in the overall process of writing. No one model encompasses all aspects of what is entailed in motorically converting ideas into well-structured text but examples from neuro-psycholinguistics as well as from experimental psychology all contribute to our understanding. Particular models to explain the acquisition and development of writing skills uniquely demonstrate how the child performs at different stages of maturity, influenced by gender. Finally, experimental work on the role of orthographic-motor integration has led to a greater understanding of how these two aspects of transcription inter-relate. However, although the particular difficulties experienced by children with language and literacy disorders is receiving attention in current research projects there is a gap in knowledge of how orthographic constraints impact motorically on the writer and the particular implications for children with motor coordination disorders. This is at the core of the work of this thesis.

Chapter 4

Developmental Coordination Disorder (DCD)

4.1 Introduction

At the heart of this thesis are children of normal intellectual ability, in mainstream education, whose motor development is atypical and whose handwriting is a major concern. Frequently, these problems go unidentified and the child's difficulties are either misunderstood or neglected. Alternatively, they are given a label which directs focus away from the motor core of their difficulty (e.g. dyslexia). Both these are unhelpful, for, whilst making a diagnosis is never an end in itself, if a child's motor difficulties are not acknowledged as part of the spectrum of difficulties experienced, this can result either in no provision being made or in the provision of intervention which is ineffective. For these reasons alone, having a clear picture of the history and development of our understanding of what the disorder constitutes is critically important, particularly for teachers.

4.2 Historical background

Developmental Coordination Disorder (DCD) is the term currently used to describe children of normal intelligence who experience difficulties of motor coordination that cannot be explained by disease, injury or known neurological impairment. Although rarely diagnosed in the early years, in many cases, motor milestones have been achieved rather late and may sometimes be bypassed altogether, as in children who do not crawl or who fail to develop the fine pincer grip between forefinger and thumb. Once recognised, the core features of this disorder are often grouped under the headings of poor manual dexterity, poor balance and underdeveloped balls skills, with a wide range of non-motor difficulties being seen as secondary or associated in some way (Zoia et al., 2006; Barnett & Henderson, 2005). Taken together, the motor and non-motor difficulties have a real impact upon the lives of those who suffer from them, both practically and academically. In many cases, both the motor and non-motor difficulties persist into adolescence (Cantell et al., 2003; Cantell & Kooistra, 2002; Gillberg & Kadesjo, 1998; Losse et al., 1991) and more recent studies following this group into adulthood highlight substantial social, emotional, psychiatric and medical difficulties (Cousins & Smyth, 2005; Kirby, Sugden, Beveridge, & Edwards, 2008).

Although the label DCD is relatively recent, this is not a recent phenomenon and such children have been described in the literature for many decades (e.g. Gillberg, 1985; Gubbay, 1975; Hall, 1988; Henderson & Hall, 1982; Walton et al., 1962; Zoia et al., 2006). As far back as 1937, Orton (1937) observed 'clumsiness' has been a recurring feature, as has failure in the development of 'normal' skills, not only of smooth coordinated movement but often also of speech and writing. Over the years, many different professionals have contributed to our understanding of children with coordination or movement difficulties (Cermak & Larkin, 2002). While there is no doubt that all of these lines of enquiry have been useful, the down side has been that the various groups of professionals still approach the subject from their own perspective, using their own terms. This is borne out by the literature which emanates from medical, through psychological to very practical educational journals, where the sharing of information across disciplines can be minimal.

The medical profession has always had a crucial role to play. In the early days of recognition of "clumsiness" in children, neurologists used terms such as "minimal brain dysfunction" (e.g. Clements, 1966; Wiggleworth, 1963), "minimal cerebral palsy" (Kong, 1963), "developmental apraxia and agnosia" (Walton & Ellis, 1962) and "developmental apraxia and agnostic ataxia" (Gubbay, 1975) to describe this particular group of children. In some cases, the observers were making comparisons with adults suffering from known medical conditions, in others, the "reference point" was children with known cerebral palsy (CP), the inference being that these were simply children with a mild form of CP. There were many difficulties with these early terms (see Henderson and Henderson (2002) for a detailed discussion) but one of the most difficult was the definition of what "minimal" actually meant. Another was how one might decide how a brain was "dysfunctional". More recently, more sophisticated techniques to study neurological abnormality, such as fMRI scanning, has enabled this line of research to continue apace and is producing useful data on the aetiology of the entire spectrum of motor difficulties from "overt" cerebral palsy through to milder motor difficulties, which may be classifiable as DCD. Individual movements can also be analysed using sophisticated computerised systems that digitally record the position of joints, limbs, etc. in three dimensions. Advances in technology are influencing the accuracy with which movements are described and perhaps in the longer term how diagnoses are made.

In parallel with the medical work on this condition, psychologists and physical educators were writing about the same children by a different name (e.g. "motor impairment"). Since they were seeking to develop interventions to improve performance (e.g. Arnheim & Sinclair, 1975; Cratty, 1994; Oliver & Keogh, 1967), the emphasis here was less on the origins of the symptoms but more on the symptoms themselves. A range of terms described the condition, from "congenital maladroitness" (Ford, 1967) and "physical awkwardness" (Keogh, 1968; Wall, 1982) to "clumsy", a term frequently used over a long period by many different professionals. Yet, other clinical professionals, developing ideas from studies of adult apraxia, used the term "developmental dyspraxia" to describe children who display disturbance of the ability to plan and execute certain actions which require a sequence of movements (Cermak, 1985; Denkla, 1984; Dewey, 1995; Miyahara & Möbs, 1995; Peters et al., 2001) and this particular term has endured in certain circles (see later). Attempts were made experimentally to link perceptual motor factors and motor impairment using information processing approaches (e.g. Lazlo & Bairstow, 1983; Lord & Hulme, 1988; MonWilliams et al., 1999; Wilson & McKenzie, 1998) but no clear evidence emerged to determine whether these were causes or manifestations of DCD.

4.3 Issues surrounding definition and terminology

Studying children who could be described as having a movement impairment is made difficult not only by the lack of consensus on the exact nature of the disorder, but also by a failure to agree on a working definition and associated terminology (Cermak & Larkin, 2002; Henderson & Henderson, 2002; Henderson & Barnett, 1998). For example, most studies approach the subject of motor in-coordination as if they were dealing with a single, discrete condition with an identifiable aetiology (Henderson & Barnett, 1998) yet even now, research evidence to support this assumption is inconclusive. Some researchers have sought evidence of general dysfunction of the motor system through magnetic resonance imaging (MRI) of the parts of the central nervous system associated with control of movement (Dewey & Tupper, 2004). However, this approach takes no account of the extreme variations found within individual children and evidence of specific difficulties alongside comparative strengths in other domains is not uncommon (Ahonen, 1990; Dewey & Kaplan, 1994; Hoare, 1994; Macnab Miller, &

Polatajko, 1999; Miyahara, 1994; Taylor, 1990; Wann, Mon-Williams, & Rushton, 1998; Wright & Sugden, 1996). The alternative approach in the literature acknowledges the marked heterogeneity of the condition but views it as having clear, identifiable sub-groups with set groups of characteristics (Henderson & Barnett, 1998). Again, evidence to link certain groups of symptoms together to form syndromes is not forthcoming, though there have been several attempts to find some (see above authors). In this thesis, the approach taken assumes that the children involved have enough in common to warrant treating them as a homogenous group for some purposes, while at the same time acknowledging that individual differences will exist. This might in the long-term lead to a better understanding of the problem being studied – in this case, writing difficulties.

It is not only factors within the child which result in inconsistencies in definition and terminology. Henderson & Henderson (2002), for example, note that:

- different countries have adopted, and continue to use particular terms;
- different professionals favour different terms, e.g. health and education;
- different levels of enquiry have led to different terminology e.g. whether describing pure movement ability or relating movement to practical functioning (as of everyday tasks, for example);
- different interpretations of what "causes" the child's problems .e.g. motor planning versus motor execution;
- different needs: academic, i.e. for identifying populations for research purposes, or clinical, i.e. for seeking provision of appropriate services.

Indeed, the historical picture bears this out and a good example is confusion in the use of the terms "clumsy" and "physically awkward" which, as observed by Peters (2006), used to be used both as a descriptor of motor dysfunction and also as the label for the medical condition which has motor dysfunction as its defining feature. Also in the UK, "dyspraxia", a term derived from adult neurology, has been applied to the development of the childhood motor impairment. Coined by Ayres (1979, p. 91) to distinguish children whose problems were more to do with motor *planning* than bio mechanical motor *execution*, this term is currently still in common usage in the UK, especially among educationalists. One could challenge whether it matters which term best describes children with movement problems? However, what emanates from the literature is that having a consensus on what constitutes the "core" disorder, if that were possible, would be helpful for both research and intervention.

Since their inception, the World Health Organisation (WHO) and the American Psychiatric Association (APA) have attempted to define and classify diseases and disorders in order to chart their prevalence. Both have included a disorder of motor coordination, the WHO describing it as a "Specific Developmental Disorder of Motor Function" (SDDMF) in the International Classification of Diseases: Diagnostic Criteria for Research (WHO: ICD-10, 1993) whilst the APA describes it as "Developmental Coordination Disorder" (DCD) in its Diagnostic and Statistical Manual (DSM-IV, APA, 1994, 2000). These two documents find common ground in their definition on functionality of movement and variation with age. They specify that chronological age and normal intelligence are factors in diagnosis and, in addition, ICD-10 specifies a cut-off point relative to age.

DCD, as a descriptive term, has appeared increasingly in the literature since a consensus meeting, held in London, Ontario in 1994 for those professionally involved with poorly coordinated children, recommended the adoption of the American Psychiatric Association DSM-IV (APA: 1987, 2000) definition to describe this population. Here the essential feature of DCD is described as a "marked impairment in the development of motor coordination" (p. 53). It includes four diagnostic criteria to be met for the child to be considered to have DCD, two of which are inclusive (A and B) and two which are exclusive (C and D). Criterion A states that "performance in daily activities that require motor coordination is substantially below that expected, given the person's chronological age and measured intelligence" and gives poor handwriting as a specific example. Criterion B qualifies this as "significantly interfering with academic achievement or activities of daily living". Thus, it is to be expected that a large number of children who meet the general criteria for DCD experience real difficulties with handwriting.

Despite having survived for nearly twenty years, the diagnostic criteria for DCD have often been criticised from within the research community, particularly for the non-specific nature of Criterion A and the subjective nature of Criterion B. Criterion A depends upon an arbitrary level of performance which is recognised according to an expectation which is not specified, and Criterion B demands evaluation dependent upon subjective criteria. Calls are frequently made for absolute measures of performance to be found to quantify (if at all possible) the core impairment of the disorder, but to date this has proved problematic (see below). For a critical evaluation of the terms and definitions contained in DSM-IV (2000) see The Leeds Consensus statement arising from the ESRC Seminar Series (Sugden, 2006).

Most recently, recommendations from the European Academy of Childhood Disability (EACD) were approved at two Consensus Conferences in Maulbronn (Germany) for the EACD on March and July 2010. These meetings sought, among other things, to bring together the diagnostic criteria used by the ICD -10 (commonly used in Europe) with the DSM IV (commonly used in the UK and North America) and to make recommendations in advance of the publication of DSM V in May 2013. One interesting feature to emerge from these consensus meetings, attended by educators, clinical professionals and members of the research community, was whether it was still appropriate to use the formerly applied medical model of diagnosis in the case of DCD, where the considerable heterogeneity within the condition makes such a diagnosis difficult. However, a significant change likely to become adopted in the new edition of the European Guidelines (EACD; Blank, Smits-Engelsman, Polatajko, & Wilson, 2012) relates to acknowledging the co-occurrence of different disorders (see later in this chapter) and it is believed that the revision will include recognition that diagnosis of one disorder does not preclude diagnosis of others.

With regard to the identification of poorly coordinated children from an educational, as opposed to a clinical, perspective, very specific issues arise. For example, the first two DSM-IV criteria are easily operational in school in that teachers may use general class standards as reference points, identifying those whose motor or writing performance is below the class norms. They will also have class grades to use to as markers for under-achievement to meet Criterion B, though the degree to which they reliably can or do associate the poor handwriting with poor academic performance is questionable, hence the need for the present research. However, real difficulties arise within a school population over meeting Criterion C, which states that the poor motor coordination observed cannot be accounted for by any medical or neurological condition. Generally, schools have scant, if any, records of children's birth or medical history and may be unaware of the aetiology of a problem. When teachers refer children on the basis of comparative underachievement, unless those children are examined by a neurologist or clinical psychologist, underlying medical or neurological problems cannot be ruled out. What was recommended within the EACD consensus statement was that DCD ("Specific Developmental Disorder of Motor Function" – ICD-10, 2000) should not be diagnosed "if motor performance cannot be assessed by a motor test (e.g. because of mental retardation or a medical disorder)" (EACD, 2010). This clearly recommends that the use of a standardised test should be an essential element in the identification of children with a motor disorder.

4.4 Problems of identification and assessment

As was mentioned in the introduction to this chapter, not all children who show movement difficulties receive a full and accurate assessment of their motor skills or a clear diagnosis. In my own experience, teachers are usually aware that these children experience problems and would like to understand better how to help them. Yet, many feel unqualified to assess the condition and indeed, most motor assessment instruments are not geared for use by professionals in education. Also, as not all children present with the same set of symptoms or the same level of disability, it is hard for teachers to know what sets of symptoms constitute a "disorder". Similarly, parents often voice concerns but do not know where to turn for advice. Some go down the medical route, seeking help from their family doctor or paediatrician, though some still report that GPs believe the child will grow out of their difficulties. Others approach school to apply for a statement of special needs, though again, this often does not prove fruitful, as motor problems on their own in many authorities are not deemed to constitute "a special educational need".

Thus, the most common route to assessment used by schools is through referral to an Occupational Therapist, and this can prove helpful, though there are problems even with this. For example, the use of Sensory Integration therapy, first advocated by Jean Ayres (1979), is often still used despite being challenged in the literature, and the range of assessment tests favoured by this group of professionals tend often to focus on the perceptual development of the child (e.g. the VMI: Beery et al., 1989) and few use a more comprehensive motor test, such as the Movement Assessment Battery for Children (M-ABC-2: Henderson, Sugden & Barnett, 2007; see Chapter 5, p. 78) to assess the full range of motor skills. Another problem is a practical one: that waiting lists for an Occupational Therapist's assessment can be extensive, and even when the child is eventually seen, professional time is often not available in many authorities for follow up treatment programmes.

Despite the importance of home and classroom observations in the identifying of children with impaired motor skills, assessment instruments which measure motor function play a critical role in the diagnosis of DCD. Tests which are reliable and provide appropriate norms enable clinicians and researchers alike to measure performance consistently across groups, ages and contexts. Several such tests have been developed over the years and a short review of some of these tests is covered in Chapter 5, p. 78. However, there are several general issues surrounding the nature and content of such a test which need to be discussed. For example, the decisions over which aspects of motor competence to measure; the types of task best able to demonstrate this competence; what levels of temporal and spatial constraints to impose, etc. All need careful consideration. A further issue to recognise is that any test measures performance only at one moment and in the particular tasks selected, raises questions over generalisability. Also, there is debate over whether motor *competence* as demonstrated by performance in a test situation should be differentiated from motor *ability* in a more general sense. Performance may be influenced by specific training (e.g. coaching in balls skills for a field sport) but may not indicate the ability to *learn* a motor skill or to transfer that skill into other contexts, both of which characterise a skilled mover. This area was addressed in many domains in the era of dynamic assessment which sought to measure the learning potential of the individual (e.g. Feuerstein, Rand, & Hoffman, 1979) but often proved too time consuming and thus too costly to continue. It also demands knowledge and specialised understanding which many testers do not have. One issue arising from the studies that follow in this thesis is the suitability of this, or indeed any, test in accurately describing the motor coordination levels of the participants.

One further issue that can influence the way in which motor ability is identified is that it is frequently found that children's motor impairment is not an isolated problem; that difficulties in other areas are also apparent, such as poor attention or problems with communication skills. This can cause confusion in terms of knowing which of the child's problems to focus on. The incidence of the co-occurrence of different disorders in a child is common, as discussed further below and it is important here to recognise that many children with developmental disorders often display poor motor skills (e.g. Gillberg & Kadesjo, 1998; Henderson & Green, 2001). Further work needs to be done to assess whether the motor profiles of children whose primary diagnosis is of Attention Deficit Disorder, Specific Language Impairment, dyslexia or autism show particular characteristics, different from those whose primary disorder is one of motor control.

4.5 Prevalence

Seeking to quantify how frequently a particular condition occurs is common to all medical and developmental disorders and can contribute to a general picture of the human impact of that condition. DCD is no exception and prevalence figures are often quoted in the literature. However, there is a need for caution in how published figures are interpreted. For example, estimates on the prevalence of DCD in the school population have been reported to range from 5 - 6% (APA, 2000) through 15% (Henderson & Sugden, 1992) to 22% (Kadesjo & Gillberg, 1999; Keogh, 1968; Wright & Sugden, 1996). In contrast to these, a recent study in the UK, the Avon Longitudinal Study of Parents and Children (ALSPAC), has cited the UK prevalence at between 1.7% and 3.2% for children aged 7-8 years (Lingam, Hunt, Golding, Jongmans, & Emond, 2009), though this is considered to be conservative, first, because of the young age of the children tested and, second, because of issues with the methods of identification. However, what becomes clear is that unless there is a consensus over exactly what the disorder constitutes, which symptoms are included and the levels of severity considered appropriate, together with a standard test, all these estimates have to be unreliable. Previously discussed issues of definition and diagnosis may account for much of the variance in the findings, as may the type of assessment instrument selected. For example, Kaplan demonstrated that no two tests produce identical results possibly identifying different children (Kaplan et al., 1998, p. 484), and, in addition, account must be taken of the fact that the cut-off points for diagnosis are arbitrarily set (Sugden & Keogh, 1990). Some studies include children only if they score below the 5th percentile, others the 10th or 15th. A review of the previously accepted 15th percentile cut-off in the Movement ABC (Henderson & Sugden, 1992) and Movement ABC-2 (Henderson, Sugden & Barnett, 2007) is described in Chapter 5. Other studies do not use percentiles at all, using the terms "mild", "moderate" and "severe" to describe quality of movement detected by electronic scanning. These different methods and approaches all affect how widespread the condition is believed to be. What is undisputed is that a significant minority of children in mainstream education has motor coordination problems which impact upon their daily lives and are worthy of our attention.

4.6 DCD and academic achievement

Whilst under-achievement in school for children with DCD has long been recognised (e.g. Cantell et al., 1994; Gubbay, 1975; Henderson & Hall, 1982), research which looks specifically at the relationship between DCD and academic success has been relatively rare. Gubbay (1975) reported that 50% of children with motor coordination difficulties had schoolwork difficulties, with Sprinkle and Hammond (1997) 41%. Drillien and Drummond (1983) reported academic problems in 32% of children with moderate motor problems and also in the majority of those more severely affected. Van Dellen, Vaessen and Schoemaker (1990) reported that one third of "clumsy" children had to repeat a grade at school. Hadders-Algra Huisjes and Touwen (1988) reported that clumsiness in the early years is linked to learning difficulties later in life. Two longitudinal studies to 16 years of age (Hellgren et al., 1994; Losse et al., 1991) and four to 17 years of age (Cantell et al., 2003; Geuze & Borger, 1993; Knuckey & Gubbay, 1983; Shaffer et al., 1986) which have looked at academic achievement over time report lower grades than expected in children with DCD. Whilst these studies suggest a link between DCD and underachievement they do not go into depth about the specific nature of the difficulties. Losse et al. (1991) for example, reported on PE ratings and problems in art, craft and science relating to difficulty with handling equipment. Untidy handwriting and poor presentation were also noted but there are no studies to date looking at written language in the wider context in children selected just for motor clumsiness (Berninger, 2004) and to date there is no empirical evidence to support these reports.

4.7 Long-term outcomes of DCD

The literature on motor coordination suggests that the majority of children who experience difficulties with movement at a young age do not grow out of them (e.g. Hellgren et al., 1994; Losse et al., 1991; Cantell et al., 2003; Cantell & Kooistra, 2002). The DSM IV states that the developmental course may "vary with age and development... and in some cases, lack of coordination continues through adolescence and adulthood" (APA, 1994, pp. 53-56). In order to test this statement, several studies have followed children through to late adolescence (e.g. Geuze & Borger, 1993; Knuckey & Gubbay, 1983; Shaffer et al., 1986). Other follow-up studies have continued up to 15–16 years of age (e.g. Hellgren et al., 1993; Losse et al., 1991). As Cantell reports, methodological differences have made it difficult to compare results across these studies as some involved large epidemiological samples of 6 and 12 year old children whose selection was based on neurological screening (e.g. Shaffer et al., 1986) whereas others used six year olds selected on teacher evaluation and/or motor proficiency tests (e.g. Losse et al., 1991). There was a view by Gubbay (1987) that only the most severe cases of poor motor coordination persisted beyond childhood. Indeed, other authors found that some children with milder problems did show improvements in their motor skills when re-tested after time (Cantell et al., 1994; Geuze & Borger, 1993; Losse et al., 1991). However, in all the studies mentioned, the majority of poorly coordinated children retained their difficulties at least into adolescence.

Unfortunately, none of these studies provide sufficient evidence to detail the profiles of those who are thought to have "caught up" and it has to be noted that differences in the findings between studies perhaps relate to a lack of standardised instruments for measuring motor performance for older pupils when these studies were conducted. Certainly, no norms existed then for adolescents and adults. The definition of improvement was highly relative and often purely anecdotal as most often the motor ability was not formally re-tested.

The central theme of this thesis is the role of poor motor control in the production of good written composition. Although several of the longitudinal studies undertaken on children with poor motor coordination report on educational achievement, none look specifically at the content of writing. Cantell and her colleagues, following up 115 Finnish 5-year-olds after 10 and 12 years, measured IQ, self-perception and school grades in six different academic subjects as well as reporting on hobbies and pastimes and on social, emotional and behavioural development (Cantell et al., 1994; Cantell et al., 2003). Although Finnish language and literature were included in this list, the data collected were only the grade levels from school records. No experimental work was conducted to test language performance, and, additionally, writing was not singled out for particular attention. Similarly, Losse and colleagues, following up British school children from 5 to 16 years of age, also reported the results from teacher evaluation and grades from school records in core academic subjects. Although teachers reported continuing difficulties with handwriting this was not formally tested and the study did not look at writing in general nor analyse written assignments (Losse et al., 1991). The final groups of studies worthy of mention, though not directly relevant to the current research, found concomitant difficulties in other areas of development, such as social, emotional and behavioural in adolescents and young adults (e.g. Gillberg & Kadesjo, 1998; Kirby & Drew, 1999; Larkin & Summers, 2004).

4.8 Co-occurrence of DCD with other developmental disorders

The International Consensus Meeting on Children and Clumsiness in London Ontario (1994) acknowledged that the obsolete term Minimal Brain Dysfunction had lead to recognition of Developmental Coordination Disorder (DCD), Attention Deficit and Hyperactive Disorder (ADHD) and later of Learning Disorder (LD) as separate entities (Kalverboer, 1995; Cratty, 1994). More recent research suggests that more than one of these developmental disorders may commonly occur within one individual (Brown, 2000; Denckla, 2000; Gillberg et al., 1998). Indeed, Kaplan (1998) and Hill et al. (1998) first suggested that co-occurrence is the rule rather than the exception, several other studies replicating these findings subsequently (Gilger & Kaplan, 2001; Henderson & Barnett, 1998; Kadesjo & Gillberg, 1998; Kaplan, Wilson, Dewey, & Crawford, 1998; Powell & Bishop, 1992). An influential study by Kaplan (1998) of over 200 Canadian schoolchildren, looking at the incidence of Reading Disorder, DCD and ADHD found co-occurrence to be common. Of the 115 children who met the criteria for at least one of the three developmental disorders, only 46% were pure cases and 20% met the criteria for all three. Interestingly, co-occurrence was particularly high for those with DCD. Different assessment instruments accounted for slight variations in results, particularly for DCD where the Movement Assessment Battery for Children (Movement ABC) (Henderson & Sugden, 1992) had replaced the Test of Motor Impairment (TOMI) (Stott, Moyes & Henderson, 1984) in the assessment in some cases; and also the results were influenced by the IQ scores of the participants though there seems to be no evidence, in this or any other study, that either DCD or ADHD is affected by intelligence, given it is within the normal range. It may be that since the reading measures used included a test of reading comprehension, they favoured those children of higher verbal ability. Nonetheless, the findings of this study lend weight to the view that some symptoms commonly observed in children with DCD, such as those addressed in this paper, could well be linked with a co-existing difficulty of a different kind. Gillberg's work in Sweden (1998) replicated Kaplan's findings and found that certain conditions co-occur with particular frequency, e.g. DCD with ADHD. This led him to make the diagnosis of DAMP to describe children who have the combined "disorders of attention, motor control and perception". Later work, testing over 950 schoolchildren, showed that the particular combination DCD and ADHD was more strongly associated with classroom dysfunction than any of the other disorders or combinations (Kadesjo & Gillberg, 1999). Other, population-based studies of children with combined motor/perceptual disorders and attention disorders indicate that the longer term outcomes and prognoses are much worse for those with this combination of disorders than when either disorder occurs separately (Hellgren et al., 1994), identifying this as a particularly vulnerable group of students. Gillberg's work has focused mainly on the social and behavioural aspects of classroom success yet anecdotal evidence from teachers suggests that the problems spill over into the academic domain showing that there is indeed more research needed in this area.

A review of literature on the incidence of these overlapping conditions shows that estimates vary greatly. Kaplan et al. (1995) reported a 50% overlap of DCD with either ADHD or LD. Sugden and Wann (1988) found that 29-33% of children with LD also have DCD. A large meta-analysis of 1077 studies indicated that 70% of children with LD had perceptual/motor problems and almost 75% had attention deficits (Kavale & Nye 1985-86). All studies acknowledged a significant overlap between DCD and LD, and for this reason, in selecting participants for the research reported later, the need to screen out those who might meet the criteria of additional disorders is recognised.

4.9 DCD and handwriting

Ever since "clumsiness" in children was first reported, handwriting has been identified as an indicator of a motor coordination disorder so it is not surprising that it is mentioned within the list of diagnostic criteria in the DSM-IV. However, the relationship between handwriting and general motor difficulties is not straightforward, as it would seem that the overlap of symptoms between the two is not total. For example, as was described in Chapter 2, handwriting is not purely a motor skill, such as bead threading or cutting with scissors which are dependent in the most part upon the coordination of fine movements. It involves other cognitive, linguistic and perceptual skills. Also, although it is common for general coordination problems to impact upon the execution of handwriting, cases have been reported in the literature where, despite a lack of coordinated movements in general, handwriting seems not be affected (e.g. Chang & Yu, 2010). From the opposite perspective, there is considerable evidence of children who display handwriting difficulties but who do not meet the criteria for DCD (e.g. Flapper, Houwen, & Schoemaker, 2006; O'Hare, 1999; Touwen & Precht, 1970). What is clear from these studies is that different qualities in the handwriting may characterise the difficulty, showing that not all the problems are identical in nature and share the same aetiology. This raises the question of whether "a handwriting difficulty" can reliably be considered as evidence of DCD without specifying the particular characteristics of that difficulty.

A further question arises from including handwriting among the diagnostic criteria for DCD when considering the core movement features. For example, although it could be argued that, despite handwriting being a whole-body activity requiring core body strength and stability if fluency is to be achieved, it is frequently noted that manual dexterity is particularly poor in those with writing problems and some researchers show that boys are particularly vulnerable in this respect (e.g. Junaid & Fellowes, 2006). Several studies have also noted a tendency among boys to excel in ball skills over the other areas of movement and where this is the case, overall motor scores are correspondingly affected. One issue for debate is the degree to which significant weakness in one area combined with relative superiority in another, affecting the overall test score, qualitatively affects a diagnosis of

DCD. This may have implications for life skills but more importantly here, it affects the selection of participants for research.

4.10 Summary and research questions

A significant number of children experience difficulties of motor coordination severe enough to interfere with activities of daily living, especially in school where their academic achievement may be lower than expected. The history of the condition suggests a level of heterogeneity within the disorder and this sometime causes problems for both identification and labelling. Observation and formal assessment both play a part in diagnosis, and handwriting difficulties are listed among the diagnostic criteria for DCD as they are commonly found in this group of children. Questions over the degree to which poor handwriting and DCD overlap are crucial to identifying those with a writing difficulty and whether the two are indefinably linked. Co-occurrence of DCD with other developmental disorders is high and the incidence of poor handwriting as well as of difficulties of written expression in these groups means that the possible presence of other disorders needs to be considered, both when assessing children with DCD and when selecting participants for research. Longitudinal research reports that the disorder persists into adolescence and beyond in the majority of cases.

Chapter 5

General Aims of the Studies and Research Methods

5.1 Introduction: research focus and research questions

5.1.1 Research focus

As the general focus of this research is the quality of written expression of children whose motor coordination is poor, it explores any possible association between that and the poor handwriting commonly found in this group, and examines writing outcomes at certain critical stages of their education. The significance of this as an area of study arose from personal observations of the difficulties encountered by such children, together with evidence from past research reporting academic underachievement in children with DCD (e.g. Henderson & Hall, 1982; Losse et al., 1991). Although some theorists warn of the risk of "experimenter bias" where research questions arise from personal experience (e.g. Blaikie, 1993), others regard experiential knowledge as an asset to be capitalised on (e.g. Maxwell, 1996). In this particular case, whilst acknowledging the possible dangers of bias, much has been gained by prior exposure to this topic in a number of ways. First, a specific population for the study has been identified (i.e. those with "above average" levels of intellectual function); second, possible assumptions frequently made in researching areas of literacy have been avoided (such as that of *not* dissociating writing from other forms of literacy); and third, awareness has been raised of the possible vulnerability of children in this group (such as the risk of fatigue posed by over-use of writing tasks during testing).

5.1.2 More specific research questions

As described above, the starting point for investigation arose from professional experience, with the research literature serving as a background resource for the study. The core questions addressed run through the whole thesis and are listed below (not in any particular order) and are developed in detail in the introduction to each study:

- Are teacher perceptions of handwriting difficulties accurate?
- How can a handwriting difficulty be conceptualised?
- Is there a relationship between the physical ability to write by hand and the more general ability to express oneself on paper?
- Do the difficulties identified persist beyond the primary years?
- In what ways are the demands of the physical production of text exacerbated by the constraints of complex orthography?

In order to best address these questions, various methodological approaches were considered.

5.2 Methodological approach and methods of enquiry

Research paradigms were sought to fulfil three main functions: exploratory, descriptive and explanatory. To encompass these three meant that the required approach would have to be both targeted and flexible. A review of the literature showed that two particular approaches have been favoured in social science research historically: *positivism* and *realism/constructivism*. The first is often described as a quantitative approach, the second as qualitative. After considerations of the particular needs of this research it was decided that for the core, some form of positivist approach in which a fixed design was adopted would best serve the purpose. The reasons for this choice were threefold. First, empirical research is systematic, demanding that detailed prior thought is given to the focus of study and also to the rationale behind it. Second, it is regarded as sceptical, making the ideas proposed subject to challenge. Third, it strives to be ethical with a strict code of conduct to be followed (see Kimmel, 1998). Within these bounds the intention is not just to seek the "truth" (however that might be defined) but rather to eliminate "false truths", something many regard as the most science can ever do.

Traditional positivism assumes the "standard view" of science: i.e. that it is objective, value-free, based on quantitative data and on facts, allowing for the testing of hypotheses to be undertaken with the intention of developing causal laws. It is generally accepted that positivists look for the existence of a constant relationship between events or variables. In this context, cause is established through demonstrating empirical irregularities and lends itself well to this form of study (Cohen & Manion, 1994). However, positivism as an approach has received a great deal of criticism from a range of philosophical standpoints, most frequently along the lines that it does not represent the real world in many ways (such as reality not being able to be defined objectively) and that the real meaning of social behaviour cannot be captured through empirical means (e.g. Koch, 1959; Sarantakos, 1998, pp. 43-5). Also, questions about generalisability are also often raised (e.g. LeCompte & Goetz, 1982) and where testing is confined to specific groups, as is the case here, application to other groups may need to be conducted using non-statistical methods. As a counter argument, it can be said that empirical research is able to contribute greatly to our knowledge by providing evidence in a highly structured way in particular areas which *can* be measured using experimental means. Against the background of this debate, a more apt description of the approach adopted for this research might be considered "post-positivist", where it is accepted that the theories, hypotheses, background knowledge and values of the researcher might influence what is observed (Reichardt & Rallis, 1994) but that there is a commitment to objectivity which minimises the possible effects of these likely biases and seeks to counterbalance them.

5.3 Study design in relation to the aims

Study design is concerned with operationalising research questions. Considerable skill is involved in creating a design which best addresses the issues identified and both planning and piloting are required to ensure the best results. The strategies used in designing the four studies here were made with reference to the following considerations:

1. The purpose of the study or studies.
2. The theory or theories guiding the choice of design.
3. The questions the research is geared to answering.
4. The specific techniques to be used to collect the data.
5. How the sampling strategies are defined.

With these questions in mind, a mixed design was chosen to best fit the needs of the enquiry. The research starts with an exploratory approach with an experimental part to it and progresses to a highly structured experimental paradigm in the final study. To a great extent the design was theory-driven with areas for exploration being defined with reference to models of writing (see Chapter 3). However, within this it was recognised that an initial stage using a flexible design of a primarily exploratory nature would ensure that the best structure for the job was devised. Following this, subsequent fixed design stages incorporating highly structured focused experiments could be undertaken (see below). One perceived advantage of using a fixed design method was to allow the tester to retain as great a physical and emotional distance from the participants as possible in order to minimise observer interference. In the planning of the studies thought was also given to issues of *validity* (does it measure what it is meant to measure?), *reliability* (is the measurement stable and consistent?) and *generalisability* (can this be applied to a wider population?). In addition, two other aspects were considered: *objectivity* and *credibility*. Objectivity is achieved where several observers agree on the existence of a phenomenon (inter-subject agreement) and may be at risk where the methodology or involvement of the examiner distorts responses (Robson, 2002). Credibility is maintained only where the detail of the experimental work is clearly stated, and this is particularly relevant in a contemporary context with the use of detailed computer-designed analytical tools, such as innovative electronic software programmes like those utilised in Study 4 (Shipman, 1988).

In this thesis, four studies revolving round a similar theme are presented. Each one has a specific focus and therefore required a tailored design to meet the research needs set out. These will be described individually below.

5.3.1 Study 1 – an exploratory study

The aims of the first study which also served as a pilot investigation for some of the design issues to be addressed were largely exploratory. The starting point was that the concept of a "handwriting difficulty" might not be consistent either across professions or between individuals within professions. One objective, therefore, was to invite teachers to identify those they considered to have a handwriting difficulty, and explore first, what the nature of those difficulties might be, second, to what extent there was consensus between teachers over the factors they identified and third, to test the degree to which their perceptions were accurate. A further aim of the study was to evaluate whether the focus and manner chosen to assess handwriting difficulties, as well as the most appropriate age selected to do it, would answer the research questions. Thus, this study could be described as quasi-experimental. First, the sample selection was deliberately left vague: children "with handwriting writing difficulties" were sought but the nature of the difficulties was not specified. Also, they were to have wider writing difficulties which were regarded as "unexpected" given their general levels of language and literacy, though selection was inevitably dependent upon teacher expectation. Once selected, the children were tested on a number of variables, both on standardised measures and on an experimental task, using a factorial design. The experimental task was conducted in two contrasting modes, oral and written, thus incorporating repeated measures. As their performance was compared with a control group main effects as well as possible interactions could be tested.

5.3.2 Study 2 – an investigation of the effect of order and a partial replication of Study 1

As is common with a repeated measures design, concerns arose about a possible "order effect" in Study 1 as the two tasks undertaken by the same participants were the identical in content but completed in different modes were administered in the same order - first written then oral. For this reason, Study 2 was constructed to test whether an effect of order had in fact influenced outcomes. This "counter-balancing" study used a mixed design where the participants and tasks remained constant but that two separate groups performed the tasks in different orders. A further benefit was recognised, namely, if no significant order effects *were* found on testing, Study 2 could then be used to replicate the findings of Study 1 (so increasing the sample size from 24 to 64) and explore some gender effects which could not be previously measured due to a small sample size.

5.3.3 Study 3 – a follow-up study

The objective of this third study was to determine whether writing and motor difficulties identified when children were of primary school age persisted through adolescence to the same intensity and in the same way. This, therefore, involved the five-year follow-up of the children tested in Study 1, replicating the original design, changing only those aspects that were necessitated by the passage of time, such as the age of the children and the appropriateness of the tests used for that age group. Longitudinal studies pose particular challenges for the researcher since ways of controlling for possibly performance-changing events occurring during the intervening period have to be considered. For this reason, Study 3 also utilised a mixed design, since, as well as the statistical analysis of the quantitative data, some qualitative data was collected. This was conducted in the form of a semi-structured questionnaire to the parents, recording information on educational, health and personal issues relating to the intervening years (see Appendix 11). Data gained through this method contributed to the discussion and general interpretation of outcomes of the study.

5.3.4 Study 4 – an experimental study

The design of this final study grew out of findings of the earlier three studies, while at the same time entering new territory previously unexplored in this field of research. By drawing upon a body of experimental work which seeks to investigate the relationships between the motoric and linguistic aspects of writing, this study examines the effect of varying orthographic and motor complexity on aspects of motor control. Since the precise questions asked in this study require very detailed development and the measurement instruments used are best described within that context, a proper introduction to this study will be reserved for Chapter 9.

5.4 Issues relating to participant choice

The participants for these four studies were all recruited from maintained primary and secondary schools in and around London. All were in mainstream education and were selected by teachers on a range of criteria set out by the author.

A range of different issues needed to be considered when selecting participants. The first factor to be taken into consideration, given that the role of poor motor coordination in the production of writing was central to the thesis, was to decide whether to select children from a clinical sample diagnosed with DCD or whether to focus on the handwriting ability and confirm motor status later. The second issue related to the age of the children, given that the literature on the development of both written and oral language suggests different developmental trajectories. The amount of schooling and years of handwriting teaching was a further factor when deciding on the children's age. Finally, as a writing discrepancy was the focus of the studies, a decision had to be taken on levels of general intellectual ability and literacy. Details of the decisions taken are described below for each group separately

Target group

The children whose difficulties inspired this research were identified from a school population. Thus, in order to explore the problem as it had presented, the target group needed to come from an educational rather than a clinical setting. To this end, teachers in local schools were approached to select those who would meet set criteria. Interest was in those who were in mainstream education rather than those with more severe special educational needs. The main requirement was that the children should be poor writers but what that description meant had to be clarified. *Hand*writing had to be the primary concern but two other elements were also important: the first, that they were unable to perform written assignments adequately in class, and second, that this difficulty was *unexpected*, given the children's perceived levels of oral competence. Furthermore, in order to rule out the possibility that low intellect, language impairment or general literacy problems could account for the writing difficulty, these children needed to be of at least average intellectual ability, be orally fluent and have no reading problems.

The next factor related to the age of the children selected. The review of the literature on language development was very clear in suggesting the age at which oral and written language competence might be comparable, i.e. at around 10-11 years of age (see Chapter 2, p. 25) so in order that written-oral comparisons could be made, children from the top of the primary school were chosen. This also ensured that they had had at least five years of formal schooling and that any problems found could not be accounted for either by lack of teaching or scant exposure to written language.

Looking next at the link between motor coordination and poor handwriting, the research evidence suggests a close association between these two (see Chapter 4, p. 60). In the example of writing shown in the introduction (Chapter 1, p. 15), problems of poor motor control were hinted at though not confirmed, so it was decided that whilst not specifying that a diagnosis of DCD was a requirement for the exploratory work, testing the motor status of these participants would be important before the experimental work.

The factors described above are the core criteria for inclusion in all four studies reported in the thesis. However, as the studies progressed, other issues emerged as relevant. For example, in Study 2, since all the target children in Study 1 had met the criteria for DCD and a larger sample was required, it was decided to select the target group on the basis of an existing diagnosis of DCD whilst recruiting controls from class groups in local schools. The testing time this saved enabled a larger sample to be included.

Because Study 4 built on evidence from the previous three studies, a range of new issues had to be considered. These changes were determined partly on results of the findings from Studies 1, 2 and 3 and partly on updates in the research literature, particularly with regard to the diagnostic criteria of motor disorders (see below, p. 90). First, Study 3 having identified a gender bias in favour of girls it was felt that clearer results would be obtained if comparisons in this study were confined to boys alone. Second, with regard to age, although Studies 1 and 2 involved children only from the top of the primary school, i.e. ages from 10-11 years, there was no evidence to justify exclusion of those who had transferred to secondary school, given that those with marked handwriting impairments did not improve speed significantly with age in Study 3. However, evidence on the development of writing speed at this age is conflicting. While some earlier studies suggest that no significant changes occur between the ages of 9 -14 years (Dutton, 1992; Ziviani & Elkins, 1984) the UK handwriting speed norms in the DASH (Barnett et al., 2007) show a steady increase from the age of 9 years levelling off only after 14 years of age. Taking these findings into consideration, it was decided that this wider age-band was acceptable but that priority in recruitment should be given to selecting participants who strictly met the study's inclusion criteria in other respects. But in order to minimise the age effect, controls were closely age matched, controls being chosen who were within six months of age of each target child. Thus the resulting age band for each group was from 9 years 10 months to 14 years 2 months.

The third way in which the inclusion criteria were altered for Study 4 was in the identification of motor impairment and two recent developments influenced the selection of participants. First, for the earlier studies it had been a condition of inclusion that motor ability fell below the 15th percentile on the Movement ABC. This cut-off point was consistent within research communities to indicate some degree of impairment, with those scoring below the 5th percentile being more severely affected. However, recent proposed revisions to the DCD-IV (APA, 2000) in the form of DCD-V (to be published in May 2013) recommend that the diagnosis of Developmental Coordination Disorder be restricted to those who fall below the 5th percentile alone rather than the 15th. (See below for further discussion on cut-off points for identification). Technically, this would have excluded a small number of these participants whose relatively stronger balls skills placed them slightly above the cut-off level, despite general motor skills being markedly below the norm in every other respect. However, this is not inconsistent with Criterion A for SDDMF which states that children should be included if "the score on a standardised test of fine *or* gross motor coordination is at least 2 standard deviations below the level expected for the child's chronological age" (ICD 10-R, 2000). Applying this condition in addition to the DSM IV guidelines, all participants for the study met the criteria for DCD.

A further development affecting the inclusion criteria arose from analysing the gender differences in the performance scores for the three Movement ABC sub-tests in the earlier studies. In these, not only was manual dexterity found to be poorer among boys than girls and corresponded with poorer handwriting control but boys generally outscored girls on ball skills. This gender difference in the development of these two types of motor skill is consistent with that recognised in the research literature (e.g. Junaid & Fellowes, 2006) but as analysis in this study showed no correlation between balls skills and handwriting competence, boys were not excluded if their overall scores on the Movement ABC-2 were between the 5th and 15th percentile as long as their manual dexterity scores fell below the 5th. Support for this decision was drawn from the findings of a study of 125 Dutch schoolchildren where the most serious handwriting problems were found in those with what the authors termed 'fine-motor deficits' (Smits-Engelsman, Niemeijer & van Galen, 2001) though overall scores for motor competence were not necessarily within the generally accepted levels of impairment.

Controls

By way of a comparison, control children were selected from mainstream primary schools in the same area of London. The original plan was to compare the performance of the target group with that of typical classes of Year

5 and 6 pupils. However, when this was piloted and the class scripts for the experimental task rated, it was found that, because of the social and cultural diversity within the classes, the target children did not always represent "the tail of the curve" in written expression. Thus, it was decided to manipulate the match by banding the class into three bands for intellect: "average", "above average" or "superior" and individual controls matched for age, gender and age were selected from the band matching the IQ scores of the target children they were to be matched with. In addition, each had to be verbally fluent, to read well, to be well coordinated and to have no difficulties with handwriting. This way, a closer match was found for each target child.

5.4.2 Problems encountered during participant selection

Sample size: One challenge in planning and executing research for a thesis is that conflicting demands have to be reconciled. The meeting of strict criteria for inclusion requires considerable testing. Practicalities regarding the time available for assessment have to be considered, often resulting in fewer participants being included than might be ideal. It is acknowledged that sample sizes in these four studies are small but this was compensated for where possible. For example, in Study 2 once it had been established that order of performance made no significant difference to outcomes, the addition of forty children of similar age and profile to those in Study 1 enabled a repeat of the task analysis to be undertaken, resulting in the rating overall of one hundred and twenty eight scripts – a more robust sample size. As Study 3 was a follow-up study it was not possible to increase sample size. In Study 4 the rule of thumb proposed by Mertens (2003) of fifteen participants per variable in non-experimental designs was extended into the experimental context, acceptable according to Robson (2002) particularly where grouping is homogenous, as in this case. Compensation for limited numbers in Study 4 was indeed achieved by the more rigorous testing of participants, ensuring that groups were as "pure" as could be achieved. This way it was hoped that clearer results would ensue. Indeed, there is a view among certain researchers (e.g. Robson, 2002) that clear results in smaller samples can indicate a more robust finding. Despite this, it is recognised that where sample sizes are small, results must be interpreted cautiously and findings regarded as indicators for further exploration for the future.

Tracing participants at follow-up: A problem peculiar to follow-up studies is the issue of tracing those who had participated earlier. In this case, after five years, making contact was not straightforward. Several of the target children had changed schools, some more than once and some had moved for family reasons, two out of London. In addition, one had been excluded from mainstream education and was under the care of the Youth Offending Service and one was home educated because of a prolonged medical condition. Most young people were no longer closely supervised by their parents which led to unreliable attendance at appointed assessment sessions. Furthermore, two were disaffected with education and made the minimum of effort, despite having agreed to participate. In contrast, the controls were more compliant and had had experienced less disruption to their lives.

5.5 Data collection

Data collection for the thesis was in four distinct parts. The first relates to the gathering of data on standardised measures, the second on experimental tasks, the third on responses to the questionnaire and the fourth using an electronic digitiser tablet and computer software specifically designed to collect data on a number of handwriting measures set out by the author.

5.5.1 Data collection I - Standardised measures

Standardised instruments selected for assessing core skills and abilities were chosen according to the level of detail required of the data to be collected. For example, some of the tests needed only to make a fairly superficial assessment and were used to confirm that inclusion criteria for the studies were met, e.g. general IQ levels. Others were designed to yield more detailed data on specific topics, e.g. on handwriting speed. The purpose of the testing is reflected in the choice of instrument (see below).

General intellectual ability

Testing intelligence for these studies was to ascertain that the children selected had no general intellectual impairments and were of at least average ability. The Wechsler Intelligence Scales for Children - third edition (WISC-III UK)(Wechsler, 1992) and fourth edition (WISC IV) (Wechsler, 2004) and the British Ability Scales II (Elliot, 1996) are the instruments most widely used with children in the UK. A detailed assessment of intelligence requires time and is demanding of the child's focus and cognitive energies. As such, a detailed analysis was not required for the purposes of this research so the short form of the WISC-III UK was chosen. It is an individually administered clinical instrument for assessing the intellectual ability of children from 6 -16 years 11 months. It provides reasonably up-to-date normative reference points based on a UK validation programme conducted by Rust in 1992 in which 814 cases were sampled. As, according to the manual, the US validation programme achieves very high levels of reliability, the power of the US data was used to underpin the UK validation.

For this series of studies, the short form using two verbal subtests (Similarities and Vocabulary) and two performance subtests (Block Design and Object Assembly) was chosen for two reasons: to minimise the amount of testing and because, as dyads, they have high reliability and validity coefficients (Sattler, 1992). Although the more recent Wechsler Intelligence Scale for Children – fourth edition (WISC-IV UK, 2004) is often used by researchers and clinicians, the earlier version was preferred here because of the inclusion of the Object Assembly subtest, omitted from the later edition. This subtest purports to measure planning ability, simultaneous processing and speed of mental processing (Kaufman & Lichtenberger, 2000), all sub-skills which are essential for good composition (Berninger & Amtmann, 2003); thus it was felt important to choose an assessment instrument which included this test.

Word reading

In order to eliminate general literacy difficulties in Study 1, a measure of decoding text was required. One that was simple, quick to administer and yielded standard scores with UK norms was sought. At the time of testing The British Ability Scale - second edition (Elliot, 1996) was widely used among highly regarded researchers and practitioners as a standardised measure of context-free word recognition in younger children (e.g. Snowling, Gallagher & Frith, 2003) influencing the choice. Within this test, a list of single words of increasing difficulty were presented to the child on a card to be read aloud. Numbers of errors were recorded. Raw scores were converted into standard scores with a mean of 100 and standard deviation of 15.

For Study 3 a decoding test similar to the one above was used. Selected for its more up-to-date choice of vocabulary and its suitability to the older age group, participants were tested using The Wechsler Individual Achievement Test – second UK edition (WIAT II UK: Wechsler, 2005). As before, a single word list was presented on a card and successful attempts provided raw scores for conversion into standard scores with a mean of 100 and standard deviation of 15.

Spelling

Written spelling levels were tested first to provide background information on general levels of literacy but also as a useful marker of a vital transcription skill for the later studies contained in the thesis. Consideration was given to subjecting struggling writers to additional testing involving writing, so again a test which was simple, brief and reliable was favoured. Consistent with decisions regarding the assessment of word reading, the BAS II was again chosen (Elliot, 1996). Lists of single words were read aloud to the child to be written down. As with the word reading, numbers of errors were recorded. Raw scores were converted into standard scores with a mean of 100 and standard deviation of 15. For the purposes of this study standard scores were reported but error patterns were not analysed.

For Study 3, in line with the decision taken on word reading, the WIAT II-UK (2005) replaced the BAS II for measuring spelling ability. The test is similar in its administration and analysis to that used for Study 1.

Reading comprehension

Evidence suggests that narrative writing is influenced by a child's reading ability (Berninger et al., 2002; Shanahan, 2006) but that decoding and comprehending skills are not uniquely linked (Nation & Snowling, 1998). Thus, it was felt to be important to have some measure of reading comprehension in addition to the single word reading scores. At the time of testing the most widely used standardised reading comprehension test was The Neale Analysis of Reading Ability (NARA: Neale, 1989) which provides a measure of reading comprehension separate from decoding. Passages of increasing linguistic difficulty are presented to the child to be read aloud or silently. Questions about the topic read are then asked. Reading speed as well as number of errors was recorded.

As Study 3 replicated the assessment in Study 1, reading comprehension was again tested using the NARA II (Neale, 1989). However, for Study 4 this test was omitted as it was felt that this aspect of reading would not significantly contribute to the general assessment of reading levels required for testing in this study. Also, as conducting the NARA II is time-consuming it was decided that the time could be more usefully spent elsewhere.

Motor ability

A literature review showed that two tests of motor ability are in most common usage. The first, the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2, Bruininks & Bruininks, 2005) a norm-referenced test of motor function, is commonly used in the USA and Canada by physical and occupational therapists. The recent second edition provides norms from 4 to 21 years of age and has separate norms for each gender. However, it requires considerable time to administer and includes components not considered essential to the current research. In contrast, the Movement Assessment Battery for Children (M-ABC: Henderson & Sugden, 1992) and its more recent edition, the Movement ABC-2 (M-ABC-2: Henderson, Sugden & Barnett, 2007), developed from the Test of Motor Impairment (TOMI: Stott, Moyes, & Henderson, 1984) are by far the best evaluated tests available and most widely used, particularly in Europe (EACD, 2010). For these reasons, and also its UK norms, the M-ABC first edition was chosen for Study 1 (conducted before the second edition was published). Designed for use with children aged 4 – 12 years, it contains four age bands, each with eight items. Its focus is an objective assessment of movement difficulties and performance is recorded in a number of ways: raw scores are collected and conversion into standard scores allows that performance to be evaluated according to the standardization sample. There is also a qualitative as well as quantitative element to this test as observations are encouraged of how the child performs. The second edition, used for Studies 3 and 4, includes an extended age range, from 3 to 16 years of age. It comprises three parts: a standardised test, a checklist and a companion manual describing the Ecological Approach to Intervention for Children with Movement Difficulties. As the manual states, the test and checklist focus on the identification and description of impairments of motor function in children. It requires a child to perform a series of motor tasks in a strictly specified way and, in addition, provides qualitative information on how the child approaches and performs the tasks. The test is divided into three different age bands: AB1: 3-6 years; AB2: 7-10 years; AB3 11-16 years. Within each age band eight tasks (items) are grouped under three headings: *Manual Dexterity, Aiming & Catching* and *Balance.*

A useful critique conducted by the European Academy of Childhood Disability reviewed studies evaluating these two test instruments (EACD: 2010: 1.1.1.1). They looked at the psychometric properties of each test as well as their limitations. They found that the M-ABC shows good to excellent inter-rater reliability, good to excellent test-retest reliability and fair to good validity. In addition, they noted that specificity seemed to be good and sensitivity fair to good, depending on the chosen cut-off point. (Interestingly, these studies noted that sensitivity was particularly good using the 15th percentile cut-off). Major limitations recorded included a lack of research on the discriminant validity of the M-ABC and that attentional problems may interfere significantly with performance. However, one further potential problem for this test is the scaling of the reference values and the "discontinuation" of the scales between age-bands. The EACD review comments that these issues may be especially problematic when diagnosing and monitoring after treatment and it is true that within this research some concern over scoring was observed for those children whose birthdays fell near the age limits. Commenting on the difference in editions of this test they found that most validity measures from the M-ABC might be valid for M-ABC-2. EACD evaluation of the BOTMP/BOT-2 found fairly good results on reliability and construct validity overall, but lower sensitivity than the M-ABC. The primary limitations found in this test were weak test-retest reliability for some subtests and a scoring process which was so time-intensive and exacting that errors seemed likely to occur in the computing of scores.

Overall, this meta-analysis found in favour of the Movement ABC/Movement ABC-2 over the BOTMP/BOT-2. Geuze notes that, as well as being ideal for applying Criterion A, the first of the four diagnostic criteria for DCD of the DSM IV-TR (2000, p. 58), the Movement ABC checklist offers a way of operationalising Criterion B (see Chapter 4: Geuze et al., 2001). Most importantly for Study 3 of this thesis - the longitudinal study - the second edition with its extended age range provides a unique opportunity to assess the performance of children and adolescents over time within one test instrument.

Handwriting speed

Several attempts to devise handwriting speed tests have been made over the years in different countries using different approaches and these vary in their purpose, the type, number and variety of tasks, the form of instruction used, the length of the test and the method of scoring. However, there is little research evidence to support the choice of tasks and little information provided on sample and characteristics of the data (Barnett et al., 2007). At the time when Studies 1 and 2 were conducted no single speed test was considered worth including in the battery of assessment tests administered. This was partly because the data yielded were not thought to contribute significantly to profiles of the children over and above what could be calculated from the test scripts and also, because of cultural differences in the teaching on handwriting, the absence of UK norms was considered to be a critical factor. Therefore, instead of formal testing, a word-per-minute count was taken from the narrative tasks completed during the experimental phase of the first two studies. By the time Study 3 was conducted, the Detailed Assessment of Speed of Handwriting (DASH: Barnett et al., 2007) had been published and this was added to the test battery both in this and in Study 4.

The DASH recognises that performance over a single task yields limited data and therefore assesses children across five different tasks: two sentence copying, one in best writing one in fast; writing the alphabet from memory; a free-writing task and a graphic speed task. Thus, four of them involve alphabetic content and one tests purely grapho-motor skill. Standard scores are derived for each of the five tasks and an overall standard score and percentile ranking are calculated on the results of the four alphabetic tasks. Internal consistency on these four tasks, tested by the authors for each age group, produced values for Cronbach's alpha between .83 and .89, indicating a high degree of homogeneity (test-retest coefficients = .50 - .92; inter-rater coefficients = > .90). Inter-item values between the graphic speed task and other tasks were lower (ranging from .43 to .54) and as a result it is recommended that scores for this task be recorded separately. Content validity of this test was sought with reference to other speed tests. Particular attention was given to the influence of other cognitive factors during testing, such as the role of memory in certain tasks or the perceptual skills required for copying. This was overcome by the inclusion of a range of tasks. Ecological validity was achieved with the inclusion of the free-writing task. Discriminative validity was tested in two studies, one of children aged 11-13 with Special Educational Needs and one of university students with Dyslexia. Both found the DASH sensitive to the differences between the groups and typically developing children. In addition to the quantitative data yielded, this test provides opportunities for recording observations on qualitative aspects of the writing. The broad range of the component skills for handwriting assessed, the high reliability coefficients and the UK norms make this test the most obvious choice for use in these studies, particularly as it can be administered within thirty minutes.

5.5.2 Data collection II – non-standardised measures

The second type of data to be collected was that arising from the experimental writing tasks devised for each study. On each occasion, children were required to produce a narrative in response to a prompt and the scripts they produced were analysed on a number of specified measures (see below).

Stimuli and tasks for narrative writing: Thought was given to the genre of writing for the tasks and to the stimulus to be chosen. Decisions were made according to what would be most appropriate for the age of the participants in each study. Studies of children's writing suggest that, in typical development, children are skilled in writing narrative by the end of the primary school, with expository discourse developing slightly later (Hooper, 2002; Scott & Windsor, 2000). Ease of writing was felt to be important in the choice of genre for Studies 1 and 2 so, since the children were in their final year of primary school, a narrative task was deemed most appropriate. With regard to the stimulus for writing, research shows that the type of prompt chosen, whether verbal or visual, might also influence results (Hooper, 2002). Guidelines proposed by Hooper et al. (1994) directed the choice of a pictorial prompt: the use of a real picture. These guidelines suggest that the pictures should contain at least two characters, show an interesting scene or event and include possible conflict between two characters which would require a goal-based sequence of events for resolution to occur. The pictures used in this study, taken from a study by Stainthorp and Hughes (1999), depict three main characters: potential protagonists - the two children, and a possible antagonist - the dragon. The same set of pictures was used as the stimulus for both writing and for telling a story. Thought was also given to the manner of instruction given. The following was chosen to encourage the children to write imaginatively and to give them a sense of audience (Prior, 2006):

> "Write/tell a story based on these pictures. Make it as exciting as you can so that it can be read/told to other children."

With the change in age group for Study 3 it was decided that the writing task needed to be modified. Several issues influenced the decision. First, in order to be consistent with the type of task expected of 15-16 year olds in school the duration of the task should increase. This would also test the students' ability to sustain writing over time. However, confining the total testing time to practical levels was also a defining factor so it was decided to increase the writing time from ten minutes but no longer than fifteen. Second, a topic needed to be found which was demanding enough to engage students for the whole period. The choice of genre was also important as it was felt that simple narrative would be not demanding enough for this age group whose range of genres for writing would have significantly increased. Third, it was important to choose a task which could also be performed in oral as well as written mode, as a comparison between modes was again to be made. Finally, a verbal rather than a pictorial prompt was deemed to be more adult and thus more likely to engage interest.

Several different writing tasks, using both narrative and expository discourse (chosen with guidance from teachers of this age group) were piloted with children in Years 10 and 11 in local comprehensive schools. However, none of the author-devised tasks proved satisfactory in stimulating the students to write for the length of time chosen. Thus, reference to existing writing tests was made and a descriptive task, "My Ideal House", was chosen from the test for Written Expression from the Wechsler Objective Language Dimension (WOLD: Rust, 1996). This task met all the criteria set out: (a) it was stimulating enough to produce a variety of responses; (b) the mode of scoring was clear and detailed (see below), and (c) it lent itself to replication in oral mode. The prompt for the task was verbal: the tester read out the statement from the WOLD prompt booklet (see Appendix 12). In written mode, the student was required to write a letter to the architect describing the house. Scripts were transcribed into typed form ready for rating and spelling and punctuation were corrected. In oral mode, the student was required to describe the house to the architect by phone. The oral accounts were recorded using a dictaphone (Sony IC recorder ICD-MS515) and were later also transcribed into typed form. Words and sounds of hesitation and repetition were omitted. The individual total times taken in written and in oral task were recorded.

The writing tasks for Study 4 were very different from those of the earlier studies. The reason for this was that very specific factors needed to be included to meet the criteria for the experiment set out. These are described in great detail together with the rationale for choosing them in the methods section of Chapter 9.

5.5.3 Data collection III – Questionnaire responses

The third type of data collected was of a qualitative nature and came from the questionnaire sent to all parents of the participants in Study 3. Questions were grouped under the following headings:

1. Home and family stability (e.g. family break-up, bereavement).
2. Health and general wellbeing (e.g. prolonged illness, emotional instability, difficulties relating to puberty, diagnosis of medical conditions or developmental disorders).
3. Educational issues (e.g. change of school, truancy, school underachievement, preferred mode of producing text).
4. Interventions (such as for reading, spelling, motor control or specifically for handwriting, learning to touch-type).

The intent behind the questions was to identify possible reasons for under-achievement which could be accounted for by medical, social, emotional or environmental events which were unrelated to the study but which might impact upon the performance tested.

5.5.4 Data collection IV – computerised systems

Study 4 sets out to test a particular theory, that of the limited cognitive capacity, and how that might impact on the relationship between transcription and composition. It focuses more on the *process* of the writing than on the *product*, thus much of the data sought is not visible to (or quantifiable by) the naked eye. Testing, therefore, had to be conducted using computerised means. The use of computerised digitiser systems for analysing handwriting has grown widely in the last decade, as has the range of software programmes available for research purposes. It is generally accepted that the use of such devices enables the researcher to achieve much greater precision and detail than was previously possible (Rosenblum, Parush, & Weiss, 2003). These authors note that it also provides the possibility of examining changes in a child's handwriting as a function of fatigue, task complexity or mode of text presentation. A number of different programmes are now available but they tend to be programmed with specific diagnostic aims in mind (see below).

Rational for the choice of the Computerised Penmanship Electronic Tool (ComPET)

An increasing number of studies employ computerised technology for handwriting analysis. A review of some of the most relevant studies suggests that much of it is self-designed by the researchers, targeted to elicit data of a highly specific nature. One example of this is that of Christian Marquardt whose software was devised to measure the parameters of writing strokes and their deviation from a mean for purposes of measuring (or attempting to measure) degrees of automaticity (Marquardt, Gentz & Mai, 1999). Several programmes are available to measure kinematic characteristics of handwriting, such as that used by Smits-Engelsman, Niemeijer, and Van Galen (2001) and Chang & Yu (2010), both of whom collected spatial, temporal and force measures to answer their particular research questions. Another programme devised to analyse handwriting patterns is "Eye and Pen" (Alamargot, Chesnet, Dansac, & Ros, 2006), which is designed to take synchronous recordings of the nature and duration of the eye fixations as a function of the writer's grapho-motor activity during written composition. This way, the researchers are able to collect data to measure and analyse pauses within a writing task, particularly their length, position and frequency. All these different programmes offer a new range of methods for quantifying handwriting performance in a natural setting, recording activity on the writing surface. However, one of the anomalies detected in the experimental work conducted in the early studies of the thesis is that the time poor writers spend *on* the page does not necessarily equate to the total amount of time spent on a writing task. This has led to questions over what is happening when the pen is *off* the page. The only software programme found which, in addition to recording the spatial, temporal and force measures basic to the handwriting itself, records the duration and pathways of the pen in the air during the pause times is the ComPET. This made it the software of choice for this final project.

Data collection

The experimental tasks were conducted using a WACOM Intuos 4 digitiser tablet and WACOM Intuos Cinteq sensitive inking pen. Children wrote on lined A4 paper, fixed to the surface of the tablet and used an ink-pen, chosen to leave a trace on the paper to allow the child to monitor what he was writing. The tablet was linked to a Sony Vaio laptop computer on which the ComPET software programme had been installed. The data were collected automatically by the software in real time, involving no objective interpretation by the tester. After testing, the raw data were returned to the software designers to be aggregated to a final measure, programmed through the ComPET data analysis system on MATLAB software toolkits (for more details see Rosenblum, Chevion, & Weiss, 2006; Rosenblum, Dvorkin, & Weiss, 2006). Data files created for each child using the software were then returned to the researcher in visual and numerical form for statistical analysis.

Data preparation

The ComPET software yields two types of measures – the child's visible trace plus a number of kinematic variables computed from performance on the digitiser tablet via the sensitive ink-pen. These comprise 14 variables, not all of which will be discussed in this thesis, but they can broadly be divided into *temporal, spatial* and *force* measures. The digitiser provides accurate temporal and spatial measures throughout the writing tasks, both when the pen is touching the tablet ("on paper" time) and when the pen is lifted above the digitiser (up to 6 mm) (beyond 6 mm the spatial measurement is not reliable). This is described as "in air" time. Force measures are recorded on the tablet from the pressure of the pen above 50 (non-scaled) units upwards.

It is important to note that this handwriting evaluation system does not recognise letters, words or sentences. It only analyses *segments*, i.e. the pathways created by the movement of the pen-tip on the paper, represented on an *x-y* co-ordinate system (Mergl, Tigges, Schröter, Möller, & Hergerl, 1999). This means that the computerised analysis recognises only points when the pen is in contact with the paper or leaves it. Segments are measured from when the pen pressure rises above 50 units at the beginning of the segment (see above) to when the pen returns to 50 at the end of the segment and is raised from the paper. Authors of the programme note that intra-individual variability across different measures can be recorded by the aggregation of measures for the entire task, providing both mean values and standard deviations (Luria & Rosenblum, 2011). The standard deviations between segments can be calculated in each condition. Also, because the tablet reports readings of the measures 100 times per second, it is possible to capture changes in pressure even within segments.

5.6 Data analysis

5.6.1 Data from standardised tests

All data from the standardised tests were scored according to the test manuals and prepared for statistical analysis (see below).

5.6.2 Data from narrative tasks - oral and written

5.6.2.1 Scoring procedures

All transcribed scripts yielded the following quantitative measures:

Length of scripts:	Word count included complete words, repetitions and errors, but not partial words nor crossings out.
Total time taken:	The number of minutes the children took to complete the task.
Speed of production:	The total number of words produced divided by the total time spent writing/speaking.

Next, all the scripts were rated on a qualitative measure:

Composition quality

This was rated by educationalists familiar with the work of children at each age. Two experienced teachers were used for Studies 1 and 2. For Study 3, where the full WOLD was used, raters were two Educational Psychologists, familiar with scoring this test. Initially, the recommended holistic method was used. This is advocated by Rust as a quick and easy tool for assessing a general level of composition quality (Rust, 1996) and was chosen on this occasion to reveal the possible presence of differences in composition quality which might warrant more detailed investigation. Raters were given written guidelines for holistic scoring and were trained using sample scripts. Criteria were taken from the composition guidelines for holistic assessment in the Wechsler Objective Language Dimension (WOLD) (Rust, 1996), though punctuation, spelling and handwriting quality were not taken into consideration (see Appendix 7). Scripts were rated on a scale of 1 - 6, 1 representing the poorest performance and 6 the best. Confidence in this type of assessment was drawn from unpublished studies conducted by The Psychological Corporation include reliabilities (in the range of .80) between scorers trained in rating scripts in this way. In this study, inter-rater agreement on transcribed scripts was measured using Cohen's Kappa (K) to correct for chance agreement. To assess the significance of Kappa, Fleiss (1981) suggests that K of .40-.60 demonstrates agreement which is 'fair', between .60-.75 'good' and above .75 'excellent'. Excellent agreement between raters was recorded here ($K = .84$)

Once this assessment had been completed and an analysis conducted (see Chapter 6, p. 93), results indicated that it would be appropriate to apply a second, more detailed analysis which measured different components of composition. To achieve this objective, the scripts were next rated according to the analytic criteria set out in the WOLD on a 4-point scale in line with the test instructions, 1 representing the poorest and 4 the best. Five of the seven different components of composition were rated separately: *generation and development of ideas, organisation, cohesion and unity, vocabulary, sentence structure,* and *grammar. Capitalisation* and *punctuation* were not included (see Appendix 8). The transcribed scripts were re-rated by the same two experienced teachers.

If, on the first assessment, inter-rater reliability was only good (.65), reassessment was undertaken following discussion on marginal decisions to bring it to the level of excellent (i.e. above .86).

5.6.2.2 Assessment of handwritten scripts (un-transcribed)

In order to examine the effect of presentation on perceptions of composition quality, handwritten scripts were separately exposed to analysis. These were presented in their original form without spelling or punctuation errors corrected. The scripts were assessed on the following measures:

Handwriting quality

Scripts were rated holistically on a scale of 1 - 6 according to general neatness and legibility, 1 representing the poorest and 6 = best. This method of measuring handwriting quality correlates highly with electronic measurement in which graphic or digitiser tablets are used with appropriate software (see Rosenblum, Weiss, & Parush, 2004). Raters for this assessment were specifically selected from the board of the National Handwriting Association for their expertise in the subject. They were given written guidelines for categorising scripts, devised with reference to Sassoon (1990) and Taylor (2001) (see Appendix 6). Emphasis was on legibility, correctness of form, consistency of form and neatness. Scripts were not penalised if an un-joined style was used, though it was expected that where used, the joining strokes should be correct. As before, Cohen's Kappa was calculated to measure inter-rater agreement. As above, if the initial value of K showed that the initial agreement was only good, discussion between raters would follow to elucidate salient points within the set criteria, and scripts were re-rated and Kappa was re-calculated until excellent agreement was reached.

Spelling

The number of correctly spelt words was calculated as a percentage of the total of the number of words written.

Composition quality

Handwritten scripts were rated as above for composition quality using the holistic assessment.

5.6.3 Statistical analysis

As all data in the studies, with the exception of those gained from the questionnaire, yielded quantitative data, statistical analysis was possible. The particular tests chosen on each occasion matched the type of data gathered and are set out in each study. The Statistical Package for Social Sciences (SPSS) was the software of choice for the analyses. As this is the most popular software package for the social sciences currently used (Robson, 2002) and the one recommended for this type of research by the university there was no reason to look elsewhere. Later to become PASW, version 12 was used in Study 1, version 16 in Study 2, version 18 in Study 3 and version 20 in Study 4.

5.7 Ethical framework

5.7.1 Ethical approval

The ethical framework within which this research has been carried out is in keeping with the guidelines set out by the British Psychological Society (BPS, 2009). These were chosen for their particular suitability to the psychological nature of this research. The design of each individual study was approved by the Ethics' Committee within the Institute of Education, London University (see Appendix 1). The guidelines were studied by the author, and were adhered to as follows:

5.7.2 Participants

Testing

Participants in the study were from mainstream schools either in top primary or secondary education. They were tested individually by the author in a quiet room, either at her consulting room or at school, according to preference. The author is a qualified and experienced teacher and has Criminal Records Bureau (CRB) clearance.

Child consent

Participants for each study had the purpose and procedures of the research explained to them in a face-to-face pre-test interview. As the children selected were all of at least average intellectual ability, no difficulty in understanding their role in the research was encountered and all were able to give informed consent. For the classroom tasks the mode of consent sought for each child was dictated by each school (some schools required written permission from each parent, others did not). Schools and children who were approached for a repeat performance were consulted on each occasion. The parents of individual participants were consulted in face-to-face interviews and an explanatory letter was subsequently sent. Written permission for participation was received from at least one parent and from each child individually.

Appreciation

Participants were not offered material reward. The children and schools who participated received a personal letter of thanks on each occasion. Travel and other incidental expenses were offered by the researcher.

Risk assessment

Risks to the participants were minimal. The tester ensured that each child felt comfortable in the testing environment, fully understood the tasks set and did not feel undue pressure to perform. Children were put at their ease with conversation at the start of testing sessions and the purpose of the research was explained. They were also told that they were at liberty to stop participating at any point during the testing if they so wished. They were reassured about confidentiality of the findings.

5.7.3 Feedback

Written feedback was provided for parents and schools. A simplified written version was also made available to the children. Opportunities for further discussion were offered. Some parents took up this offer and follow-up meetings were held by phone.

5.7.4 Data protection

Individual protection

Each participant was reassured that his/her work would remain anonymous. Coded letters and numbers were used to identify scripts and this coding was known only to the researcher. Where scripts were rated by independent raters, these codes protected the identity of the children. In addition, all computer data files were coded so that no child was identified. This information was also included in any letters that went between the researcher and any adults involved in the research.

Compliance with legal requirements

According to the author's understanding of the Data Protection Act 1998, the data collected could not be considered to be "sensitive". However, any seemingly personal material which might have emerged from the writing of an individual was respected and kept anonymous. Although at the time of writing there were no incidents of material causing concern, should any future issues arise regarding the disclosure of information of a deeply personal nature which might cause concern, this will be discussed with supervisors and dealt with appropriately.

5.7.5 Benefits of the research

It is anticipated that the beneficiaries of this research will be the teachers of the children who participated and their parents. It is also hoped that the children themselves will benefit, indirectly, through a greater understanding of their writing difficulties. Findings from the research should provide increased understanding on the part of teachers in their dealings with these and future pupils.

Chapter 6

Study 1: Difficulties of written expression in children in the top of the primary school: An exploratory study.

6.1 Introduction

In school, children spend as much as 50% of the day engaged in activities involving writing (Dennis & Swinth, 2001; Rosenblum et al., 2004), yet this vital skill poses problems for a substantial number of them. In the United Kingdom, empirical evidence of the extent of this issue can be found in regular reports provided by the Department for Education (DfE: www.education.gov.uk). In 2011, for example, 81% of girls but only 68% of boys reached the required standard for writing at 11 years of age. Included in these figures are children who would be expected to write well given their general levels of intelligence and linguistic ability, but who fail to do so. It is these children who form the focus of this study.

As previous chapters have shown, writing is a complex and intellectually demanding skill requiring the integration of a number of cognitive, meta-cognitive, linguistic, perceptual and motor processes (Torrance & Galbraith, 2006). In essence, ideas must be generated and developed into organised and cohesive units (Rust, 1996), after which the physical expression of those ideas must be achieved through the integration of orthographic knowledge (i.e. mastery of the rules of the spelling and writing systems to be used) with the motor demands of handwriting (i.e. the ability to form letters, maintain the alignment of words, etc.) (Christensen, 2005). Between the idea and the mark on the paper, writing also requires the accessing of lexical, or word, knowledge, semantic coding, phonological processing and the monitoring of syntactical structures (Bain, 1991; Berninger, 1994). Broadly speaking, the literature treats these many processes under two separate headings: *composition* which involves planning, translating and reviewing; and *transcription* which involves handwriting and spelling. Despite this separation, most recent research has shown a strong relationship between these two aspects of writing (e.g. McCutchen, 1998; Torrance & Galbraith, 2006) which develops over time (Olive & Kellogg, 2002). Not only does transcription serve to record composed thoughts but also the physical act of handwriting and spelling influences the composition itself (Galbraith, 2009). Not surprisingly, where transcription skills are impaired there is evidence that composition suffers (Christensen, 2005; Connelly & Hurst, 2001; Medwell, Strand & Wray, 2009).

Studies which have attempted to estimate the number of children who experience problems with writing produce figures ranging between 10 and 30% (e.g. Rosenblum, Weiss & Parush, 2004). Within these estimates, there will be children with many different problems from those with low IQ and global learning difficulties, through those with generalised literacy problems to those with highly specific handwriting difficulties, sometimes labelled dysgraphia. The primary aim of the present study is to explore the characteristics of a particular subset of children, whose high intelligence and verbal ability render their problems with written expression rather puzzling. In many of these children the difference between their ability to relate stories orally and their ability to write them down also adds to the puzzle, since many are able to tell a story very well. Aware of the fact that their pupils are bright and have the potential to write well, their teachers express frustration at their writing problem and often describe their composition as meagre or 'thin'. Frequently, difficulty with the physical mechanics of producing written text, i.e. handwriting, is present and may well have a role to play in the problem, but exactly how a deficit in physical production leads to a deficit in composition is yet to be determined. It is well known that children with generalised motor coordination problems i.e. DCD, have difficulty with handwriting (e.g. Barnett & Henderson, 2005; Geuze, 2005; Miller et al., 2001) so it seems reasonable to expect that this literature would reveal studies relevant to this problem. To date, however, no studies of children with DCD which attempt to link the physical and compositional aspects of writing were found.

The aims of the present study, therefore, are twofold. The first objective is to describe in detail children whose teachers have selected them on the basis of two criteria: (a) their handwriting is poor given their age, and (b) their written expression is poorer than would be expected given their general levels of ability. The extent to which a movement difficulty might account for their difficulties in writing in the broader sense will be a major part of this enquiry. In order to ensure that the difficulties experienced by the selected children are not due either to a generalised learning difficulty or to specific language or literacy problem, IQ and various aspects of literacy will be assessed. In order to minimise the chances of a problem being attributable to insufficient teaching in those aspects of literacy relevant to writing, only children with five or six years of formal education will be included. In the UK, this means children of ten or eleven years of age. In addition to providing a detailed profile of the individual children, these data will show whether teachers are accurate in identifying such difficulties.

As noted in Chapter 1, my own experience of this group of children is that they are much more able to express themselves orally than in writing. This is in contrast to the pattern predicted by the literature on typical development which suggests that children are able to express themselves at a comparable level in either mode at this age. (Loban, 1976). A second question to be addressed in this study, therefore, will be whether children selected by their teachers as having unexpected writing difficulties do actually show this pattern. To this end, the children's performance on a narrative task in both written and oral modes will be compared in detail. Since little normative data is available on the differences between children's oral and written performance in the population at large, each child with difficulty will be compared with a control child, matched on age, gender and intelligence. This will enable the similarities and differences in the two modes of expression to be examined. In addition, since evidence from the literature suggests different developmental rates for girls and boys, possible gender effects can also be explored.

6.2 Method

6.2.1 Participants

Twelve children, six boys and six girls, aged 10-11 years were recruited from Years 5 and 6 in mainstream primary schools in North London. All had been referred by their teachers for help with handwriting difficulties and were described as having writing problems extending beyond the physical production of text which were 'unexpected', given the children's general level of intelligence and verbal ability. In addition, twelve control children with no known writing difficulties were selected. They were matched for age and gender, and were from similar bands for general ability as the target children. They were all from similar schools in the same geographical location (see Chapter 5 for detailed description of subject selection).

6.2.2 *Data collection*

6.2.2.1 Standardised Tests

General Intelligence

The children in the target group were formally assessed for general intelligence using The Wechsler Intelligence Scale for Children 3rd Version UK, short form, (WISC III-R UK, Wechsler, 1992). The verbal components used were Similarities and Vocabulary whilst the performance components were Block Design and Object Assembly. Verbal and Performance IQ scores were derived.

Reading

Reading levels were tested using The British Ability Scales II - Word Reading (Elliot, 1996) which requires the child to read aloud a list of words of increasing difficulty. Correct answers were recorded as raw scores from which standard scores were calculated. Children with scores 2 standard deviations (henceforth SDs) below the mean were considered to have a significant word reading difficulty.

Spelling

The British Ability Scales II - Spelling (Elliot, 1996) was used to test spelling ability. A list of words of increasing difficulty was dictated to the child to be written down. Numbers of correct answers were recorded. As with the reading sub test, raw scores were converted into standard scores and children with scores 2 SDs below the mean were regarded as having a significant spelling difficulty.

Reading Comprehension

Reading comprehension was tested using The Neale Analysis of Reading Ability (NARA) II (Neale, 1989). Children were given a passage to read and then asked questions about the text. Standard scores were obtained and, again, scores falling two SDs below the mean were taken to indicate a significant reading comprehension difficulty.

Motor Competence

Motor ability was assessed using the standardised test from the Movement Assessment Battery for Children (M-ABC, Henderson & Sugden, 1992). This test is in three parts, yielding separate scores and percentile ranks for manual dexterity, ball skills and balance. Higher scores indicate greater levels of motor impairment. Scores below the15th percentile suggest mild levels of motor impairment whilst scores below the 5th percentile suggest more marked impairment. When combined with other data, this test is often used as an indicator of Developmental Coordination Disorder (see Chapter 5. p. 90).

6.2.2.2 Scoring

Standard scores were obtained on all standardised tests. Where appropriate, cut-off points were set as suggested in each test as criteria for identifying children with difficulties.

6.2.2.3 Narrative Tasks

The prompt for the narrative tasks for the study was a six-card picture sequence, depicting a dragon and two children (see below in Figure 6.1). Chosen in line with research evidence on suitable stimuli (see Chapter 5, p. 72), the children were instructed as illustrated:

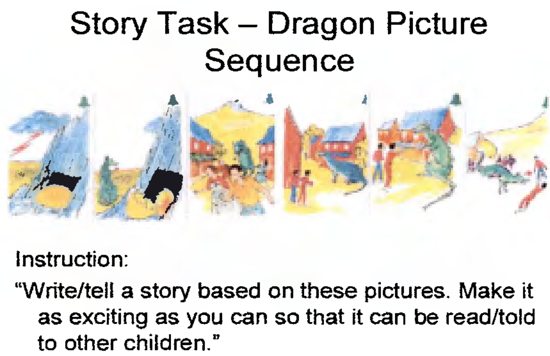

Figure 6.1 Prompt for narratives in written and oral mode.

Written Narrative

Each child was shown the six-card picture sequence and instructed to write a story based on it, as shown above. A maximum of 30 minutes was allotted for writing the story and the actual time taken by each child was recorded on each occasion.

Oral Narrative

After one week each child was asked to produce a story orally in response to the same picture stimulus. Stories were recorded using a dictaphone (Sony IC recorder ICD-MS515). No time limit was applied but the total time taken for each individual child was recorded.

6.2.3 Data preparation

Written and oral narratives

All stories, both written and oral, were transcribed into typed text. Written stories were corrected for spelling and punctuation and in the oral stories signs of hesitation such as 'um' 'er' were removed. The 48 scripts were coded for anonymity using a random number table. The 24 handwritten scripts were retained for separate assessment (see later). All transcribed scripts yielded the following quantitative measures:

1. *Number of words produced*: word count included complete words, repetitions and errors, but not partial words nor crossings out.
2. *Total time taken*: the number of minutes the children took to complete the task.

3. *Speed of production*: the total number of words produced divided by the total time spent writing/speaking.

Next, all the scripts were rated on a qualitative measure:

4. *Composition quality*

All scripts were rated first holistically on a scale of 1 - 6, 1 representing the poorest performance and 6 the best. Results from this analysis indicated that a more detailed, analytic assessment would be appropriate (see below). Using 5 of the 7 criteria taken from the Wechsler Objective Language Dimension – Written expression (WOLD) (see Chapter 5, p. 76), scripts were further rated on a 4-point scale in line with the test instructions, 1 representing the poorest and 4 the best. Each of the following different components selected were rated separately: generation and development of ideas, organisation, cohesion and unity, vocabulary, sentence structure, and grammar. Two Educational Psychologists familiar with the test conducted the rating of scripts.

Assessment of handwritten scripts (un-transcribed)

A further analysis was conducted on the handwritten scripts in order to examine the effect of presentation on perceptions of composition quality. These were presented in their original form with spelling and punctuation errors uncorrected. The scripts were assessed on the following measures:

Handwriting quality: Scripts were rated holistically on a scale of 1 - 6 according to general neatness and legibility, 1 representing the poorest and 6 the best.

Spelling: The number of correctly spelt words was calculated as a percentage of the total of the number of words written.

Composition quality: Handwritten scripts were rated holistically, as above for composition quality.

6.2.4 Procedures

The children in the target group were seen individually for two x 2-hour sessions. They were assessed on standardised measures for intelligence, literacy and motor ability, and were set a narrative task, first in written, then in oral mode. All were tested under similar environmental conditions, i.e. in a quiet room with only the tester present, seated at a table and writing on lined A4 paper with their own chosen pen. Each session was timetabled so that all tasks were covered in the same order for each child. Tasks requiring writing were interspersed with non-writing tasks to sustain motivation and minimise fatigue. The story tasks were given on separate occasions with the written task always preceding the oral task. The controls were also seen individually in the same way and completed the narrative tasks for comparison. They also wrote their stories before producing them orally.

Table 6.1 Order of Testing in each of two sessions

SESSION 1	SESSION 2
BAS II Reading	NARA Reading comprehension
Dragon Story (written)	WISC III-R (Vocabulary, Object Assembly)
Movement ABC	Dragon Story (oral)
WISC III-R (Similarities, Block Design)	BAS II Spelling

6.2.5 Statistical analysis

Scores for the narrative tasks were derived from ratings on set measures by independent raters. Parametric data were analysed using ANOVA. Where data were non-parametric, Mann Whitney U tests and Wilcoxon matched pairs tests were used as appropriate. A Pearson's Product Moment or Spearman's Rho were used for correlational analysis where appropriate.

6.3 Results

6.3.1 Standardised tests: target children only

Table 6.2 shows the individual subject data for the target group, along with means and standard deviations for age, verbal and performance IQ, single word reading ability, spelling, reading comprehension, and motor competence.

Table 6.2 Individual data on standardised tests for target children

Name	Age	Sex	VIQ	PIQ	BAS Reading SS	BAS Reading Comprehension SS	BAS Spelling	MABC %
1	10.58	F	139	91	145	1166	157	1
2	10.17	F	139	115	1332	113	137	1
3	11.17	F	141	103	131	109	116	1
4	11.17	F	130	103	86	108	122	1
5	9.83	F	142	120	139	114	137	1
6	11.08	F	114	100	85	75	66	1
7	10.33	M	92	77	75	72	80	1
8	9.58	M	141	80	94	103	93	8
9	10.25	M	108	54	84	77	82	1
10	11.92	M	138	109	145	110	128	8
11	10.58	M	122	103	136	109	116	1
12	10.25	M	100	74	81	86	90	1
Mean	10.49		1225.5	94.08	111.08	99.33	110.33	2.17
SD	0.52		17.88	19.4	28.73	16.75	27.82	2.72

General ability

As Table 6.2 shows, all children scored within the normal range or above for verbal ability with eight of the twelve scoring in the high/gifted range i.e. above 120. In contrast, Performance IQ was below Verbal IQ in all cases. In four cases the scores were extremely low, falling at least two standard deviations below the norm.

Literacy

The children's scores on the British Ability Scale II (BAS II) word reading and spelling tests and on the NARA test of reading comprehension are also shown in Table 6.2. Seven children, 4 girls and 3 boys scored within the normal range or above on all three measures of literacy. For three boys (nos. 7, 9, 12), scores were at the low end of average across the three measures. One girl (4) had normal spelling and reading comprehension scores but obtained a poor score on the single word reading test (1 SD below the mean). The remaining child (7) obtained scores more than 2 SDs below the mean on all three measures, suggesting very weak literacy skills.

Motor Competence

Table 6.2 shows that on the standardised test contained within the Movement ABC, ten children scored below the 5th percentile (below the 1st percentile) indicating significant motor impairment or a "definite motor difficulty", and the remaining two scored between the 5-15th percentile (on the 8th percentile), described by the authors of the test as "at risk". Within the overall movement scores the results on the three subtests, manual dexterity, balls skills and balance, were then examined for evidence of particular patterns of impairment which might have relevance to a handwriting problem. Figure 6.2 shows the comparative performance on these subtests: the higher the score, the greater the impairment.

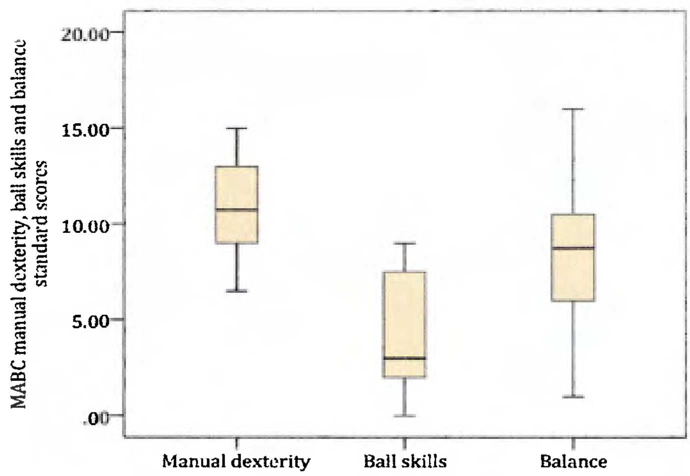

Figure 6.2 Box plots for MABC subtests of manual dexterity, ball skills and balance

Paired-samples t tests were conducted between pairs of subtests. Results showed that scores for ball skills were significantly lower (i.e. better) than scores for both manual dexterity ($t = 4.77$, $p = .001$) and for balance ($t = 3.94$, $p = .002$). The difference between manual dexterity and balance was not significant ($t = 1.91$; ns). However, within these subtest scores it seemed that the pattern for girls might be rather different from that for the boys (see Figure 6.3).

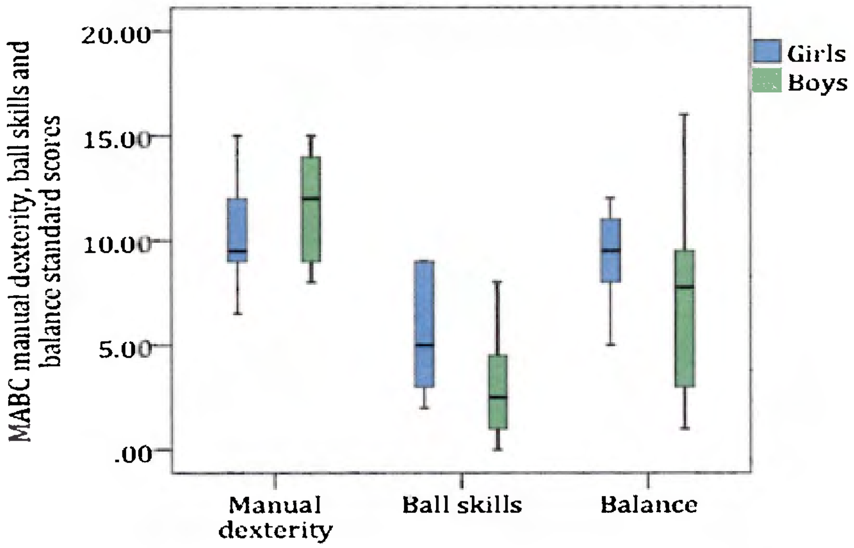

Figure 6.3 Box plot showing gender differences in MABC subtests

Despite the apparent girl-boy difference in the three sub-tests, a one-way ANOVA in this small sample found that these differences were not significant.

6.3.2 Summary of target children's results on standardised tests - evidence of DCD

All 12 children were of at least average verbal intelligence, eight scoring in the high/gifted range. All recorded markedly lower scores for Performance IQ than for Verbal IQ. Movement ABC scores showed that ten children fell below the 5th percentile and two fell between the 5th and 15th percentile. Taken together with IQ scores within the normal range, all twelve children met Criteria A and B for DCD (See Chapter 4). Although the numbers were too small for statistical analysis, it appeared that manual dexterity was the weakest area of performance, particularly for the boys. Nine children scored within the normal range or above on measures of general literacy, but three showed some level of impairment in reading. One of these scored low also on both spelling and reading comprehension.

6.3.3 Narrative Tasks

Table 6.3a and 6.3b present individual subject data for each of the target and control children on six measures for the written narrative task and four for the oral, followed by the group means and standard deviations for each variable. The measures taken are: number of words, total time taken, production speed, composition quality, and where relevant, handwriting quality and spelling.

Table 6.3 Individual subject data on written and oral narrative tasks

Table 6.3a. Individual subject data on written and oral narrative tasks for target group

Target group	Number of words		Production speed (wpm)		Total time (minutes)		Rated composition quality			Hand-writing Quality	Spelling % correct
	Hand-written	Oral	Hand-written	Oral	Hand-written	Oral	Hand-written	Hand-written (typed)	Oral (typed)		
1	145	214	10	122	14	1.75	4	4	5	4	95.10
2	222	221	7	120	28	1.83	5	5	5	4	98.65
3	156	211	9	114	16	1.45	3	3	3	3	95.10
4	357	465	19	155	18	3.00	6	5	5	6	84.03
5	118	158	11	108	10	1.45	3	3	4	3	100.00
6	67	82	7	122	9	0.67	2	1	2	2	71.64
7	60	63	13	105	4	0.60	1	1	2	1	88.67
8	66	108	11	100	6	1.08	2	2	3	3	88.06
9	50	92	10	180	5	0.51	1	1	2	1	77.55
10	119	128	14	128	8	1.00	3	3	4	3	97.46
11	109	158	12	190	9	0.83	3	2	3	4	99.10
12	54	79	8	136	6	0.58	1	1	2	1	88.13
Mean	127	165	12.00	138	11.11	1.23	2.83	2.58	3.50	2.75	90.00
SD	88.74	109	3.37	30.89	7.13	0.72	1.59	1.51	1.31	1.22	9.05

Table 6.3b. Individual subject data on written and oral narrative tasks for control group

Control group	Number of words		Production speed (wpm)		Total time (minutes)		Rated composition quality			Hand-writing Quality	Spelling % correct
	Hand-written	Oral	Hand-written	Oral	Hand-written	Oral	Hand-written	Hand-written (typed)	Oral (typed)		
13	96	116	11	116	9	1.00	3	3	4	4	95.9
14	161	200	11	114	15	1.75	5	5	5	4	99.4
15	278	167	19	155	15	1.08	6	5	4	5	98.6
16	113	79	11	158	10	1.08	4	3	3	5	99.2
17	315	146	21	118	15	1.24	6	5	4	5	99.7
18	193	162	13	97	15	167	5	5	5	6	96.4
19	60	61	7	124	9	0.49	3	2	3	2	90.5
20	140	95	7	116	20	0.82	4	3	3	3	99.3
21	102	100	7	133	15	0.75	3	3	3	2	93.4
22	145	158	15	95	10	1.67	4	3	6	3	100
23	111	76	7	117	15	0.65	3	3	2	5	98.2
24	79	63	8	94	10	0.67	3	3	2	5	98.8
Mean	150	119	11.00	120	13.17	1.07	4.08	3.5	3.75	4.08	97.00
SD	77.07	46.5	4.71	20.82	3.46	0.43	1.16	1.16	1.14	1.31	2.90

Number of words produced for target group and controls

The number of words produced in written and oral mode by target and control group children are shown in Figure 6.4. These data were analysed using MANOVA with two levels of the between-subjects factor (*group: target* and *control*) and two levels of the within-subjects factor (*mode of production*: *written* and *oral).*

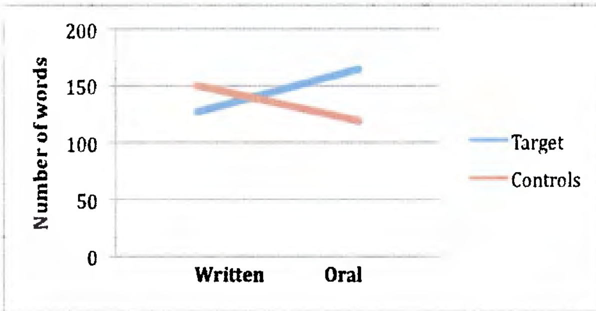

Figure 6.4 Number of words produced in written and oral narratives for target children and controls

This analysis revealed no significant main effect of group (F (1,22) = 0.13, ns) or mode (F (1,22) = 0.13, p = .719 ns) but the group x mode interaction was significant (F (1,22) = 13.23, p = .001). In order to explore this interaction further paired-sample t tests showed that the difference between modes was highly significant for the target group (t = -4.24 p = .001) but not in the control group (t = 1.86, ns). Thus, whilst the target group *spoke* significantly more than they *wrote*, the difference between modes for the control group was just outside the significant level. Difference between groups was not significant in either written mode (t = -.668) or oral (t = 1.347).

Total time taken and production speed in written and oral mode for target group and controls

The means and standard deviations for the time taken to complete the tasks in written and oral mode are shown alongside speed in words per minute for the two groups in Table 6.3a and b and illustrated in Figures 6.5a and b.

Figure 6.5 Total time taken and production speed for written and oral narratives in the target and control groups

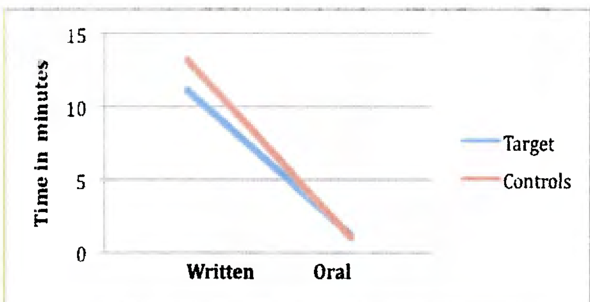

Figure 6.5a. Total time taken for written and oral narratives in the target and control groups

Although there was considerable individual variation in the amount of time children spent writing and speaking, a one-way ANOVA revealed that the differences between the two groups in total time taken was not significant for either task: writing (F = .81, ns); speaking (F = .42, ns). Because this result was unexpected, the medians as well as the means were calculated. These showed a marked difference between groups (target = 9 minutes; control = 15 minutes). Closer examination of the raw data revealed one outlier in the target group (S2) who took considerably longer than any other child from either group (28 minutes). When this child was omitted, the difference between groups was indeed significant (F = 5.154, p = .034), the target group writing for significantly less time than the controls.

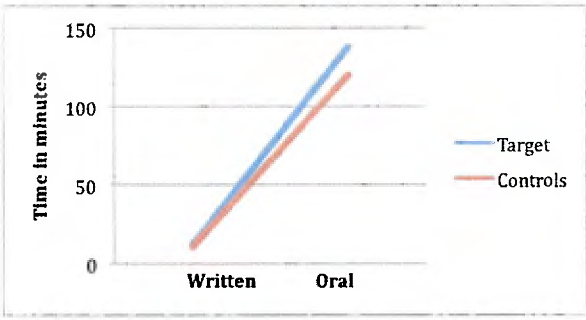

Figure 6.5b. Speed of production for written and oral narratives for the target and controls groups

The difference between groups on speed of production in words per minute was not significant: writing speed (F = .09, ns); speaking (F = 2.60, ns). A Pearson's Product Moment showed that handwriting speed and total time spent writing were not significantly correlated in either group (r = -.11 and .06 respectively) neither were speaking speed and total time spent speaking: target (r = .00, ns); controls (r = -.27, ns). Since these results were unexpected for the written task, a closer analysis of the children's writing performance over time was conducted.

Total time taken in the written mode for target group and controls

Table 6.4 shows the total time taken to complete the written story in three 10-minute blocks for each group.

Table 6.4 Number of children taking 0-30 minutes to complete written task

	Target	Controls
1-10	8	4
11-20	3	7
21-30	1	1
TOTAL	12	12

There was a marked difference between groups in the number of children who stopped writing in the first two blocks of time. Whereas the majority of the target group stopped within 10 minutes, the majority of the control group wrote for between 10 and 20 minutes. Since there was no difference in the speed at which the children actually produced words (wpm), the target children appeared to find it harder than the controls to sustain their performance over time. The examples above suggest that a more meaningful measure of production rate would result if the word-per-minute scores were interpreted alongside the length of time for which writing was sustained.

Handwriting quality in target group and controls

Rated handwriting quality of the two groups is shown below in Figure 6.6.

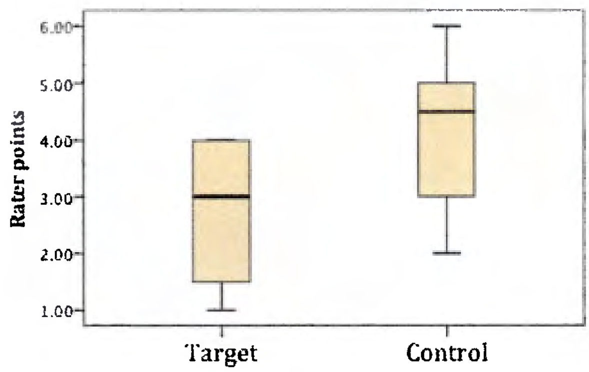

Figure 6.6 Rated handwriting quality for the target group and controls

Since these data are not suitable for analysis by parametric statistics, the non-parametric Mann -Whitney *U* test was conducted to examine possible group differences. A significant between-group difference was found on the ratings assigned to the handwritten scripts ($U = 35.00$, $p < .03$) with the handwriting ratings for the target group being significantly poorer than those for the controls. The two examples of handwriting shown in Figures 6.7a and 6.7b illustrate the difference between the target and the control children.

Figure 6.7 Sample of handwriting from the target and control groups

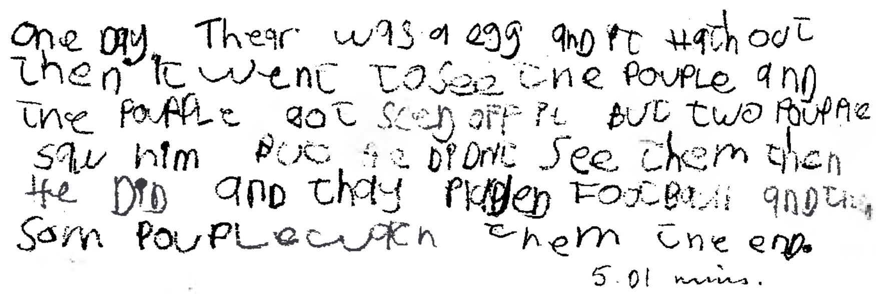

Figure 6.7a. Sample of handwriting from the target group

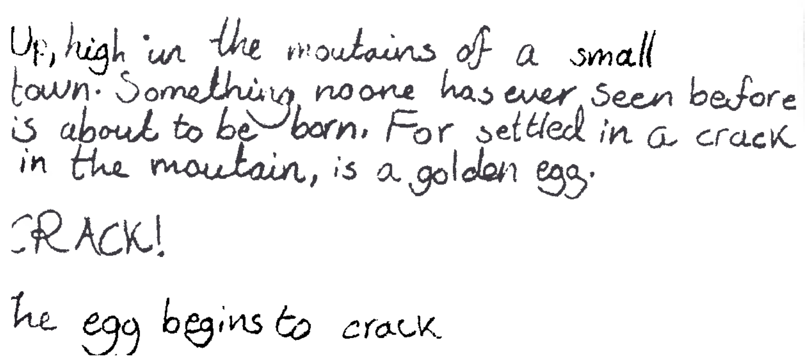

Figure 6.7b. Sample of handwriting from the control group

In the first sample, taken from the target group, the handwriting quality was assigned 2 points out of a possible 6. Whilst it is partially legible and many of the letters are correctly formed, it is quite difficult to read. Raters noted inconsistencies in the letterforms and strokes and that lower and upper case letters were interspersed. They also found many letters wrongly aligned with poor within-word spacing affecting legibility in places. In addition, they noted evidence of variable pressure on the page.

The second sample, taken from the control group, was assigned 4 points out of 6. In contrast to the first sample, this handwriting was considered to be legible and to contain a degree of consistency of letter size, with most, though not all, letters being correctly executed, joined and aligned. However, raters noted some inconsistencies in letter strokes which they considered to affect neatness, such as the vertical strokes not being consistently parallel.

Percentage of words correctly spelt for target group and controls

Figure 6.8 below shows the percentage of words spelt correctly in the written narratives for the two groups.

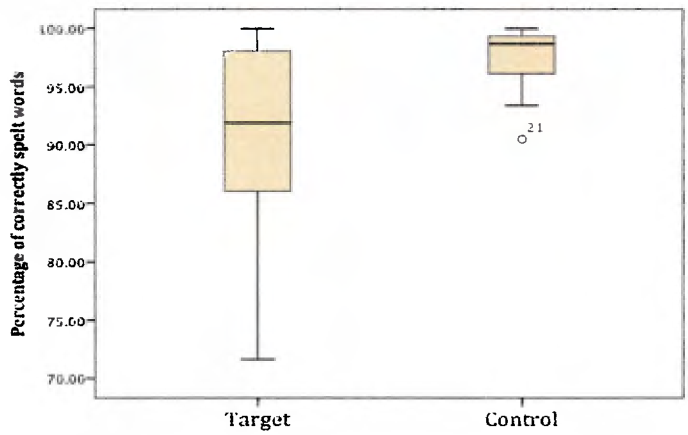

Figure 6.8 Percentage of correctly spelt words for target group and controls

Although there was considerable overlap between groups, a one-way ANOVA showed that children in the target group made significantly more spelling errors than the controls ($F = 6.80$, $p = .02$).

Rated composition quality for transcribed written and oral stories for target group and controls

The transcribed scripts of both written and oral stories were compared for rated composition quality and the results are shown below in Table 6.5. In this transcribed form, raters were blind to the mode of production.

Table 6.5 Means and SDs for rated for composition quality for transcribed written and oral scripts for target and controls

	Target	Controls
	Mean (SD)	Mean (SD)
Written	2.83 (1.34)	4.08 (1.16)
Oral	3.50 (1.31)	3.75 (1.14)

This difference is illustrated in Figure 6.9 below.

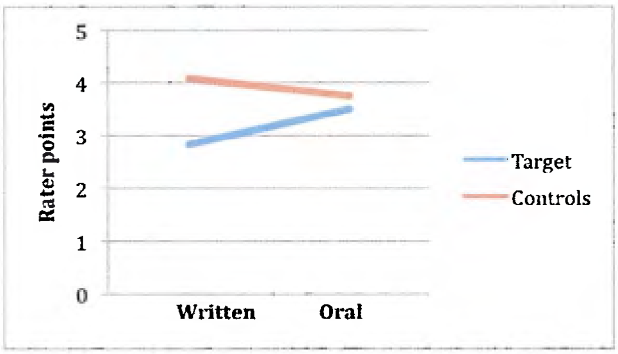

Figure 6.9 Rated composition quality for written and oral stories for target group and controls

Results of the Mann-Whitney *U* test showed a significant difference between groups in the ratings for the transcribed handwritten scripts ($U = 36.5$, p = < .05) but not for the transcribed oral scripts ($U = 57.5$, ns): in written mode composition quality for the target group was rated lower than controls but rating was the same for both groups in oral mode. In addition, looking at differences between modes for both groups, this was significant for the target group ($Z = -2.12$, $p < .002$) but not for the controls ($Z = -.95$, ns). Thus, compositional quality of written and oral stories was rated equally high for the control group. Stories for the target group were rated lower in written than in oral mode, and written stories were rated lower than the written stories of the controls.

The following examples, one from each group, shown in Figures 6.10a and 6.10b, demonstrate ratings of composition quality:

Figure 6.10 Examples of writing

Figure 6.10a Example 1 (Rated 1 point)

"One day there was an egg and it hatched out then it went to see the people and the people got scared but two people saw him but it didn't see them then he did and they played football and then some people caught them. the end."

Figure 6.10b Example 2 (Rated 5 points)

"Up, high in the mountains of a small town, something no one has ever seen before is about to be born. For, settled in a crack in the mountain, is a golden egg.
CRACK!
The egg begins to crack.
CLICK! The pieces of eggshell have fallen out of place and a dragon is born.
The dragon wondered, "Where are my parents?' He waited patiently for a hundred years, then decided to leave the mountain. Down he went, past a desert and through a river and there lay a town. The dragon had travelled far and now was searching for food. The dragon ate two people straightaway. He liked them and decided that this was his favourite dish. The townspeople were terrified. They didn't know what to do. But then a smart boy had an idea. He got some scarecrows from his farm, took out the hay and replaced it with stones.
"Hey, dragon!" shouted the boy, "Try this." The boy threw the scarecrows at the dragon and ran.
"Yum", said the dragon, "more people to eat." The dragon gobbled up the scarecrows and then had terrible bellyache.
"Yuck", said the dragon, "people are not my favourite dish after all" and he left the town snorting."

The first example (illustrated in Figure 6.10a), written by a child from the target group, was rated 1 point for composition. It scored at the minimum level as the grammatical limitations make the story barely comprehensible, and even if it had been punctuated the reader would have found it hard to follow. In addition, only the skeleton of events has been written about. There is no elaboration of the facts, the language is very simple and no interesting vocabulary has been used. The piece lacks imagery or ideas additional to the story which enhance it. The second example (illustrated in Figure 6.10b), written by one of the control children (part shown from transcribed handwritten form above) was assigned 5 points for composition. The story has cohesion, the grammar and sentence structure are correct. However, in addition, the child has assimilated the story sequence from the stimulus and used it to create something over and above the basic facts. Although it is quite simply written and the vocabulary is not particularly varied, the writer has managed to convey an instant sense of drama and expectation from the outset. The story continues in similar vein throughout, drawing the reader through the narrative and bringing it to a satisfactory, if brief, conclusion. Full marks (6) might have been awarded if more extensive vocabulary had been used, if the imagery had been developed further and a greater degree of description had been included.

Rated composition quality across individual components

Having looked at holistic ratings on composition quality for both groups in both modes, a further analytic assessment of certain components of compositions was conducted for evidence of specific areas of weakness. Here, transcribed written and oral scripts for both groups were rated on five composition components based on those from the WOLD (Rust, 1996). These were: *generation and development of ideas, organisation cohesion and unity, vocabulary, sentence structure, grammar.* Results are shown in Table 6.6.

Table 6.6 Means and standard deviations on composition components on written and oral narrative tasks for target group and controls

	Target		Controls	
	Written	Oral	Written	Oral
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Generation and development of ideas	1.83 (.83)	2.25 (.75)	2.50 (.67)	2.33 (.89)
Organisation cohesion and unity	2.67 (.89)	2.58 (.90)	2.83 (.72)	2.58 (.69)
Vocabulary	2.08 (1.08)	2.17 (.83)	2.42 (.67)	2.17 (.58)
Sentence structure	2.42 (1.08)	2.42 (.79)	2.50 (.67)	2.50 (.67)
Grammar and usage	2.75 (1.14)	2.75 (.87)	2.92 (.51)	2.83 (.72)

First, using a series of Mann-Whitney U tests, the target children's ratings for performance on each of the five components of composition were compared with those of the controls in both modes. In oral mode, no significant group differences were found in any of the components measured: *generation and development of ideas* ($U = 69.5$, ns; *organisation, cohesion and unity* ($U = 63.5$, ns; *vocabulary* ($U = 69.5$, ns; *sentence structure* ($U = 68.00$, ns; and *grammar and usage* ($U = 69.00$, ns).

In written mode, the pattern of results was the same for both groups on four of the five components. No significant group differences were found on organisation, cohesion and unity ($U = 65$, ns), vocabulary ($U = 52.5$, ns), sentence structure ($U = 68.5$, ns) and grammar and usage ($U = 68.5$, ns). However, in one component, *generation and development of ideas,* there was a significant group difference ($U = 41.0$, $p = .005$): the target group was weaker than the controls in this respect. Because of possible repetition effects within the groups on the five components, a more stringent application of the significance level from .05 to .01 is suggested (Siegel & Castellan, 1988) and that replication of the analysis on this component with a larger sample is needed for a more robust result.

Next, the difference between modes for each group separately was tested using a series of Wilcoxon matched-pairs tests on each of the five components of composition. For the control group no significant differences were found on any measure (Maximum *Z* value = -.30). For the target group, whilst no significant differences were found between oral and written narrative production on organisation, cohesion and unity (Maximum *Z* value 0.45), a significant difference was found in the generation and development of ideas in favour of oral over written narratives (Wilcoxon $Z = -2.24$, $p = .03$). This suggests that the groups performed similarly in both modes in all components of composition measured with one exception: the target children's stories were rated poorer than the control children on the generation and development of ideas in written mode and poorer than in their own stories told orally in this respect.

Rated composition quality for stories (handwritten) for target group and controls.

In addition to the analysis in which differences in composition quality between modes and groups were found in transcribed scripts rated blind, a further analysis was conducted to assess whether rater perception of composition quality might be influenced by quality of presentation and whether this differed across the two groups. For this analysis the original stories were assessed in their handwritten form (which included uncorrected errors of spelling and punctuation). The same raters were used as had rated scripts un-transcribed, though one week had elapsed between these ratings. The means and standard deviations for the groups together for both transcribed and un-transcribed written scripts are shown below in Table 6.7.

Table 6.7 Means and standard deviations for composition quality rated holistically for the transcribed and un-transcribed written scripts for both groups together

	All	Target	Controls
	Mean (SD)	Mean (SD)	Mean (SD)
Transcribed	3.45 (1.38)	2.83 (1.34)	4.08 (1.16)
Un-transcribed	3.04 (1.39)	2.58 (1.50)	3.50 (1.17)

Analysis of these data using the Wilcoxon Signed Ranks Test showed that when the groups were taken together, composition quality ratings were higher for the transcribed (typed) scripts than when assessed in their un-transcribed (handwritten) form (Wilcoxon $Z = -3.16$, $p < .01$). A further analysis was then conducted to see if the groups were similarly affected.

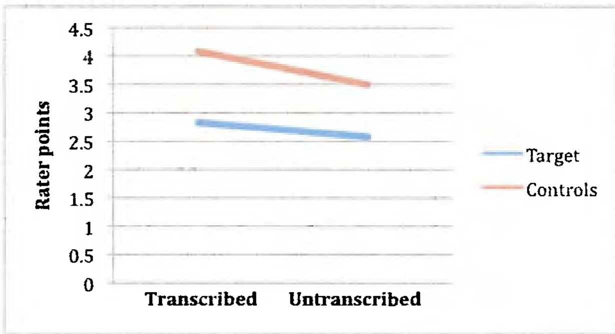

Figure 6.11 Rated compositon quality between the transcribed and un-transcribed written scripts for target group and controls

There was a significant difference in ratings between transcribed and un-transcribed written scripts for the same stories for the control group (Wilcoxon $Z = -2.65$, $p < .01$ two-tailed): un-transcribed were rated lower than in transcribed form. This result suggests that for this group, raters' judgments of composition quality *were* influenced by the presentation, which encompassed handwriting, spelling and punctuation.

In contrast, the difference in ratings between modes of presentation was not significant for the target group (Wilcoxon $Z = -1.73$, ns). Thus, for this group, despite producing handwriting which overall was of poorer quality than that of the controls, the ratings for their stories were not significantly worse when assessed in handwritten form, including the original spelling and punctuation, than in transcribed form. This result provides further evidence that it could be the *actual* level of rated composition quality which is lower in the target group not simply a question of impaired perception influenced by poor presentation.

The relationship between handwriting measures and composition quality

In order to explore the extent of the relationship between the speed and quality of a child's handwriting and the ratings obtained for composition quality Spearman Rho correlations were calculated (see Table 6.8).

Table 6.8 Correlations between written composition quality and number of words written, handwriting speed, handwriting quality across groups

	Numbers of words	Handwriting Speed	Handwriting quality	Written composition quality
Number of words written	1.00	.38	.63**	.91**
Handwriting speed		1.00	.25	.48*
Handwriting quality			1.00	.72**
Written composition quality				.1.00

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Results showed that number of words written and handwriting speed and quality were positively correlated with written composition quality ($r = 0.91$, 0.48 and 0.72 respectively).

6.3.4 Gender differences on narrative tasks

Table 6.9 shows the handwriting measures separately for girls and boys in each group.

Table 6.9 Narrative writing measures separately for girls and boys

	Girls		Boys	
	Written	Oral	Written	Oral
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Number of words	185.05 (91.00)	185.08 (100.52)	91.50 (33.72)	98.42(34.26)
Total time taken	14.63 (5.29)	1.50 (0.59)	9.64 (4.86)	.80 (0.33)
Production speed	12.57 (4.63)	123.39 (31.36)	10.42 (3.13)	126.59(30.97)
Handwriting quality	4.08 (1.08)	-	2.75 (1.42)	-
Composition quality	4.17 (1.47)	4.25 (0.97)	2.75 (0.87)	3.00 (1.13)

Results of a one-way ANOVA comparing the performance of girls with boys across groups showed clear differences on all but one measure (see Table 6.10).

Table 6.10 Summary of the comparison between girls and boys on narrative measures

	Written		Oral	
	F	*p* value	F	*p* value
Number of words	11.16	.003**	7.99	.010*
Total time taken	5.80	.025*	12.53	.002**
Production speed	1.77	.197	.104	.750
Handwriting quality	6.67	.017*	-	-
Composition quality	8.3	.009**	8.51	.008**

There are significant differences between girls' and boys' on all narrative measures except for speed of production in both written and oral mode: girls outperform boys.

6.3.5 Summary

The main findings which emerge from the above analyses are shown below:

- For the number of words produced target children *spoke* significantly more than they wrote whereas there was no difference between modes for the control group.
- There were no significant group differences in the total time taken to tell the stories but the control group wrote for longer than the target group. 75% of the children from the target group chose to stop writing within ten minutes of the task whereas 75% of the controls continued to write for up to twice as long.
- There were no significant group differences in handwriting (word-per-minute) speed.
- Rated handwriting quality was significantly poorer in the target group than in the control group.
- When composition quality was rated holistically from transcribed scripts, the target children were poorer in written mode than in oral. This differed from the control children, whose compositions were

of similar quality when written as when spoken. There were no group differences in composition quality of oral stories.

- Detailed analysis of the quality composition showed no significant difference between groups on four of five components. However, it would appear that target children alone were poorer on the *generation and development of ideas* in written than in oral stories. There was no difference between written and oral stories for the control group in this respect. Scripts which were uncorrected for handwriting and spelling were rated as poorer in composition quality than when rated in transcribed form for the control group but not the target group. There were strong correlations between handwriting quality and handwriting speed and written composition quality.
- Girls outperformed boys on all narrative measures in both modes except for production speed.

6.4 Discussion

The teachers selected the twelve children for the study on the basis of two criteria: (a) their handwriting was poor given their age, and (b) their written expression was poorer than would be expected given their general levels of ability. Data from a series of five standardised tests were used to shed light on how the teachers had applied these criteria and allowed us to explore what the term writing difficulties might have meant to the teachers. First, a standardised IQ test confirmed that they were all able children with verbal ability at least in the average range with eight scoring within the gifted range. On this measure alone, it would have been perfectly reasonable to expect such children to write competently by the age of 11.

On the measures of literacy used in the study, nine were good readers and all but one scored within the normal range for word reading, spelling and reading comprehension. However, there was one child whose verbal IQ score fell in the high average range, but who scored below the norm on all three literacy measures. On these measures alone, one might have expected such a child to be labelled dyslexic but no formal diagnosis had been made at this point (see Chapter 8). On speculation about why the teacher had considered this child's writing difficulties to be "unexpected", the only conclusion to be reached was that the fact that her verbal IQ was in the high average range had played a part. Omitting her from the study was considered as she was clearly different from the others in the group, but as she met the general inclusion criterion (i.e. her teacher felt her writing difficulties were unexpected) she was retained.

Using the Movement ABC to assess motor competence, all twelve children obtained scores which showed some motor impairment, ten of those twelve being severely affected although coordination problems had only been previously recognised in two. Although poor coordination had not been stated as a criterion for participation in the study, the fact that all target children selected by their teachers were found to have a significant motor difficulty supports the idea that there is an association between poor motor coordination and aspects of the writing process. In Chapter 4, it was noted that not all children with DCD have handwriting difficulties and conversely not all children with handwriting difficulties have DCD. In this study, we have found that all of the children whose problems with handwriting were severe enough to affect the content of their written work had more generalised motor difficulties. However, the different types of data obtained on the children's handwriting did raise a number of issues. Whereas the difference between the target and control children on the legibility and quality of their writing was significant, the results for speed were not so clear, as no group differences emerged.

However, as there were no UK norms at the time the study was conducted, it is not clear whether all the children, both target and controls, wrote slower than might be expected (hence the similar overall means of scores) or whether for the target children, handwriting speed was not an area of concern. It is worth noting that as the evidence that teaching of handwriting in UK schools is patchy (see Barnett et al., 2007), the control children's writing speed scores may well be artificially depressed through lack of adequate instruction.

Performance on the narrative tasks also supported the teachers' judgments when it emerged that the target children, as well as having poorer handwriting than the controls, wrote fewer words, spent less time writing their stories than the controls and produced stories which independent reviewers judged to be of weaker composition quality. When taken together with the differences between the target children and controls on the oral and written versions of the task, it was considered that this gave further confirmation that the concerns of the teachers were well founded.

As noted in the introduction to this study, the literature on language development suggests that parity of performance between oral and written mode is to be expected for children around the age of 10-11 years (see Loban, 1976) However, in the type of child of concern in this study, a discrepancy between oral and written ability is often noted. The children selected were all articulate and orally competent, hence classroom evidence of the relative writing deficit being worthy of note. Consequently, another objective of this study was to compare the difference between the ability to tell and write a story in both groups. The result of this comparison was very interesting. Whereas the control children performed, as predicted in the literature, to a similar level across modes, the target children's performance in both modes shows that their written stories did not match up to what they could produce orally. They produced fewer words when writing than when speaking, whilst there was no difference between modes for the controls.

It had been suggested that handwriting constraints might lead to reduced quality of compositions produced in handwritten form (Jones & Christensen, 1999; Christensen, 2005) and this did prove to be the case. Stories in the two modes when transcribed and rated blind, were scored significantly lower for the written stories than for the oral ones in the target group and lower also than the written stories of the controls. If teachers were comparing the story quality of these children with that of their peers they would indeed have found them poorer. In addition, in the control group, four children produced ceiling scores for composition in written mode where none did so in oral, yet no such differences were found in the target group.

Turning the focus now to handwriting, the analysis of the data raised interesting questions regarding the effect of speed of production. Handwriting fluency (often measured in terms of speed) has been shown in the literature to correlate with length and quality of written composition in typically developing children (Berninger & Swanson, 1994; Graham et al., 1997) and this was found to be the case in this study also. However, contrary to expectation, handwriting speed was not statistically different between groups. Closer analysis of the individual data shows marked variability within both groups, as described on p. 89, making it difficult to draw any clear conclusions from the group data.

Although individual differences in performance, such as those just described, go some way towards explaining the absence of group differences in handwriting word-per-minute speed, a more detailed analysis of the relationship between total time taken and speed of production proved fruitful. To achieve this, the groups were divided according to the time at which they chose to stop writing. These data showed that the target children wrote for a shorter time than the controls, three quarters of them choosing to stop in under ten minutes. As the contrasting examples of writing speed versus length of writing time show (p. 90), in cases such as these, the simple word-per-minute calculation of handwriting speed, taken in isolation from other factors, may not be a reliable measure of writing competence by the age of 11, many school assignments requiring children to write for longer. For example, one boy recorded a speed of 10 wpm, having written only 50 words but stopping after 5 minutes. In contrast, one girl scored 8 wpm because although she wrote 222 words, she took 28 minutes to do so. A more accurate assessment ought, therefore, to take account of both the word-per-minute score *and* the length of time for which a child can sustain writing.

The evidence from this study shows that some children who write at an acceptable speed over a short time (e.g. up to ten minutes) may not be able to sustain production at this rate for longer. Possible reasons for shorter writing duration can only be postulated. Physical fatigue might certainly be one and many children do indeed report that their hands get tired if they are required to write for extended periods of time, such as during exams. Equally, the possibility cannot be ruled out that lack of ideas for content might be another. One line of thinking that brings both these ideas together is that "exhaustion of resources for composing" may result from the excess effort required for handwriting and this is consistent with theories of limited capacity (e.g. McCutchen, 1998; Torrance & Galbraith, 2006). As regards task length, the narrative task in this study produced many confounding factors which might affect the way handwriting speed should be measured. These could be avoided if several different tasks were administered. Placing markers at equal intervals throughout the task can also yield useful data on the sustainability question but extending writing tasks for longer than ten minutes might also be considered. Further work is needed to explore these different possibilities.

A further factor which emerges here but which has not always been the focus of earlier studies is the importance of production rate on composition quality. If handwriting speed is interpreted together with the reduced ability to sustain writing over time (noted in the target group), it could be the case that to write *well* in compositional terms it is necessary to produce *enough*, and these findings that amount of text produced accounts for so much of the variance in composition quality (57%) may have particular implications for poorly coordinated writers. If the effect of poor motor coordination is to constrain the amount a child writes *and* the length of time over which writing can be sustained without fatigue, this would go some way to explaining why the children referred produce written assignments at school which are unexpectedly meagre.

The findings in this study on quality of handwriting are also highly relevant to this thesis. Correlations between factors revealed a strong association between handwriting quality and rated composition quality across groups, evidence which is consistent with other research findings suggesting a relationship between the two (e.g. Christensen, 2005; Jones & Christensen, 1999). A significant difference was found between groups in handwriting quality, confirming the findings of other studies that poor handwriting is common in children with DCD (e.g. Rosenblum & Livneh-Zirinsky, 2008). However, although this difference was anticipated, a surprising finding was that the handwriting of the controls was not of higher quality. This could, of course, be the result of environmental factors, such as insufficient teaching, and some studies have demonstrated that different approaches between schools make an impact (e.g. Medwell, Strand & Wray, 2009). The data from this study could not confirm or reject this possibility. So, in order to examine this outcome more closely, and because correlations were found between handwriting quality and composition quality for both groups, individual results were again investigated. Scores revealed marked individual variation within the groups. It emerged that whilst no child in the control group scored at the minimum level for handwriting quality, there were four from the target group who did, something that was not apparent from the group analysis. These same four children also scored the minimum for composition quality. The fact that extremes of poor performance were found within the target but not the control group confirmed that teachers had referred at least some children with significant handwriting and composition problems, and evidence from this study shows that written content is, as hypothesised, poorest in children who have the most severe handwriting difficulties. At the other end of the scale one child in the control group scored the maximum for handwriting quality, something which none of the children in the target group achieved.

The analysis of these data produced one other interesting and important finding relating to the impact on the rater of handwriting quality. When the written scripts of both groups together were rated in their original handwritten form they were awarded significantly poorer marks than when the same stories were rated having been transcribed. This replicates findings of earlier studies (e.g. Briggs, 1970; Graham et al., 2011; Simner, 1991) which show that teacher perception can be influenced by the quality of the presentation, with work that is poorly handwritten being perceived as poorer in composition quality. However, when ratings were analysed for each group separately, only the control group were affected in this way. Thus, it would appear that when assessment for composition quality is viewed overall, the target children's disadvantage is not compounded by further false perceptions of poor content quality as a result of poor handwriting and this perhaps is the result of a basement effect, i.e. that the presentation is too poor to go any lower. The fact remains that it is their *actual*, not the *perceived*, content quality which is poorer, as shown in this study when scripts were rated transcribed and blind. If this were universally to be the case, it has clear implications for schools since, for the majority of children, educational achievement is still measured by tests or exams which have to be performed in handwritten form. It is important for teachers to ensure that handwriting of all pupils is clear and legible and that for those who are poorly coordinated, handwriting must become both fluent and automatic and be able to be sustained over long periods of time.

The quality of written composition when rated globally was significantly lower in the target group and this is consistent with research findings for DCD where under-achievement in school is reported (e.g. Losse et al., 1991). However, when individual components were compared, it became clear that only the generation and development of ideas differentiated the two groups and the two modes, with the target children's performance poorer than the controls in this respect and only in written mode. In an attempt to interpret this result it was noted that the target children, even with the limitations on their ability to handwrite, were sound on basic language measures, such as grammar, sentence structure and vocabulary, as was demonstrated by their high verbal IQ scores and their competent performance in oral mode. The absence of any explanation on language or intellectual ability grounds leads to the consideration of whether a contributory factor is indeed the failure to allocate adequate cognitive resources to formulating ideas. This would certainly be consistent with cognitive capacity theory, put forward by Torrance and Galbraith (2007). The poor handwriting quality, reduced written output, and weaker spelling in the target group would support the theory that by requiring effort they could be responsible for diverting attention away from the producing and crafting of ideas, processes which are highly demanding of focus. This theme will be explored further in the studies which follow.

Finally, the gender analysis undertaken on the narrative measures showed that on all but one, girls outperform boys, reflecting the gender differences in writing development noted in the literature (Berninger et al., 1994; Stainthorp & Rauf, 2009) and this will also be followed up in later studies.

6.5 Limitations of the study

This pilot study has thrown up many useful issues for future study which can be summarised under the following headings:

Instructions for selection of participants

While it was a deliberate decision to set out to acquire a broad spectrum of children with writing difficulties, later evaluation of the teachers' reasons for referral suggested that the form of the request was slightly too open-ended. For some children there were general issues relating to literacy and these would need to be excluded in future studies, if possible. For others, there were difficulties related specifically to a single aspect of writing (such as speed), whilst for others there were problems across in all areas. More specific inclusion criteria would perhaps provide a more homogenous group for future work.

More accurate matching of controls

Whilst the original intention was to compare the target children's language performance with that of children within a typical classroom, more detailed data on the controls would have given the comparison increased validity. In order for reliable comparisons to be made standardised test data from both groups needs to be collected.

Sample size

The small size of the sample meant that first, comparisons between sub-groups within the main groups were not possible. A particularly relevant comparison would have been to look at possible effects of gender. Second, a larger sample would have allowed the use of statistical techniques to identify sub-groups within the population of children described as having "writing difficulties".

Choice of more than one written/oral task

Although the narrative was chosen as being the genre of writing most easily accessible to the age of child selected for the study, there was evidence from some of the target children that giving the picture sequence made the task easier than school tasks where all the content has to be self-generated. Also, as the generation and development of ideas is at the core of this investigation, tasks which make particular demands of the children in this area might provide important data. By testing the children's responses in two different writing contexts and with tasks of different levels of complexity some interesting differences might emerge.

Controlling for order effect

In all cases the written task was completed before the oral task. The reason order of testing was not controlled at this stage was that writing without first speaking was considered to reflect common practice in schools. Whilst it is often the case that general classroom discussion to stimulate ideas precedes written assignments, it would seem that children are rarely allowed or encouraged to express their individual narratives orally, prior to writing them. However, while the written-first condition does have ecological validity, it is recognised that this decision may have compromised the interpretation of the results and a possible order effect needs to be investigated.

6.6 Conclusion

This exploratory study has provided useful preliminary data on the unexpected writing difficulties experienced by some children in mainstream schools. It has confirmed that teachers are able to recognise those with difficulties but demonstrates the heterogeneity of the profiles of children classed as having writing difficulties. It highlights certain factors which appear to contribute to the quality of written composition, namely, verbal and performance ability, general literacy and motor competence. It also highlights the complex inter-relationship between the many processes involved in writing, as indicated in the literature but has not made clear either how those component processes interact in this instance, or how much each variable contributes to the writing quality. The results suggest that although certain factors are prerequisites for good written composition, such as verbal intelligence and good language skills, other factors explored, particularly motor skill, also contribute.

Some progress has been made through this pilot study towards confirming the observation made at the outset, that the writing of poorly coordinated children is 'thin' in content, in that difficulty generating and developing ideas has emerged as a characteristic in the quality of written stories of this group. What needs now to be considered is how to account for this weakness in poorly coordinated children and whether it results from disruption to the composing process by the constraints imposed by the effort required for producing handwritten text.

The question to be considered now, given that these young writers appear to have the basic prerequisites of writing (i.e. good language and literacy skills), is what aspects of handwriting in those who are poorly coordinated can be identified as barriers to writing and how much they constrain the composition quality. Dockrell (2009, p. 13) makes the point that "constraints are barriers that make writing difficult but may not be the single cause of the breakdown in writing" and similarly, Christensen (2000, p. 67) suggests that the teaching of handwriting cannot be seen as the universal panacea for all children's problems in writing text. Thus, further work needs to distinguish between the factors which are fundamental to the writing process and which deficits make writing more difficult to execute, recognising that neither may necessarily account for all the difficulties experienced, although the interaction of the two may be crucial.

Chapter 7

Study 2: An investigation of the order of presentation effect and partial replication of Study 1

7.1 Background

In Study 1, twelve unexpectedly poor writers were compared with twelve control children of the same age (10-11 years) on their ability to produce a narrative in two modes, speaking and writing. In that study, the children were required to write their stories first, then to tell them orally. Thus, order of testing was not counterbalanced (see Chapter 6, p. 112). For this reason the current study investigates any possible effect of order of testing.

The literature on the development of oral language suggests that a child's ability to narrate a story develops between the ages of 6-9 years of age (Bereiter & Scardamalia, 1987). This "knowledge-telling" style mastered orally is then adopted in written form as handwriting and spelling are mastered (Loban, 1976; Shanahan, 2006); thus narrative becomes the earliest genre of writing which children demonstrate in both modes. In typical development, research shows that handwriting and spelling are well advanced by the top of the primary school so that handwritten scripts can be produced with ease (e.g. McCutchen, 1998). This being the case, it seemed reasonable to expect that typically developing children of 11 years of age would competently produce narrative in oral and written mode, with both modes making similar demands on cognitive resources (Fayol, 1991 – see Chapter 3 for discussion). The results of Study 1 were consistent with this assumption: the children in the control group produced stories of equal length and rated compositional quality in both modes. In contrast, the children with difficulties produced stories which were shorter and of lower rated composition quality when writing than when speaking, and poorer than controls' stories on both measures. However, because the same task was used in both modes, it was felt necessary to determine whether order of testing might have had an effect on those results and, because the performance of the two groups differed, whether the effect of order would impact to the same degree on the two groups.

There are two ways in which oral and/or written performance might be influenced by the repetition of the task in this particular group of children. First, there might be a straightforward "practice effect", where any second performance would benefit from that of a first, irrespective of mode. In the Berninger et al. (1994) developmental model of writing, the physical expression of both oral and written language is preceded by the translation of ideas into linguistic units with no apparent differentiation attributed to mode of output. On the basis of this model, it would be logical to expect that any practice effect that did emerge would be the same for either mode. However, whilst this might be the prediction for typically developing children, one might also predict that order would have a different effect on children who find handwriting difficult from those who do not. In this case, it could be argued that speaking a story before writing (completing the thought-to-language conversion process) would allow this particular group of children to focus more attention on the motor execution of the handwriting, resulting in enhanced written performance. Only by testing can these ideas be confirmed.

In addition to testing for order effects, Study 2 presents an opportunity to further explore a number of other issues. Since it is identical to Study 1 except for the counterbalancing of task order, it offers the chance to replicate the findings of that first study. If Study 1 results are replicated in Study 2, then data from the two studies can be combined to create a larger sample for re-analysis. For example, the question of how handwriting speed should be measured emerged as important in Study 1 and this can be examined again with the bigger sample. Also, in Study 1, girls appeared to outperform boys in several writing measures but because of the small sample size, statistical analysis was not possible and the results had to be interpreted cautiously.

Thus, the aims of this study are first to test for effects of order on the main measures taken in Study 1; second, to compare the results of Study 2 with those of Study 1; third, to analyse the combined data of both studies to assess handwriting production and to test for the effect of gender.

7.2 Method

7.2.1 Participants

Forty children (20 boys, 20 girls) aged 10-11 years were recruited from Year 6 in mainstream primary schools in a North London borough. Twenty of those children (10 boys, 10 girls) already had been diagnosed with either DCD or Dyspraxia (henceforth known as the DCD group) and the remaining twenty made up the control group (henceforth described as the typically developing or TD group).

The children in the DCD group were drawn from a number of different primary schools in the borough having been referred individually to the author for help with writing. Each child had been assessed by an Educational or Clinical psychologist at the request of the school, and had been recommended for tutor support for handwriting. The different diagnostic labels assigned to each child depended on the terminology used by the particular psychologist who assessed them (as discussed in Chapter 4) but both refer to the same group of children. Teachers had identified all the children in this group as poor hand-writers.

The twenty typically developing (TD) children (10 boys, 10 girls) were recruited from the same year group as the DCD children (Year 6) in a primary school in the same borough. From the class of 30 children, the 20 participants were randomly selected by picking the first and last five boys from the class register. This was then repeated for the girls. Once selection had been completed the teacher confirmed that the children chosen had no known writing, language or motor disorders. Any child with a known difficulty was replaced by the next on the register.

7.2.2 Procedures

All children were asked to produce two stories based on the same six-card picture sequence used in Study 1, one orally and the other in written form. Administration of the task was the same as that in the former study. However, in this study the order in which the children performed the task between oral and written modes was controlled in the following way: children in both groups were randomly assigned (though gender balanced) to one of two sub-groups. The first sub-group, comprising 20 children (DCD: 5 boys, 5 girls; TD: 5 boys, 5 girls), performed the oral task first followed by the written task. The second sub-group, also comprising 20 children (DCD: 5 boys, 5 girls; TD: 5 boys, 5 girls), performed the tasks in reverse order.

The children in the DCD group performed both the oral and the written tasks individually in a quiet room but procedures for the TD group were slightly different. For them, the 10 children in the 'oral first' (OF) group first performed the task orally as above, i.e. individually in a quiet room. Following this, the whole class performed the written task. Then, the 10 remaining children (the 'written-first' (WF) group) performed the oral task, again individually as above. For both groups the two different tasks were completed within one 1-hour testing session. Unlike the TD group, the DCD children were not able to perform the written task as a class group as they had been referred individually from a number of different schools. However, the difference between administering the written task individually as opposed to in a class group was regarded as unlikely to affect outcomes. Evidence to support this decision was taken from the group-versus-individual data on the Detailed Assessment of Speed of Handwriting (DASH) where a special study was conducted to test this effect and no difference in results was found between group and individual administration (Barnett et al., 2007).

The children completed the written task using their usual writing implement on lined A4 paper. The task instructions were the same as those given in the Study 1 task (see Chapter 6, p. 83) and, as before, no general class discussion preceded the writing of the stories. All the stories from the oral condition were recorded using a digital tape recorder (Sony IC recorder ICD-MS515). A limit of 30 minutes was given for both oral and written tasks and the exact total time taken for each task for each child was noted.

Scoring procedures

All stories collected from the DCD and TD groups, i.e. 40 oral and 40 written stories, were transcribed into typed form and coded for anonymity. As before, written scripts were corrected for spelling and punctuation errors when transcribed, and in the oral scripts any non-words associated with hesitation, e.g. 'um' and 'er', were removed. The number of complete words in each script was counted and the total time taken by each child was recorded. The scripts were then assessed for composition quality by two independent raters, chosen for their experience with working with children of the age tested. The original handwritten scripts were retained and rated for handwriting quality alone by two separate raters with expertise in the handwriting field.

The choice of rater and the conditions for rating were identical to those in Study 1 (see Chapter 6, p. 83). Raters were blind to group, gender, order of task and mode of expression. The compositions were rated holistically on a 6-point Likert scale where 1 is the poorest and 6 is the best. The criteria for rating were again based on the WOLD (Wechsler, 1996) and again included *idea generation and development, cohesion, organisation and unity, vocabulary, grammar and sentence structure.* Capitalisation and punctuation were not rated.

As before, parametric statistical tests were applied to the data, except for data in ordinal form, where non parametric statistics were applied.

7.3 Results

7.3.1. Effect of order of testing on number of words produced.

Table 7.1 shows the means and standard deviations for the number of words produced for both DCD and the TD group for oral and written mode in both orders.

Table 7.1 Means and standard deviations for the number of words produced for both groups for both modes in both orders.

	All	DCD	TD
	Mean (SD)	Mean (SD)	Mean (SD)
Oral first			
Oral	155.35 (76.69)	156.00 (66.83)	154.70 (86.54)
Written	138.80 (62.71)	116.90 (60.86)	160.70 (64.55)
Written first			
Oral	106.50 (32.65)	112.20 (34.20)	100.90 (31.10)
Written	149.00 (42.19)	91.30 (25.08)	206.70 (59.30)

A MANOVA conducted on these data showed that there was a significant main effect of group on the number of words produced (F (1,79) = 5.20, $p < .05$). Overall, the children in the DCD group produced an average of 118 words while those in the TD group produced 155. There was no significant main effect of mode (F (1,79) = 2.46, ns). Equal numbers of words were produced overall across modes. There was also no main effect of order (F (1,79) = 1.44, ns). When the children told the stories first they produced an average of 147 words, when they wrote them first the average was 128 words.

There was a signficant order x mode interaction (F (1,79) =12.79, $p = .001$): across both groups oral stories contained more words when they were spoken first and written stories contained more words when they were written first. (see Figure 7.1). The order x group interaction was not significant (F (1,79) = .92, ns).

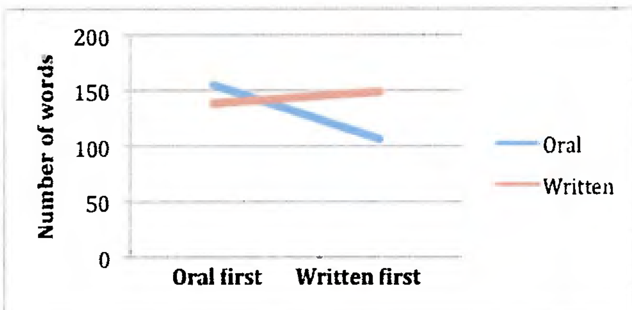

Figure 7.1 Number of words produced in oral and written mode by order

A post hoc one-way ANOVA with a Bonferroni correction found that the order difference was significant for the oral stories (F (1,39) = 7.1, $p = .011$) but not for the written ones (F (1,39) = .215, ns).

Importantly, the lack of a significant three-way interaction suggests that the two groups were similarly affected by the mode x order interaction (F (1,79) = 2.55, ns).

7.3.2 Effect of order of testing on total time taken

Table 7.2 shows the means and SD for total time taken for the DCD and TD children in both orders and in both modes.

Table 7.2 Means and SDs for total time taken for the DCD and TD children in both orders and in both modes

	All	DCD	TD
	Mean (SD)	Mean (SD)	Mean (SD)
Oral first			
Oral	1.57 (0.78)	1.86 (0.91)	1.28 (0.65)
Written	16.54 (6.84)	11.82 (6.92)	21.26 (6.76)
Written first			
Oral	0.88 (0.5)	0.94 (0.36)	0.81 (0.64)
Written	13.10 (2.32)	7.42 (4.35)	18.77 (0.28)

On this measure, there were significant main effects of group (F (1,79) = 25.83, $p < .001$), mode (F (1,79) = 215.67, $p < .001$) and order (F (1,79) = 4.38, $p < .05$): children in the DCD group took less time overall to complete the tasks than the TD group and, not surprisingly, written tasks took longer than oral ones for both groups. More time was spent on task overall when oral came first. The interactions of order x group (F (1,79) = 0.35, ns) and order x mode (F (1,79) = 2.21, ns) were not significant though the group x mode interaction was significant (F (1,79) =33.75, $p < .001$): whilst children in the DCD group wrote for less time than the TD group there was no difference when speaking (see Figure 7.2). There was no significant three-way interaction (F (1,79) = .16, ns).

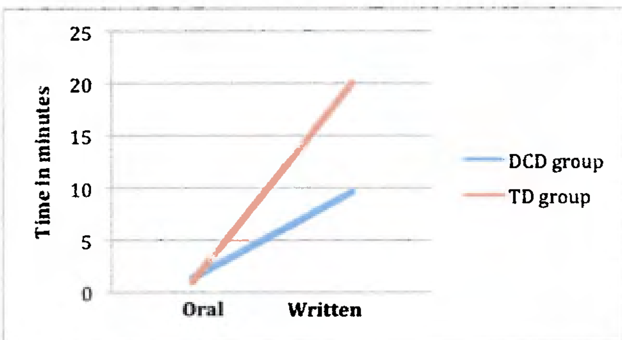

Figure 7.2 Total time taken in oral and written mode by DCD and TD groups

A one-way ANOVA conducted with a Bonferroni correction found the difference between groups on total time taken was not significant for the oral task (F = 2.60, ns) but was for the written (F = 28.65, p = .000).

7.3.3 Effect of order of testing on production speed

Table 7.3 shows the means and SDs for production speed (words per minute) for the DCD and TD groups in oral and written modes.

Table 7.3 Means and SDs for production speed (words-per-minute) for both groups in both modes.

	All Mean (SD)	DCD Mean (SD)	TD Mean (SD)
Oral first			
Oral	105.65 (30.36)	93.83 (35.76)	117.47 (24.96)
Written	9.49 (3.73)	11.06 (4.69)	7.91 (2.77)
Written first			
Oral	138.03 (3.85)	126.31 (36.12)	149.74 (98.97)
Written	13.06 (3.85)	14.78 (5.06)	11.34 (2.63)

A MANOVA conducted on these data showed no significant main effect of group on production speed (F (1,79) = 1.25, ns). There was no significant main effect of order (F (1,79) = 3.93, ns) though there was a main effect of mode (F (1,79) = 150.55, $p < .001$): oral stories were produced faster than written ones. None of the two- or three-way interactions were significant (maximum F (1,79) = 2.55, ns).

7.3.4 Effect of order of testing on rated handwriting quality

Table 7.4 shows the means and SDs for rated handwriting quality for the DCD and TD groups from a maximum of 6.

Table 7.4 Means and SDs for rated handwriting quality for the DCD and TD groups

	All Mean (SD)	DCD Mean (SD)	TD Mean (SD)
Oral first	3.15 (1.23)	2.60 (1.51)	3.70 (0.95)
Written first	2.55 (0.56)	2.80 (0.63)	2.30 (0.48)

Results of a Mann-Whitney U test showed that there were no significant differences in handwriting quality between the oral-first or written-first conditions (U = 148, ns).

7.3.5 Effect of order of testing on rated composition quality

Table 7.5 shows the means and SDs for rated composition quality for the DCD and TD groups in oral and written modes in both orders.

Table 7.5 Means and SDs for rated composition quality for both groups in both modes in both orders

	All Mean (SD)	DCD Mean (SD)	TD Mean (SD)
Oral first			
Oral	2.50 (0.53)	2.80 (0.63)	2.20 (0.42)
Written	2.65 (0.72)	2.80 (0.91)	2.50 (0.53)
Written first			
Oral	2.95 (0.95)	2.90 (0.74)	3.00 (1.15)
Written	3.00 (0.99)	2.70 (0.82)	3.30 (1.16)

Mann Whitney *U* tests on these data revealed no significant difference between rated composition quality scores attributable to order in either written mode ($U = 166.00$, ns) or oral ($U = 155.5$, ns) and the between group difference was also not significant. This showed that in rated composition quality in all conditions there was no differential effect of one order over another.

7.3.6 Discussion on effects of order

The primary objective in this study was to examine the effects of order of testing on performance on the two narrative tasks. On the major measures taken, i.e. the number of words produced, speed of production, handwriting quality and composition quality, the order in which the two narrative tasks were performed made no difference to the outcome for either group in either mode. Most importantly, therefore, it can be concluded that the results of Study 1 are robust.

In the introduction to this study two different ideas relating to possible effects of order were proposed and these will be discussed in order. The first related to the possibility a general "practice effect". Consistent with the thought-to language processes described in the Berninger and Swanson (1994) model of writing, it was suggested that planning and organising the thoughts underpinning a story would have a similar effect on the subsequent production of that story, whatever the mode of output. On the number of words produced, speed of production, handwriting quality and composition quality, there was no general practice effect when repeating the same task in different modes. Only in the total time taken on task, did there appear to be an order effect: for both groups more time was spent on the oral stories when they were performed *before* the written, but as this did not impact significantly on the length of narratives or the quality of composition for either group it was not considered to be of relevance. What is most important is that it was clear from this study that writing as story first, as was the case in Study 1, had not biased the outcome in any way.

The second possibility considered related specifically to the performance of the children in the DCD group. It was predicted that if handwriting fluency could be improved by greater focus being allocated to it, children who find handwriting difficult would gain more from the act of speaking their stories first. This was not the case. In terms of the amount written, the DCD group produced significantly less than the TD group but they were similarly unaffected by the order of tasks.

7.4 A comparison of Studies 1 and 2

For the second part of this study the data from Study 2 were compared with those of Study 1 on all measures with a view, first, to determining whether Study 2 replicated Study 1, and second, to establish the validity of combining the data for possible further analysis (see below). In Study 1 $n = 24$ and in Study 2 $n = 40$.

Table 7.6 Means and standard deviations for Studies 1 and 2 for all measures.

	STUDY 1		STUDY 2	
	DCD	TD	DCD	TD
	Mean (SD)	Mean (SD)	Mean (SD	Mean (SD)
Number of words				
Oral	164.92 (109.70)	118.58 (46.57)	134.00 (56.35)	127.80 (69.04)
Written	126.92 (88.74)	149.67 (77.70)	104.10 (47.17)	183.70 (64.78)
Total time				
Oral	1.23 (0.72)	1.07 (0.43)	1.40 (0.82)	1.05 (0.54)
Written	11.11 (7.13)	13.17 (3.46)	9.62 (6.06)	20.02 (6.20)
Speed (wpm)				
Oral	137.09 (30.89)	119.74 (20.82)	110.07 (38.74)	133.60 (72.17)
Written	11.75 (3.37)	11.24 (4.71)	12.90 (5.12)	9.62 (3.16)
Handwriting quality				
Written	2.75 (1.22)	4.08 (1.31)	2.95 (1.28)	4.00 (0.92)
Composition quality				
Oral	3.50 (1.31)	3.75 (1.14)	2.85 (0.67)	2.65 (0.93)
Written	2.83 (1.34)	4.08 (1.16)	2.75 (0.85)	3.50 (1.00)

A series of MANOVAs was conducted on number of words, total time taken and production speed with two between-groups factors (*study* and *group*) and one within-group factor (*mode*). On the ordinal data (handwriting quality and rated composition quality) Mann-Whitney U tests were applied separately in both modes.

Number of words produced

Results of the MANOVA showed that for the number of words there was no significant main effect of study (F (1,62) = .43, ns) or of group (F (1,62) = .036, ns) but there was a significant main effect of mode (F (1,62) = 4.38, p = .048): more words were produced in oral than written mode. There was also a significant group x mode interaction (F (1,62) = 12.45, p = .002): the children in the DCD group spoke more than they wrote and the children in the TD group wrote more than they spoke (see Figure 7.3 below).

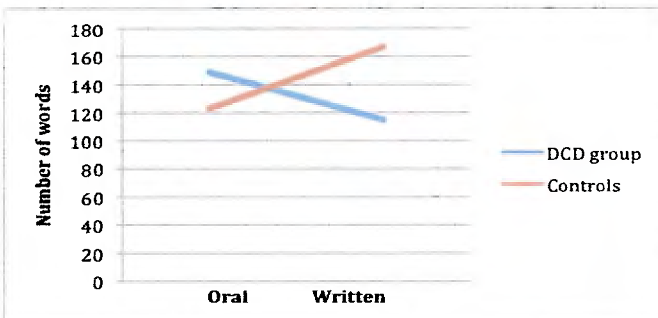

Figure 7.3 Number of words produced in oral and written stories by DCD and TD groups

In order to explore this interaction further a one-way ANOVA was conducted post hoc with a Bonferroni correction. This showed that although the TD group produced more words overall than the DCD group, they wrote more than they spoke in contrast to the DCD group who spoke more than they wrote. The group difference between the number of words in written mode was significant ($F = (1,62) = 11.72$, $p = .001$) but the difference in oral was not ($F (1,62) = 1.43$, ns). There was no three-way interaction, showing that there was no significant difference between studies.

Total time taken

There was no significant main effect of study ($F (1,62) = 1.12$, ns) or of group ($F (1,62) = 0.04$, ns) but there was a significant main effect of mode ($F (1.62) = 43.39$, $p = .000$): unsurprisingly, written stories took longer than oral stories. There were no significant interactions.

Production speed

There was no significant main effect of study ($F (1,62) = 4.28$, ns) or of group ($F (1,62) = 0.38$, ns) but again there was a significant main effect of mode ($F (1,62) = 631.45$, $p = .000$): speaking speed was faster than writing speed. There were also significant two-way interactions: study x group ($F (1,62) = 8.30$, $p = .009$) and study x mode ($F (1,62) = 4.96$, $p = .04$): the production speed was slower in Study 2 than in Study 1 and writing speed was slower than speaking speed in Study 2. The group x mode interaction was not significant ($F (1,62) = 0.75$, ns) and there was no three-way interaction. A one-way ANOVA performed post hoc with a Bonferroni correction found no significant difference between groups in Study 2 in either writing speed ($F = .00$, ns) or in speaking speed ($F = .27$, ns).

Rated handwriting quality

Mann-Whitney U tests show that in handwriting quality whilst there was no significant difference between studies for the DCD group ($U = 96.5$, ns) there were for the TD group ($U = 66.5$, $p < .05$): the handwriting of the DCD group was equally poor in both studies but that of the TD group was better in Study 2 than in Study 1.

Rated composition quality

Results of the Mann Whitney U test show that there was no significant difference in performance between studies for rated composition quality for the DCD group in either oral ($U = 110.5$, ns) or written mode ($U = 105.00$, ns). The same was true for the TD group (oral, $U = 75.00$, ns: written mode, $U = 85.00$, ns). The oral stories of both groups were rated of similar quality in both studies but the written stories were rated of lower quality for the DCD group than for the TD group.

7.4.2 Discussion on comparison between Study 1 and Study 2

The above findings showed that on the measures of most importance - number of words written, handwriting speed and composition quality - there were no significant differences between studies for either group in either mode. This is a very important finding in that it can be assumed that the findings of Study 1 are replicated in Study 2.

At this point however, it might be useful to comment on a finding relating to the control groups in each study. In Study 2, the children in the TD group wrote more slowly than the TD group in Study 1 and the quality of their handwriting was given higher ratings. In the first study it was noted that some children in the control group produced handwriting of average to poor quality. There is no clear explanation for this outcome but it is possible that the difference might be related to the ethos of the particular schools or classes from which the children were drawn, or perhaps differences in the quality of the teaching. Certainly, some studies have found that school factors make a difference to the quality of the handwriting which ensues (e.g. Medwell, Strand & Wray, 2009). The school used for Study 2, despite being in a socially mixed inner city location, was known for high quality teaching and had been rated as "outstanding" in a recent OFSTED inspection. Also, the observation of the tester was that in the class from which the children were taken was one where writing was given high status. Children were expected to be thoughtful in their writing and to check their work before handing it in. In contrast, the class in Study 1 was less structured and there was no observable evidence of additional care being given to the writing task. Thus, it is possible that these environmental factors might have influenced the result.

In response to evidence that oral and written language are both developed to a similar level by the age of 11 years and make similar demands of cognitive resources Study 1 was conducted with the expectation that performances would be similar across modes for the typically developing children. The findings of that study show that children performed much as predicted: for the TD group there were no significant differences between modes. For the DCD group oral stories were significantly in advance of written stories in terms of number of words produced, time spent on task and composition quality and the reverse was true for the controls. However, In Study 1 the controls also wrote more than they spoke, though this was just outside the level of significance. In Study 2 when this was replicated with the larger sample, the post hoc analysis found this difference to be significant. This is another important finding as it suggests that for typically developing children, not only are there no constraints to producing work in written form but the physical act of handwriting seems to convey some benefit to the production of narrative in this over oral mode.

In Study 1 the reliability of using handwriting speed, measured in words-per-minute, as an indicator of a handwriting difficulty when taken in isolation from the total writing time was questioned. The problem observed was that the children with DCD wrote for a significantly shorter time than the controls, whilst at the same time obtaining similar word-per-minute scores. The second study replicated this finding, giving greater weight to an argument that a word-per-minute speed score *alone* is insufficient for identifying a writing output problem experienced by children with DCD and that the length of time the child can sustain writing is also relevant.

7.5 Predictors of composition quality in combined sample

As Studies 1 and 2 produced similar findings, an analysis was next conducted on the combined data from those studies. This resulted in a sample size of 64 for the analysis. This increased sample enabled first, further exploration of the impact of different handwriting components upon written composition quality. Table 7.7 shows the correlation matrix for scores taken from handwritten narratives.

Table 7.7 Correlation matrix of handwriting components and composition quality on handwritten narrative task for DCD group and controls (combined sample)

	Number of words	Total time	Handwriting speed	Handwriting quality	Composition quality
Number of words	1.00	.64**	.22	,45**	.82**
Total time		1.00	.51**	.33**	.46**
Handwriting speed (wpm)			1.00	.04	.21
Handwriting quality				1.00	.42**
Composition quality					1.00

These results show strong correlations between composition quality and the number of words produced, the total time taken and handwriting quality, though not with handwriting speed calculated as a word-per-minute score.

7.5.1 Effects of gender on performance in the combined sample

The combined data for girls and boys in both groups for are set out in Table 7.8 below.

Table 7.8 Means and standard deviations for DCD and TD girls and boys total sample

	Girls Mean (SD)		Boys Mean (SD)	
	DCD	TD	DCD	TD
Number of words				
Oral	204.09 (109.35)	167.36 (75.51)	117.64 (35.01)	102.64 (42.80)
Written	168.18 (82.95)	194.36 (74.02)	76.55 (23.47)	115.00 (38.92)
Total time				
Oral	1.96 (0.83)	1.64 (0.71)	1.75 (1.07)	0.94 (0.32)
Written	24.35 (25.54)	20.26 (7.45)	6.75 (2.23)	15.42 (5.50)
Speed (wpm)				
Oral	119.79 (38.83)	125.17 (34.05)	120.71 (39.19)	131.64 (76.35)
Written	12.96 (5.11)	10.98 (4.64)	12.13 (5.01)	9.11 (3.36)
H/W quality				
Written	3.33 (1.36)	3.83 (0.75)	2.00 (1.10)	3.00 (0.89)
Composition quality				
Oral	3.55(1.29)	3.27 (1.01)	2.18 (0.75)	2.73 (0.78)
Written	3.36 (1.21)	4.09 (1.04)	1.91 (0.70)	2.91 (0.94)

Since it was possible that gender effects might be different for the DCD and control groups, when the MANOVA was conducted, *group* was entered as a between-subjects factor as well as *gender* and *mode* as within-subjects factors. On those measures yielding ordinal data (rated handwriting quality and rated composition quality), Mann-Whitney *U* tests were again applied.

Number of words produced

The number of words spoken and written for girls and boys in the DCD and TD groups are shown in Figure 7.4.

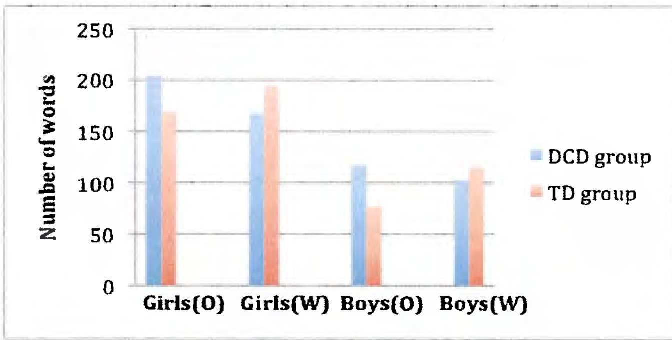

Figure 7.4 Number of words for girls and boys in oral and written stories for the DCD and TD groups

There was a significant main effect of group (F (1,63) = 13.83, p < .001) and of gender (F (1,63) = 13.13, p = .001) but there was no group x gender interaction (F (1,63) = .08, ns) and no other interactions. The TD group wrote more than the DCD group and the girls wrote more than the boys. In number of words spoken there were no significant effects of group (F (1,63) = 1.58, ns) but the main effects of gender were significant (F (1,63) = 8.18, p < .01): girls spoke more than boys. There was no group x gender interaction (F (1,63) = 0.06, ns).

Total time taken

The total time spent on task for girls and boys in the DCD and TD groups on oral and written stories is shown below in Figure 7.5.

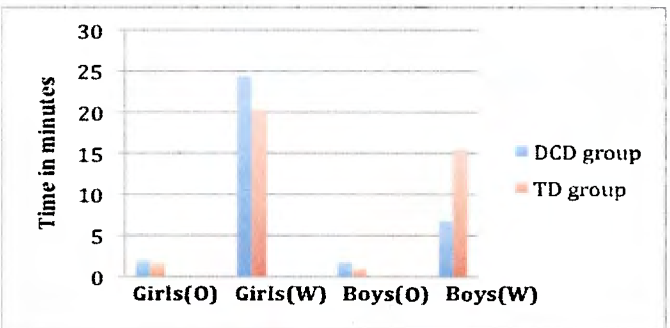

Figure 7.5 Total time spent for girls and boys on oral and written stories for the DCD and TD groups

There was no main effect of group (F (1,63) = 2.72, ns) but there was a significant main effect of gender (F (1,63) = 5.16, p < .05). The group x gender interaction was not significant (F (1,63) = .92, ns). Boys spent less time writing than girls but there was no overall difference between the TD and the DCD groups. In total time taken for speaking there was no main effect of group (F (1,63) =0.43, ns) but there was a significant main effect of gender (F (1,63) = 4.56, p < .05). The group x gender interaction was not significant (F (1,63) = 1.57, ns). Again, boys spoke for a shorter time than girls but there was no difference over all between the groups.

Production speed

The speed of production in words-per-minute for girls and boys in the DCD and TD group in oral and written stories is shown below in Figure 7.6.

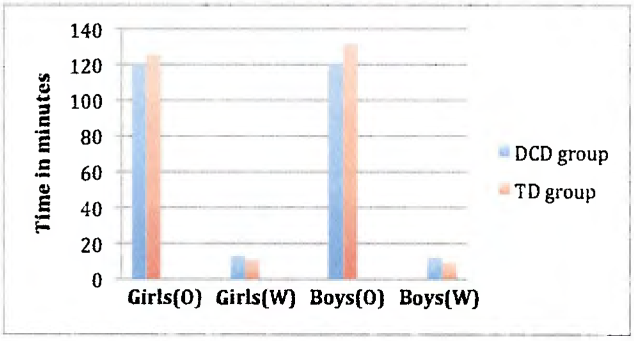

Figure 7.6 Speed of production for girls and boys in oral and written stories for the DCD and TD groups

In speed of writing there was significant main effect of group (F (1,63) = 4.76, $p < .05$): the DCD group wrote slower than the TD group overall. There was no significant main effect of gender (F (1,63) = 1.39, ns) and no group x gender interaction (F (1,63) = .21, ns). In speed of speaking there were no main effects of group (F (1,63) = .43, ns) or gender (F (1,63) = .09, ns) and no significant group x gender interaction (F (1,63) = 0.05, ns).

Rated handwriting quality

Results of the Mann-Whitney *U* test show a significant effect of gender on handwriting quality in the DCD group (U = 54.00, $p < .01$) but not in the TD group (U = 110.50, ns): the DCD boys' handwriting was rated lower than that of the DCD girls. There was no difference in the TD group. Figures 7.7a and 7b show samples of handwriting from the DCD group and the control group.

Figure 7.7 Samples of handwriting

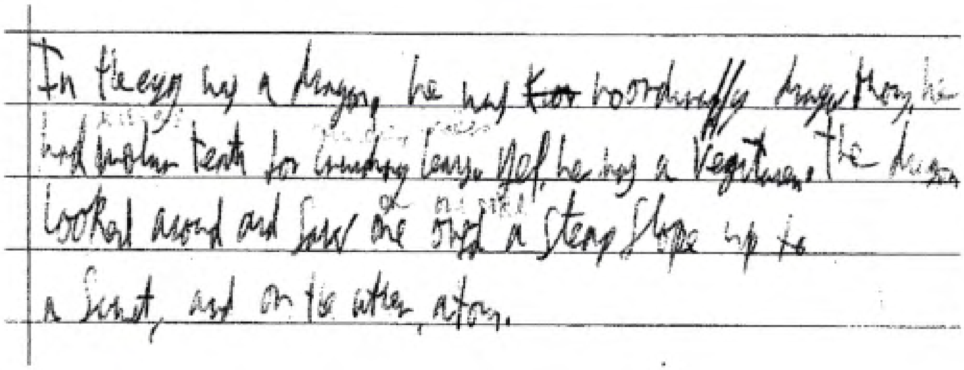

Figure 7.7a. Sample of handwriting of boy in the DCD group: rated 1 point.

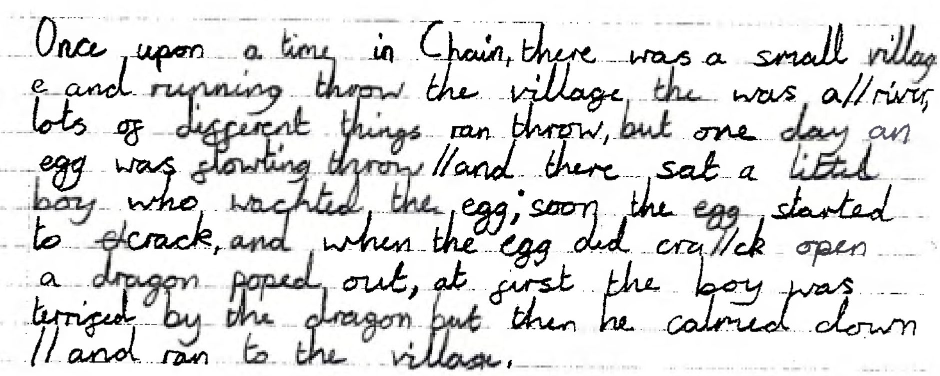

Figure 7.7b. Sample of handwriting of a girl in the TD group: rated 6 points.

Rated composition quality.

Results of Mann Whitney *U* tests revealed that there were no significant gender effects for the DCD group in written mode ($U = 89.00$; ns) but there were in oral mode ($U = 76.5$; $p = .05$): the girls in the DCD group spoke stories of higher composition quality than the boys though there was no gender difference in rating when the stories were written. In contrast, in the TD group there was a significant gender effect in written mode ($U = 65.5$, $p < .02$) where the girls wrote stories of higher composition quality than the boys though there were no gender differences in the oral narratives of this group ($U = 88.5$, ns).

7.5.2 Discussion on gender differences in the combined sample

The final question of whether boys perform differently from girls is now addressed.
Two studies conducted by Berninger and Swanson (1994), and Stainthorp and Rauf (2009) showed that girls perform better than boys throughout the primary and intermediate years on handwriting speed and quality (see Chapters 2 and 3). Analysis of the combined data from Studies 1 and 2 yielded findings not entirely consistent with these studies. On total time taken to write, and handwriting speed (in words-per-minute) there were no significant difference between boys and girls but the handwriting quality of the girls in the DCD group was rated higher than the boys. However, the data suggests a different picture for text length and composition quality in both groups. In the TD group, girls wrote more than the boys and their written compositions were of higher quality and this is more as predicted in the literature. However, in the DCD group, the gender difference was evident only in the oral stories where girls were rated higher for composition quality than boys. Girls with DCD did not show an advantage over boys in their written stories.

7.6 Conclusion

By showing that the order in which a child tells or writes a story does not affect the outcomes for either DCD or TD groups this study provides strong support for the findings of Study 1. In addition, by subjecting the combined data from the two studies to further analysis, a clear gender effect was identified, paving the way for future questions over differences in developmental patterns between boys and girls to be examined. Although these were not specific to group in basic handwriting measures – handwriting speed and quality – differences in the amount written and the ensuing composition quality, both measures of particular relevance to this thesis, showed marked gender effects and this will be explored further in Studies 3 (Chapter 8) and 4 (Chapter 9).

Chapter 8

Study 3: Difficulties of written expression in adolescents: a five-year follow-up study

8.1 Introduction

In the two studies reported in this thesis so far, the main focus has been on the relationship between poor handwriting and the quality of written composition in children of normal intelligence at the top of the primary school (aged 10-11 years). In the first study, teachers were asked to select children who they felt had unexpected difficulties with writing and in the second, children with a formal diagnosis of DCD or Dyspraxia took part. In both studies, the written performance of the children with DCD was found to be significantly poorer than children of similar age and ability on a range of measures relating to handwriting which in turn was associated with poor compositional quality. The question of how exactly a "handwriting difficulty" should be defined, however, remained an open question so it was considered that examining the individual profiles over time might increase understanding of how these difficulties develop. Thus, the present study attempts to determine (a) whether the handwriting and writing problems documented earlier continue to be experienced beyond the primary school years into adolescence and (b) whether the nature of the relationship between the physical act of putting pen to paper and the compositional quality of what is produced changes over time.

Although the children in Study1 had not been formally identified as having movement difficulties that extended beyond handwriting, all 12 scored poorly on the Movement ABC. With the exception of Criterion C, which requires the input of a paediatrician, all 12 met the formal criteria for DCD set out in DSM IV (2000). Obviously, therefore, the persistence of these more generalised motor difficulties and their relationship to the children's writing difficulties is another question of interest in this study.

As described in Chapter 4, studies on the long-term outcome for children with DCD are not in complete agreement, although the majority suggest that most children do not grow out of their difficulties. One of the main problems with studies which have followed the same children over time, however, is that they vary in the what they measure, over what period of time and in the measurement tools used, making it hard to determine consistency. Nevertheless, there is a view expressed by Gubbay (1975) and later by Cantell et al. (2003) that only the most severe cases of poor motor coordination persisted beyond childhood. The data from a number of studies support this proposition (Cantell et al., 2003; Geuze & Borger, 1993; Losse et al., 1991). Unfortunately, none of these provide sufficient evidence on those who are thought to have "caught up" to be sure that the spectrum of motor competence has been adequately covered. Also, there are some who believe that while the motor difficulties may diminish, other problems, often psychiatric, emerge (e.g. Gillberg & Kadesjo, 1998; Kirby & Drew, 1999; Larkin & Summers, 2004). One of the problems with this area of work is that the motor competence was not objectively re-tested, there being no test available for the older age group. With the recent extension of the Movement ABC, which provides norms for children up to and including 16 years of age (the Movement ABC -2, Henderson, Sugden & Barnett, 2007) tools are now available to measure the performance of the older child within the same framework of tasks as for younger ones. This is one of the first longitudinal studies of motor competence to benefit from the advantage of measuring potential change within one test instrument.

Separate from the longitudinal studies focussing on poor motor coordination generally, there are a few which focus specifically on children's handwriting difficulties and their impact on academic performance. For example, Smits-Engelsmann and Van Galen (1997), and Hamstra-Bletz and Blote (1993) both looked purely at handwriting over a one- or two-year period in the lower primary school population, focusing on letter formation, accuracy and handwriting speed. They found that the children they described as having dysgraphic handwriting (defined by scores below the 10% on the BHK quality items - Hamstra-Bletz, de Bie and den Brinker, 1987) had lower fine-motor ability and, in the higher grades, showed less preference for a personal style, perhaps implying less flexibility in production. Children with dysgraphic handwriting did not differ in writing speed from those without in those studies, something also noted in Study 1 of this thesis.

Another study which looked at a possible relationship between handwriting and other curriculum areas in specific primary school populations is that of Harvey and Henderson (1997), which examined the consistency of 46 children's handwriting over the first three years of primary school and explored its relationship with other school subjects. Of particular relevance here was the finding that those children who were found to struggle when first tested, continued to experience difficulties three years later if help was not provided. Next, the authors compared scores on the teacher-rated handwritten scripts with performance on Standard Assessment Tests, introduced as part of the National Curriculum in the UK on Reading, Writing and Maths. Correlations between handwriting and the other literacy skills were high suggesting evidence of a general ability influencing all subjects – or indeed it might have been a reflection of an early link between handwriting ability and compositional quality.

Comparisons between specific populations and typically developing children over time can provide useful insight into how difficulties identified at Time 1 manifest themselves both directly and indirectly at Time 2. For example, although typically the demands of handwriting decrease with age as writers become more fluent (Fayol, 2009) it might be that this effect does not hold for children who have found handwriting difficult to learn. Graham (1990) found that for children with learning difficulties (LD), the demands of transcription remained a persistent problem for much longer than would be expected. In this study, the question of whether the same applies to poorly coordinated children and whether any residual handwriting problems continue to impact upon composition quality will be addressed. Since Study 2 revealed some interesting gender effects that might also change over time, another objective of this study will be to examine these post puberty in both target and control children

In sum, this study, which examines the children tested in Study 1 after a period of five years, will address a total of seven questions, the results of which will be presented in two parts. In Part 1, four questions which relate to changes in the children's performance on the standardised tests employed in the original study will be examined. In addition, a standardised test of handwriting speed will be introduced in the hope that more can be revealed about the precise nature of the children's difficulty with handwriting. The four questions are:

1. Are the profiles of the children with DCD on IQ and other literacy measures the same or different after five years?
2. Does their motor impairment persist into adolescence?
3. What are the similarities and differences between the target and control children after five years on motor and non-motor measures?
4. How do the two groups compare on a new standardised test of handwriting and do girls perform differently from boys?

In Part 2 of the study, the aim is to employ a narrative task comparable to that used in Study 1 with a view to determining whether the target and control children perform in the same way five years later. Since the combined data from Studies 1 and 2 had revealed gender differences of some note, these will also be explored further in this study. Specifically, the questions addressed will be:

1. Are the patterns of performance between groups on the narrative tasks the same at T2 as they were at T1?
2. Does the relationship between handwriting and composition quality remain constant over time?
3. Are there gender differences on any of the measures, which might be informative regarding the long-term outcome for children with difficulties?

Longitudinal studies have to take account of events, possibly unrelated to the central focus of the research, which might influence outcomes. For example, it is well documented that physiological changes which accompany puberty influence motor performance outcomes (Geuze & Borger, 1993) and these may affect individuals in different ways and at different times. A quite different kind of influence might arise from family or school experience which may make a child's difficulties better or worse. Although it was not possible to investigate such effects in detail, a questionnaire was completed by the parents of all the teenagers taking part which attempted to document any intervention or any other environmental factor which might account for any changes observed after five years?

8.2 Method

The general procedures adopted in this study were similar to those employed in Study 1. However, on this second occasion all participants, control as well as target (henceforth known as DCD) children, were tested on the same standardised measures. The measures taken are described in detail in chapter 5 and summarised below.

8.2.1 Participants

All 24 children (12 DCD, 12 controls) were traced after five years and agreed to be re-assessed. All but two had transferred to secondary schools within the same or adjacent North London borough after primary school; the remaining two, one from each group, had moved away from London for family reasons.

8.2.2 Standardised tests

General Intelligence

The children in the target group were formally assessed for general intelligence as before using the Wechsler Intelligence Scale for Children 3rd Edition UK, short form, (WISC III-R UK, Wechsler, 1994). Verbal and Performance IQ scores were derived.

Reading

Reading levels were tested using WIAT-II –UK Word Reading (2006) which required the child to read aloud a list of words of increasing difficulty. Correct answers were recorded as raw scores from which standard scores were calculated. Children with scores 2 standard deviations (henceforth SDs) below the mean were considered to have a significant word reading difficulty.

Spelling

The WIAT-II UK Spelling (2006) was used to test spelling ability. A list of words of increasing difficulty was dictated to the child to be written down. Numbers of correct answers were recorded. As with the reading sub test, raw scores were converted into standard scores and children with standard scores 2 SDs below the mean were regarded as having a significant spelling difficulty.

Reading Comprehension

Reading comprehension was tested using The WIAT-II UK (2006). Children were given a passage to read and then asked questions about the text. Standard scores were obtained and, again, scores which fell 2 SDs below the mean were taken to indicate significant reading comprehension difficulty.

Motor Competence

Motor competence was assessed using the standardised test from the Movement Assessment Battery for Children - second edition (The Movement ABC-2, Henderson, Sugden & Barnett, 2007). This test is in three parts, yielding separate standard scores and percentile ranks for manual dexterity, ball skills and balance. Higher scores indicate greater levels of motor impairment. Standard scores can be derived with 100 as the mean and 15 the SD. Scores below the15th percentile suggest mild levels of motor impairment whilst scores below the 5th percentile suggest more marked impairment. When combined with other data, this test is often used as an indicator of Developmental Coordination Disorder.

Handwriting Speed

Handwriting speed was assessed using the Detailed Assessment of Speed of Handwriting (DASH) (Barnett et al., 2007). This test is designed for children between the ages of 9 – 16 years of age and has norms for the UK. It comprises five separate tasks, each of which bears a different cognitive load. For a detailed description of this test, see Chapter 5 of this thesis. Overall standard scores (calculated from tasks 1 – 4) are derived with 10 as the mean and a SD of 1.5. Scores falling below the 15th percentile indicate mild but significant slowness; scores below the 5th percentile suggest a more severe level of impairment.

8.2.3 Narrative tasks

Choice of task

As in Study 1 a task was required that could be performed in both written and oral mode. For the younger children a narrative task was chosen. However, for this older age group a descriptive writing was the genre selected (see Chapter 5 p. 72 for rationale).

Written task

The task chosen required the student to write a letter instructing an architect on the design of 'My Ideal House' (see Appendix 12). Fifteen minutes was allotted for writing the story (consistent with the instructions of the WOLD) and the actual time taken was recorded on each occasion. Markers were also entered after each two-minute period.

Oral task

The same task stimulus was used for the oral as for the written narrative (as in Study 1). Whereas the students were asked to write to the architect on the first occasion, for the second task they were asked to imagine they were instructing the architect by phone. Again, fifteen minutes was given for the task and the actual time taken was also recorded. Oral stories were recorded using a dictaphone.

8.2.4 Scoring procedures

Scores for the narrative tasks were derived from ratings on specified measures by independent raters (see below).

Written and oral narratives

All stories, both written and oral, were transcribed into typed text. As in the earlier studies, in order that scripts could be rated without awareness of transcription mode, written stories were corrected for spelling and punctuation and oral stories for signs of hesitation. Handwritten scripts were retained for separate assessment. All transcribed scripts yielded the following measures:

1. Number of words produced: word count included complete words, repetitions and errors, but not partial words or crossings out.
2. Total time: the number of minutes taken to complete the task.
3. Speed of production: the total number of words produced divided by the total time spent writing/speaking.

Next, all the scripts were rated on a qualitative measure:

4. *Composition quality*

Scripts were rated first holistically, as in Study 1, by two experienced teachers familiar with children's writing from the older age group. As before, raters were given written guidelines for holistic scoring and were trained using sample scripts. Criteria were taken from the composition guidelines for holistic assessment in the Wechsler Objective Language Dimension (WOLD) (Rust, 1996), though punctuation, spelling and handwriting were not included (see Appendix 7). Scripts were rated on a scale of 1 to 6: 1 representing the poorest performance and 6 the best. Once again, excellent inter-rater agreement was achieved ($K = .86$).

Again, consistent with the procedures used in Study 1, once the holistic assessment had been completed, a second, more detailed analysis was performed which focused on component skills of composition. For this analysis, the transcribed scripts were rated by two educational psychologists experienced at scoring the Wechsler tests. The scripts were rated according to the analytic criteria set out in the WOLD on a 4-point scale in line with the test instructions, 1 representing the poorest and 4 the best (see Appendix 8). Five of the seven different components of composition were rated separately: generation and development of ideas, organisation, cohesion and unity, vocabulary, sentence structure, grammar. Capitalisation and punctuation were not included.

Assessment of handwritten scripts (un-transcribed)

In order to examine the effect of presentation on perceptions of composition quality, scripts were separately analysed in their original handwritten form without spelling or punctuation errors corrected. Scripts were assessed in the following way:

Handwriting quality

Scripts were rated holistically on a scale of 1 - 6 according to general neatness and legibility, 1 representing the poorest and 6 = best. Raters were given written guidelines for categorising scripts. (see Appendix 6). As before, Cohen's Kappa was calculated to measure inter-rater agreement. The initial value of K in this case was 0.65, showing that the initial agreement was moderate. Following discussion between raters on how the criteria were being interpreted, scripts were re-rated and Kappa was re-calculated, resulting in a K value of 0.92, demonstrating excellent agreement.

Spelling

The number of correctly spelt words was calculated as a percentage of the total number of words written.

Composition quality

Handwritten scripts were rated as above for composition quality using the holistic assessment.

8.3 Procedures

8.3.1 Task Environment

As in Study 1, the students in the DCD and control groups were seen individually for two, two-hour sessions. They were first assessed on standardised measures for intelligence, motor competence and literacy, after which they were set a narrative task, first in written, then in oral mode. All were tested under similar environmental conditions, i.e. in a quiet room with only the tester present, seated at a table and writing on lined A4 paper with their own chosen pen. Each session was timetabled so that all tasks were covered in the same order for each child. Tasks which required writing were interspersed with non-writing tasks to sustain motivation and minimise fatigue (Sassoon, 2003). The story tasks were given on separate occasions with the written narrative task always preceding the oral narrative task.

Table 8.1 Order of testing in each session.

SESSION 1	SESSION 2
WIAT-II UK Word reading	WIAT-II UK Reading Comprehension
Narrative task (written)	WISC III-R UK (Vocabulary and Object Assembly)
Movement ABC-2	
WISC III-R UK (Similarities and Block Design)	Narrative task (oral)
WIAT II UK Spelling	DASH Handwriting speed tasks 1-4

8.4 Part 1: Results on standardised tests

In this part of the study, four questions are addressed. The first two relate to how the DCD children performed on a set of five standardised tests which were administered at two points, first when the children were aged 10-11 and again around the age of 15-16. They ask (a) whether the profiles of the DCD children on IQ and literacy measures are the same or different after 5 years, and (b) whether the motor impairment persists into adolescence.

The second two questions compare the DCD children with their controls at age 15/16 and deal with the similarities and differences between groups on motor and non-motor measures. In addition, the following questions are asked:

1. How do the two groups compare on a new standardised test of handwriting? and
2. Do girls perform differently from boys?

8.4.1 How do the children with DCD perform over the five-year period?

Tables 8.2 shows the individual subject data on standardised tests for IQ, literacy and motor competence for the DCD group at two points in time, T1 being five years before T2. Also presented are the means and standard deviations for age, verbal and performance IQ, single word reading ability, spelling, reading comprehension, motor competence and measured handwriting speed.

Table 8.2 Individual subject data on standardised tests for DCD group at T1 and T2

Table 8.2a Individual subject data on gender, age and IQ for DCD group at T1 and T2

DCD Group	Sex	Age		VIQ		PIQ	
		T1	T2	T1	T2	T1	T2
1	F	10.2	15.5	139	139	91	91
2	F	10.2	15.0	139	127	115	117
3	F	11.3	16.0	141	135	103	117
4	F	11.2	15.9	130	130	103	97
5	F	10.0	14.9	142	132	120	108
6	F	11.1	15.8	114	100	100	117
7	M	10.6	15.3	92	103	77	100
8	M	9.7	14.3	141	119	80	91
9	M	10.3	15.0	108	95	54	77
10	M	11.00	15.7	139	135	109	141
11	M	10.7	16.00	122	116	103	94
12	M	10.4	15.8	100	103	74	71
Mean		10.6	15.5	125.5	119.5	94.1	101.4
SD		0.5	0.5	17.8	15.7	19.3	17.44

Table 8.2a Individual subject data on MABC and literacy for DCD group at T1 and T2

DCD Group	MABC %		BAS Reading		BAS Reading comprehension		BAS Spelling	
	T1	T2	T1	T2	T1	T2	T1	T2
1	1	5	99	120	103	1318	112	121
2	1	63	99	112	104	1216	110	124
3	1	9	88	116	97	138	82	107
4	1	5	69	106	97	126	84	92
5	1	9	99	122	106	136	110	124
6	1	9	69	75	73	66	66	78
7	1	2	67	89	76	72	77	82
8	8	9	79	93	102	72	95	82
9	1	9	73	69	79	58	85	78
10	8	50	96	114	100	136	78	104
11	1	16	94	112	100	102	90	122
12	1	16	71	101	86	71	87	84
Mean	2.17	16.8	111.1	102.4	99.3	103.3	110.3	99.3
SD	2.72	19.2	28.7	17.4	16.8	33.2	27.8	19.2

IQ and literacy scores

Results for this group showed a significant difference in mean scores for VIQ between T1 and T2 ($t = 2.33$, $p = .04$) but not for PIQ ($t = -1.80$, ns). As far as the drop in verbal ability was concerned this was largely due to three subjects whose scores fell by more than 10 points, two of whom had received a late diagnosis of an additional disorder (one dyslexia, one Asperger's Syndrome) which may have influenced their responses to the test. In contrast, there was no significant change to standard scores for word reading over time ($t = 1.68$, ns) nor for reading comprehension ($t = -.68$, ns). However, there was a significant change in spelling ($t = 2.66$, $p = .02$) which was significantly poorer at T2 than at T1.

Motor competence

Although the structures of the Movement ABC and ABC-2 are similar, the scoring systems are different, so statistical comparison of total scores, for example, is not possible. However, looking at percentiles, it is clear that only 2 out of the 12 children could be described as having made significant gains. Of the remaining 10, most children still stay around or below the 16th percentile, showing that they have not really "grown out" of their motor difficulties: eight remain below the 10th percentile, two are on the 16th, and just two could be said to have made significant gains.

Whilst different systems of scoring between the MABC and MABC-2 make statistical analysis invalid, percentile rankings for the three sub-skills can be compared between T1 and T2 for both groups for girls and boys and are shown below in Table 8.3.

Table 8.3 Percentile rankings on the MABC subtests by gender at T1 and T2

	Manual dexterity			Balls skills			Balance		
	Below 5%	5-15%	Above 15%	Below 5%	5-15%	Above 15%	Below 5%	5-15%	Above 15%
T1									
Girls	6	0	0	3	2	1	5	1	0
Boys	6	0	0	1	2	3	3	1	2
Total	12	0	0	4	4	4	8	2	2
T2									
Girls	1	3	2	4	0	2	0	1	5
Boys	3	1	2	2	0	4	0	1	5
Total	4	4	4	6	0	6	0	2	10

As the table above shows, for manual dexterity both girls and boys have improved: whereas at T1 all 12 children fell below the 5th percentile, at T2 only one girl and three boys score at this level. For balance there has also been some positive changes: whereas at T1 five girls and three boys fell below the 5th percentile, at T2 five girls and five are now above the 15th. The picture for ball skills is less clear: whereas at T1 four children scored within each range, at T2 six still fall below the 5th percentile (4 girls, 2 boys) and six score above the 15th (2 girls, 4 boys). As no correlation has been found between ball skills and handwriting speed or quality, this result is not surprising.

8.4.2 *Comparison of DCD and control groups at T2*

Since the control children in Study 1 were not tested on the IQ and literacy measures at T1, a comparison was not possible. Table 8.4 shows scores on the standardised tests for this group at T2.

Table 8.4 Individual subject data on standardised tests for controls at T2

Control group	Time	Age	Sex	VIQ	PIQ	MABC-2 %	BAS Reading	Reading Comprehension	BAS Spelling
1	T2	14.50	F	105	86	75	116	118	118
2	T2	14.58	F	129	97	37	122	132	116
3	T2	15.68	F	119	117	84	124	118	120
4	T2	15.50	F	135	109	37	120	128	113
5	T2	14.67	F	122	123	37	122	129	123
6	T2	15.83	F	130	109	37	112	126	105
7	T2	14.67	M	105	106	84	110	120	105
8	T2	14.58	M	140	149	63	127	132	117
9	T2	14.92	M	114	115	84	131	104	116
10	T2	13.92	M	143	88	63	126	132	126
11	T2	14.75	M	121	146	75	122	125	102
12	T2	14.75	M	114	109	84	116	116	94
Mean	T2	14.94		123.18	112.83	63.33	120.67	123.33	112.92
SD	T2	0.62		12.10	19.61	20.80	6.21	8.53	8.52

A series of one-way ANOVAs were used to compare the scores of the DCD group with the controls at T2 on the standardised tests. Figure 8.1 shows mean scores on standardised tests at T2 for both groups.

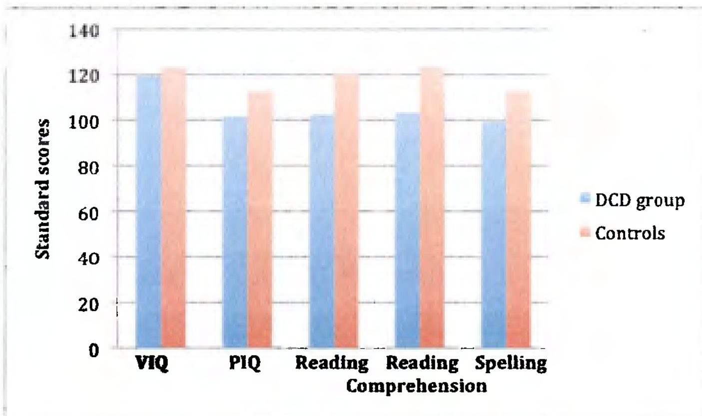

Figure 8.1 Differences between DCD group and controls at T2 on IQ and literacy

IQ and literacy

When tested at age 15/16, there was no significant difference between groups in VIQ (F (1,23) = .38, ns) or PIQ (F (1,23) = 1.97, ns). On the literacy measures, there were no significant differences between the groups at T2 on word reading (F = 2.84, ns) or reading comprehension (F = .47, ns) but the spelling scores of the DCD group were significantly lower at T2 than the controls (F = 7.06, p = .02).

Motor competence

Results for the M-ABC again show a significant group difference when measured at T2 (F (1,23) = 30.84, p < .001). Not only was there being no overlap between the groups, not a single control child obtained a score below the 25th percentile. The control group were not tested at T1.

8.4.3 Performance on the DASH

Since the DASH had not been published when Study 1 was conducted, no time comparisons for the DCD group are available. Consequently, Table 8.5 shows the data from T2 only. Means and standard deviations for overall performance as well as on the individual sub-tests are set out in Table 8.5a and 8.5b

Table 8.5 Performance on the DASH (T2 only)

Table 8.5a Standard scores for DASH and DASH subtests, percentile rankings and percentage of illegible words for the DCD group

Name	Sex	Copy Best	Copy Fast	Copy Best/ Copy Fast difference	Alpha Writing	Free Writing	Graphic Speed	DASH SS	DASH %	% words illegible
1	F	10	9	-1	13	9	16	102	57	1
2	F	10	11	+1	14	11	15	109	73	6
3	F	7	3	-4	13	11	14	92	30	2
4	F	16	16	=	13	17	15	133	98	6
5	F	10	11	+1	12	9	9	104	61	5
6	F	13	11	-2	3	8	13	93	32	0
7	M	11	9	-2	9	3	3	89	24	7
8	M	9	6	-3	6	7	12	82	12	6
9	M	8	3	-5	11	3	8	77	7	18
10	M	8	3	-5	10	6	10	80	10	6
11	M	13	9	-4	10	8	10	100	52	2
12	M	7	6	-1	4	3	9	70	2	8
Mean		10.17	8.08		9.83	7.92	11.17	94.25	38.54	5.46
SD		2.72	4.01		3.69	4.06	3.74	17.00	30.12	4.61

As Table 8.5a shows all the girls and two boys score at least within the average range for handwriting speed overall, leaving just four boys with scores 2 SDs below the mean. One girl scored low on Copy Best and Copy Fast but compensated for these on the other subtests. One additional boy who scored on the 24th percentile overall scored very low on Free Writing and Graphic Speed but his overall score was inflated by a high result on Copy Best. This suggests that he may well have problems with speeding up. The girl who scored lowest – and then still within the normal range - had a reduced score on Alphabet Writing, suggesting that perhaps her memory for the letter sequence is an influencing factor in this result. In contrast, Table 8.5b below shows the standard scores for the DASH and its subtests for the controls group. All but one child wrote some words illegibly the range being from 1-1.

Table 8.5b Standard scores for DASH and DASH subtests, percentile rankings and percentage of illegible words for the controls

Name	Sex	Copy Best	Copy Fast	Copy Best/ Copy Fast Difference	Alpha Writing	Free Writing	Graphic Speed	DASH SS	DASH %	% words illegible
1	F	15	14	-1	17	12	11	126	96	0
2	F	10	10	=	10	12	10	104	61	0
3	F	16	17	+1	16	14	17	126	96	0
4	F	13	16	+3	11	10	11	114	83	0
5	F	10	10	=	12	14	10	109	73	0
6	F	17	14	-3	14	13	16	126	96	0
7	M	14	10	-2	14	14	14	116	86	0
8	M	11	10	-1	11	7	7	94	36	0
9	M	12	11	-1	10	14	14	102	57	1
10	M	11	10	-1	10	8	8	109	73	0
11	M	15	12	-3	13	14	14	121	92	0
12	M	8	7	-1	8	12	12	86	18	0
Mean		12.67	11.08		12.17	12.00	12.00	111.08	72.65	0.08
SD		2.77	3.63		2.69	2.45	3.07	13.01	25.17	0.27

As Table 8.5b shows, all the children in the control group score within the normal range, though the last boy shows comparatively lower scores than the rest of the group at 18%. The range for the other children is from 36-96th percentile. On percentage of illegible words, all but one child wrote with 100% legibility and the remaining child scored only 1% illegible. The difference between groups on this measure was compared using an independent *t* test. Results found the difference to be significant (t = 3.851, p = .001).

Table 8.6 Means and standard deviations for DASH percentile scores and standard scores for individual DASH subtests for all the DCD group and control girls and boys

	DCD			Controls		
	All Mean (SD)	Girls Mean (SD)	Boys Mean (SD)	All Mean (SD)	Girls Mean (SD)	Boys Mean (SD)
DASH %	38.54	58.95	18.17	72.65	84.93	63.2
	(30.12)	(25.98)	(18.04)	(25.17)	(15.04)	(21.51)
Copy Best	10.17	11.00	9.33	12.67	13.5	11.83
	(2.72)	(3.1)	(2.25)	(2.77)	(3.02)	(2.48)
Alpha Writing	9.83	11.33	8.33	12.17	13.33	11.00
	(3.69)	(4.13)	(2.73)	(2.69)	(2.8)	(2.20)
Copy Fast	8.08	10.17	6.00	11.08	13.50	8.67
	(4.01)	(4.2)	(2.68)	(3.63)	(2.95)	(2.50)
Free Writing	7.92	10.83	5.00	12.00	12.5	11.50
	(4.06)	(3.25)	(2.28)	(2.45)	(1.51)	(3.21)
Graphic Speed	11.17	13.67	8.67	12.00	12.50	11.5
	(3.74)	(2.5)	(3.08)	(3.07)	(3.15)	(3.21)

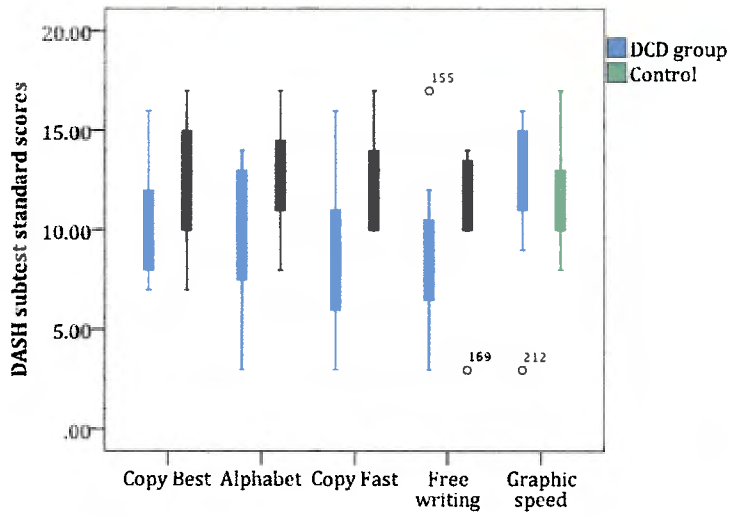

Figure 8.2 Mean DASH subtest scores for DCD group and controls

A MANOVA was conducted with *group* and *gender* as between-subjects factors and *sub test* as the within-subjects factor. Analysis showed significant main effects of both group (F (1,23) = 9.36, p < .006) and gender (F (1,23) = 13.39, p < .002): children in the DCD group obtained lower overall standard scores than the controls and boys scored lower than girls. However, there was no group x gender interaction. There was also a significant main effect of subtest (F (1,20) = 3.47, p = .02) but no further interactions.

Further analysis of the main effect of subtest within the DASH sub-tests then showed significant main effects of group in three of the five tasks: 'Alphabet Writing' (F (1,23) = 4,71, p < .05), 'Copy Fast' (F (1,23) = 10.83, p < .01) and in 'Free Writing' (F (1,23) = 7.01, p <. 05): overall, children in the DCD group wrote more slowly than the controls in these tests. Main effects of gender were also found on the 'Copy Fast '(F (1,23) = 6.93, p <. 05) and 'Free Writing' (F (1,23) = 23.04, p < .001) and 'Graphic Speed' (F (1,23) = 6.01, p < .05): boys wrote slower than girls in these conditions. As above, there was no significant group x gender interaction.

Since the two copying tasks within the DASH require the child to try to change writing strategy, it was of interest to determine whether both groups were able to respond appropriately. A MANOVA in which *group* and *gender* were the between-subjects factors and *task* (e.g. Copy Best, Copy Fast etc.) was the within-subjects factor showed a significant main effect of group (F (1,20) = 5.78, p < .03) and of task (F (1,20) = 22.72, p < .000) and of gender (F (1,20) = 7.27, p = .02): the DCD group scored lower than the controls, the 'Copy Fast' condition produced more words than the 'Copy Best'; girls wrote faster than boys. There was no task x group interaction which suggests that both groups responded to the instruction similarly. There was, however, a task x gender interaction (F (1,20) = 13.57, p = .001): interestingly, boys overall wrote *slower* when asked to copy fast than when asked to copy best. The three-way group x task x gender interaction was not significant.

Because main effects of both group and gender were found on the Free Writing task, handwriting speeds within this task, recorded at two-minute intervals, were further analysed for evidence of specific patterns of performance across the task duration. Although within the DASH the writing time limit is ten minutes, on this occasion participants were required to write for a further five minutes in order to fulfil the compositional requirements of the WOLD subtest from which the task-title was taken. Thus, the total time for writing was fifteen minutes and scores were recorded for each two-minute period up to ten and fourteen minutes as well as at fifteen minutes.

The mean number of words written in the seven x two-minute periods (i.e. fourteen minutes) of the fifteen-minute task for the DCD group and control girls and boys are illustrated below in Figure 8.3.

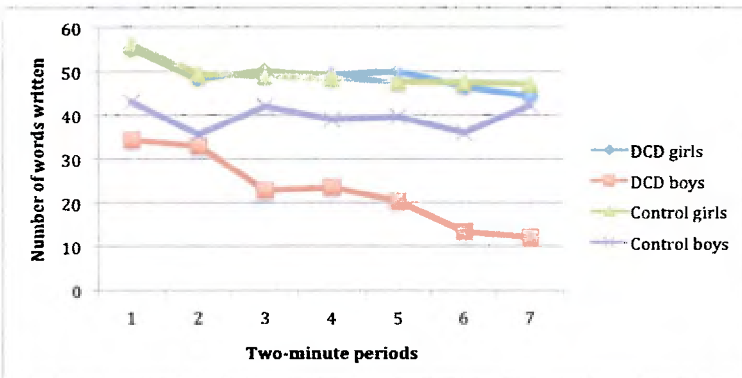

Figure 8.3 Mean number of words written for DCD group and control girls and boys

Figure 8.3 shows that all four groups produce a similar number of words for the first four minutes. However, beyond that, the boys in the DCD group are seen to 'fade' steadily over time in contrast to the children in the other three groups who continue to write at a comparable level. Closer examination shows that part of this steady reduction in word count is accounted for by the failure of some children to sustain writing for the full fifteen minutes. In all, six children (all but one from the DCD group) failed to finish. To illustrate this decline, Figure 8.4 (below) shows the numbers of children in each group who wrote continuously during each two-minute period.

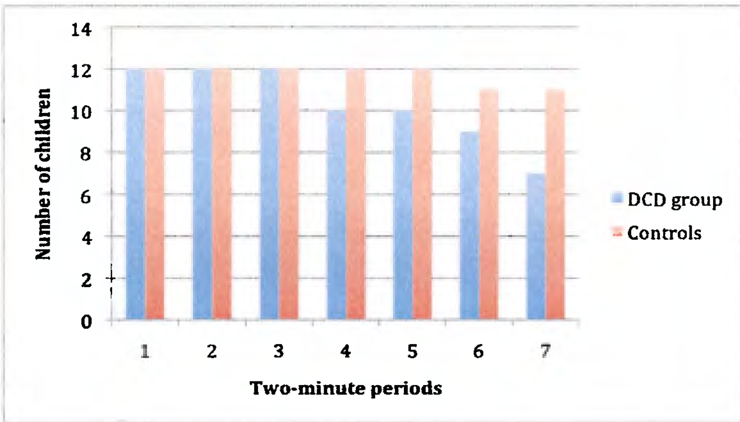

Figure 8.4 Number of children in the DCD group and controls writing in each two-minute period

This shows that all twelve controls continued for 10 minutes (five blocks) fulfilling the DASH task requirement and eleven of those continued for the full 15 minutes. In contrast, two children with DCD stopped writing after six minutes and one after 10 minutes, leaving only seven who managed to write for the full seven blocks (i.e. fourteen minutes) or beyond.

Because between-group comparisons for the whole time would not be valid (since not all children completed these) a MANOVA between Blocks 1, 2 and 3 (which all children did complete) was conducted on the number of words produced with *group* and *gender* as between-subjects factors. This showed no main effect of group (F (1,20) = .77, ns) but there was a significant main effect of block (F (1,20) = 9.89, p = .005) and of gender (F (1,20) = 23.81, p = .000). Significantly fewer words were produced in the different blocks and boys produced fewer words than the girls. There were no significant two-way interactions but the interaction of group x block x gender was significant (F (1,20) = 4.46, p = .047). Pairwise comparisons found that the difference between Blocks 1 and 3, adjusted for multiple comparisons was signficant (p = .005): fewer words were produced as time went on.

8.4.4 Discussion

Are the profiles of the children with DCD on IQ and literacy measures the same after 5 years?

When children in the DCD group were re-tested at T2 on the same standardised tests as at T1, results presented a fairly consistent picture. On standard score for verbal and performance IQ, word reading and reading comprehension no significant differences were found. Only in spelling did children score significantly differently at T2 and this was lower than at T1. This is an interesting finding and one requires further analysis. The spelling measures recorded are for *handwritten* spelling – oral knowledge of the words is not tested – and, as was discussed in Chapter 3 (p.51), there may well be a reason, linked with the motor delivery of the correct words, why these scores are lower for the target group. This is something which could be explored in the future.

Does their motor impairment persist into adolescence?

At T1 the children in the DCD group scored on the Movement ABC at a level indicating a significant degree of impairment in motor coordination, ten below 5th and two below 15th. Thus, all met the commonly used, more lenient interpretation of Criterion C for DCD (i.e. below the 15th percentile). This time only three scored below the 5th percentile and seven scored around or below the 15th. Thus, the majority of the group still met the more lenient criteria for DCD despite not meeting the more stringent level set by the EACD. Whichever of these cut-off points one might use, however, none of these children even approached the performance of their peers and clinical judgment is always involved in decisions over whether or not a child could be said to meet Criterion B. The two unexpected changes within the group data were two outliers who made gains (one from 1% – 63%; one from 8% – 50%) and the reasons for these individual changes remain unexplained.

Although these findings are mostly consistent with previous research findings (e.g. Cantell et al., 1994; Geuze & Borger, 1993; Losse et al., 1991), it is important to look at the other side of the coin and recognise that certain children have made some improvement. In order now to look for contributions to this effect, results from the parental questionnaire, especially with regard to evidence of intervention, will be examined (see p. 145)

What are the similarities and differences between the children with DCD and the controls after 5 years on motor and non-motor measures?

Matching the target and control groups was an important factor in the design of both these studies. At T2, when results on all measures for the DCD group were compared with those for the control group, no significant group differences were found in verbal or performance IQs, indicating that, as intended, the two groups were well matched for general intellectual ability. At T1 it had been noted that for the DCD group, scores on performance IQ were significantly lower than those for verbal IQ and whether this might be a contributory factor in the handwriting difficulties reported was considered. However, the absence of a difference between groups at T2 on this measure suggests that performance IQ may not be a major influence on writing outcomes at this age. It had also been intended that groups should not differ substantially as far as literacy was concerned.. Comparisons with the control group scores at T2 showed the children with DCD to be weaker on spelling, though not on word reading or reading comprehension, raising the possibility that the groups were not well matched on this measure at T1. However, lack of data for controls at T1 make this impossible to confirm.

Looking next at the motor status of the two groups, at T1 all children with DCD were found to have some level of motor impairment whilst no controls were known to have any movement difficulties. At T2 testing on the Movement ABC-2 confirmed the absence of motor problems in the control group (MABC-2 % = 63, SD = 20.8). Although two of the children with DCD had improved to a level at which they were no longer below the cut-off point of the 15th percentile, the overall scores for the remaining ten showed them still to have a significant motor impairment (MABC% = 16.8%, SD = 19.2), thus confirming that the majority had DCD.

How do the two groups compare on the DASH? Do girls perform differently from boys?

Finally, examining the formal assessment of handwriting speed, group and gender differences highlighted in the narrative tasks in Study 2 are supported by the DASH results at T2. The mean percentile score of 38.6% for the DCD group is nearly half that of the 72.8% scored by the controls. However, not only are the overall differences significant, but the sub-tests scores are revealing. When the children were asked to copy a sentence in their best writing (the 'Copy Best' task) no group or gender differences in writing speed were found. However, when asked to increase speed on this same task (the 'Copy Fast' condition) the children with DCD were less able than the controls to vary their speed of production. Speed scores showed that the children with DCD performed slower than the controls on 'Alphabet Writing', 'Copy Fast' and 'Free Writing', and that boys performed slower than girls on the 'Copy Fast', 'Free Writing' and 'Graphic Speed' tasks. In terms of the ability to deliver written work effectively in school, failing to increase speed when required to do so, and slowness in completing written assignments would indeed represent a real disadvantage in the classroom.

Another DASH result which provides evidence of a potential problem of delivery – and one which would impact more at secondary than at primary school level – is the inability to sustain writing speed over time. Within the 'Free Writing' task, recorded speeds for each two-minute block showed that whilst all children produced fewer words as the task progressed, the rate of slowing was greater for the boys, and the target boys in particular. Five of the children with DCD (though none of the controls) failed to sustain writing for the full ten minutes allotted for the DASH Free Writing task. Taken together, the failure to speed up and the inability to sustain writing for long periods of time provide evidence which contributes to an understanding of why poorly coordinated boys struggle to produce enough written work.

8.5 Part 2: Results on narrative measures

In this part of the study three further questions are addressed. These look at performance on the narrative tasks, asking whether (1) the differences in performance between the two groups found at T1 remains at T2, (2) there is the same relationship between handwriting and composition quality, and (3) girls and boys perform differently.

8.5.1 Are the patterns of performance between groups on the narrative tasks the same at T2 as they were at T1?

In order to compare the scores of the DCD group and control groups at T1 and at T2 on the narrative measures, a repeated measures ANOVA was used with two between-subjects factors (*group* and *gender)* and two within-subjects factors (*mode* and *time*). Because of the group and time differences in spelling ability observed in the results (above), a second analysis was conducted with spelling as a co-varying factor. On non-parametric data, Mann-Whitney *U* (between-subjects) and Wilcoxon Matched Pairs (within-subjects) tests were used. Individual data are shown in Tables 8.7a and 8.7b below.

Table 8.7 Individual data on narrative measures at T1 and T2

Table 8.7a. Individual data on narrative measures for children with DCD at T1 and T2

DCD	Number of words				Total time				Production speed				Composition quality				Handwriting	
Child	Written		Oral		Written		Oral		Written		Oral		Written		Oral		quality	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
1	145	362	214	388	15	1.7	4.0	1.0	10	24	122	97	4	5	5	6	4	6
2	222	331	221	503	28	15	1.8	3.5	8	22	120	143	5	5	4	5	5	3
3	156	49	211	354	17	15	1.4	3.1	9	27	108	114	5	5	5	4	3	3
4	357	535	465	588	18	15	3.0	4.7	19	36	155	123	6	5	6	5	4	3
5	118	323	882	158	10	15	1.5	2.1	12	22	108	107	3	5	3	4	3	3
6	67	205	223	146	9	15	0.7	1.5	7	17	122	97	2	4	3	3	2	5
7	60	74	63	25	3	15	0.6	0.3	10	23	105	100	2	2	2	2	1	2
8	66	179	108	156	6	15	1.1	1.3	10	22	100	124	2	4	3	3	3	2
9	50	60	92	88	5	15	0.5	0.8	19	33	180	106	2	2	2	2	1	1
10	119	226	128	225	8	15	1.0	2.3	11	28	128	97	4	5	3	4	4	3
11	109	274	158	178	9	15	0.8	2.1	21	20	109	85	3	4	2	3	4	3
12	54	120	79	16	4	15	0.6	0.8	12	18	136	21	1	3	3	1	1	2
Mean	126.9	258.2	164.9	240.8	10.9	13.7	1.2	3.0	13.5	24.1	137.1	101.6	3.3	4.1	3.7	3.6	2.9	3.0
SD	88.7	142.2	109.7	182.3	7.2	9.1	0.7	1.4	4.9	5.4	30.9	29.9	1.5	.12	1.0	1.5	1.3	1.5

Table 8.7b Individual data on narrative measures for controls at T1 and T2.

Control	Number of words				Total time				Production speed				Composition quality				Handwriting	
Child	Written		Oral		Written		Oral		Written		Oral		Written		Oral		quality	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
13	96	339	116	235	9	15	1.0	1.3	20	16	116	100	3	5	4	5	4	5
14	161	333	200	616	15	15	1.7	4.7	11	15	114	129	5	6	5	5	4	5
15	278	448	167	395	15	15	1.1	3.2	10	10	154	122	6	4	4	5	5	4
16	113	416	79	297	15	15	1.1	2.7	14	15	158	111	4	5	3	4	4	4
17	315	298	146	308	15	15	1.2	3.1	13	18	117	100	6	5	4	5	5	4
18	193	268	162	210	15	15	1.7	1.8	14	12	97	109	5	6	5	4	6	4
19	63	263	61	210	9	15	0.5	1.5	7	18	124	140	3	3	3	3	2	3
20	140	339	95	258	15	15	0.8	3.0	9	23	115	86	4	5	3	5	3	3
21	102	174	100	161	15	15	0.8	1.3	7	12	133	128	3	3	3	3	2	4
22	145	325	152	496	10	15	1.7	6.4	15	22	94	142	4	5	6	5	3	4
23	111	321	176	275	15	15	0.7	1.2	7	21	116	97	3	5	3	5	5	4
24	79	157	63	160	10	12	0.7	1.2	8	11	94	133	3	4	2	5	5	4
Mean	149.7	306.8	118.6	284.9	10.8	14.9	1.1	2.8	11.0	20.5	119	116	4.1	4.7	3.7	4.3	4.0	4.0
SD	77.1	84.6	46.6	130.3	0.5	0.4	0.5	1.5	4.9	5.6	20	18	1.0	1.0	1.0	0.9	1.3	0.6

Number of words produced

There were no significant main effects of group (F (1,23) = 0.70, ns) or of mode (F (1,23) = 0.0, ns) but there was a significant main effect of gender (F (1,23) = 10.2, $p < .01$): girls produced more words overall than boys. There was also a significant main effect of time (F (1,23) = 58.83, $p < .001$): more words were produced at T2 than at T1 though there was no difference between oral and written in the amount produced. The time effect was moderated by a time x group interaction (F (1,23) = 4.88, $p < .05$) shown in Figure 8.5 below: whilst time led to an overall increase in the number of words produced, the controls increased more than the target group. There were no further significant interactions.

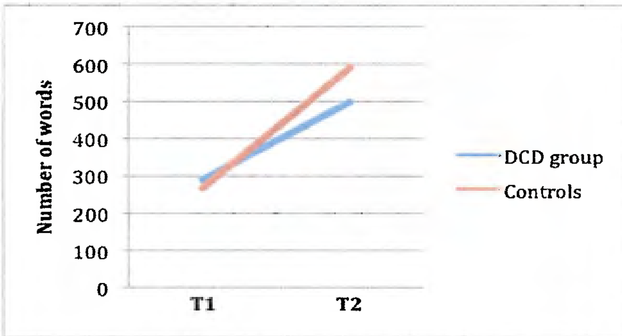

Figure 8.5 Mean number of words produced by the DCD group and controls at T1 and T2

Since spelling was found to be poorer in the DCD group than the controls at T2, a further MANCOVA was conducted on the T2 data alone with this measure as a co-varying factor. Results of this analysis showed that when spelling was taken into account, the results were similar to those above: i.e. there was no significant group difference (F (1,23) = .10, ns), though the gender difference was still significant (F (1,23) = 7.83, $p < .05$).

Total time taken

When the between subject factors in this analysis were examined, no significant main effect of group (F (1,22) = 3.54, ns) was obtained but there was a significant main effect of gender (F (1,22) = 11.28, $p < .01$): girls took longer overall than boys. Of the within subject factors both the main effect of time (F (1,22) = 910.49, $p < .01$) and of mode (F (1,22) = 461.82, $p = .000$) were significant: overall children spent longer both writing and speaking at T2 than they did at T1 and predictably writing took longer than speaking. A three-way interaction of mode x gender x group (F (I, 22) = 8.09, $p = .01$) showed that girls in the control group spent the longest time on task, particularly in written mode.

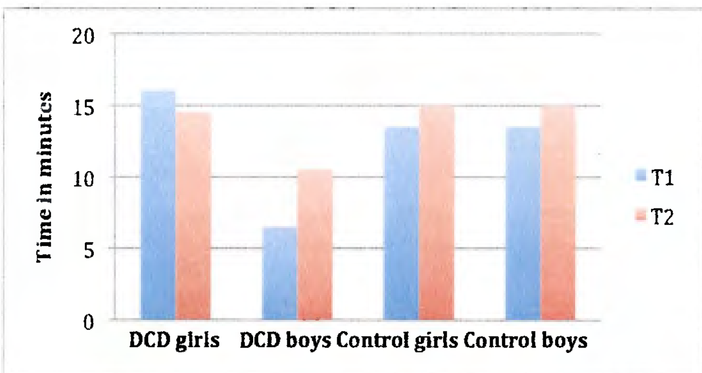

Figure 8.6 Time taken at T1 and T2 for girls and boys in the DCD and control groups

Speed of production

Handwriting speed scores calculated from the written narrative task in words-per-minute for both groups at T1 and T2 are shown below in Figure 8.7.

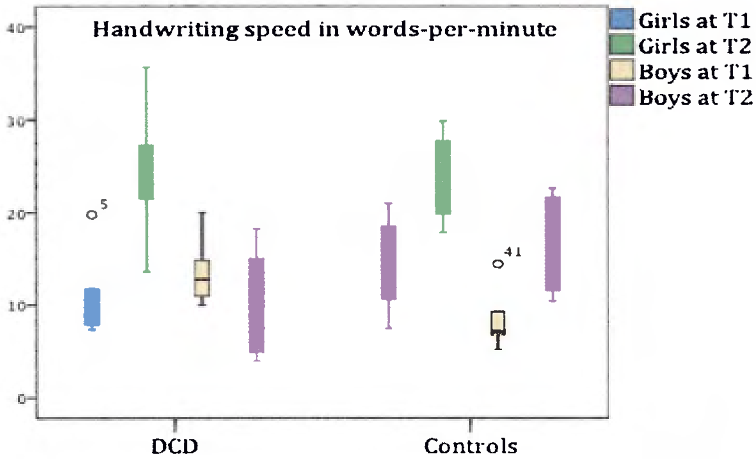

Figure 8.7 Mean handwriting speeds in word-per-minute for girls and boys in target and control groups at T1 and T2

An ANOVA with repeated measures was conducted with two between-subjects factors (*group* and *gender*) and one within-subjects factor (*time*). Results revealed no significant main effect of group (F (1,23) = .31, ns) but there was a significant main effect of time (F (1,23) = 35.14, p < .001) and of gender (F (1,23) = 10.88, p < .05): all children increased their handwriting speed over time and girls increased more than boys but the difference between target and controls was not significant overall. However, these results were moderated by a three-way time x group x gender interaction (F (1,23) = 10.3, p = < .05). Girls had improved more than boys, that the controls had improved more than the target group; that the girls in the DCD group showed the greatest increase of all.

Rated Handwriting quality

Rated handwriting quality for both groups at T1 and T2 is shown below in Figure 8.8. Data being non-parametric, a Wilcoxon matched pairs test was used to compare performance within groups over time and a Mann-Whitney U test was used to compare performance between groups at T1 and T2.

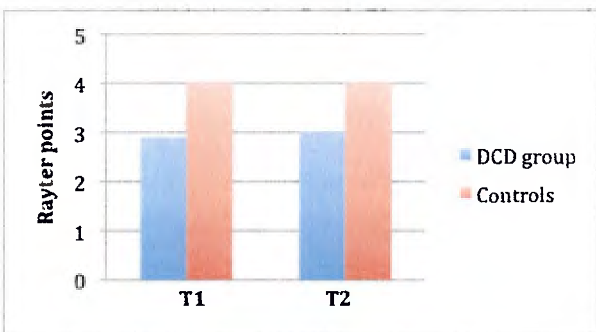

Figure 8.8 Mean rated handwriting quality scores for target and control groups at T1 and T2

Wilcoxon results showed that overall there was no significant difference between T1 and T2 in the rated quality of handwriting for either group (children with DCD: Z = -.312, ns; controls: Z = .000, ns). Mann-Whitney U tests showed that the difference between groups was significant at both T1 (U = 37.5, p < .05) and at T2 (U = 29.00, p < .05) and that there were no gender effects over time: the difference between target and control groups at T2 was the same for girls (U = 31.00, p < .05) as for boys U = 31.00, p < .05).

Figures 8.9a and 8.9b show **handwriting samples of one boy with** DCD at T1 and T2.

Figure 8.9 **Handwriting samples of one boy with DCD at T1 and T2.**

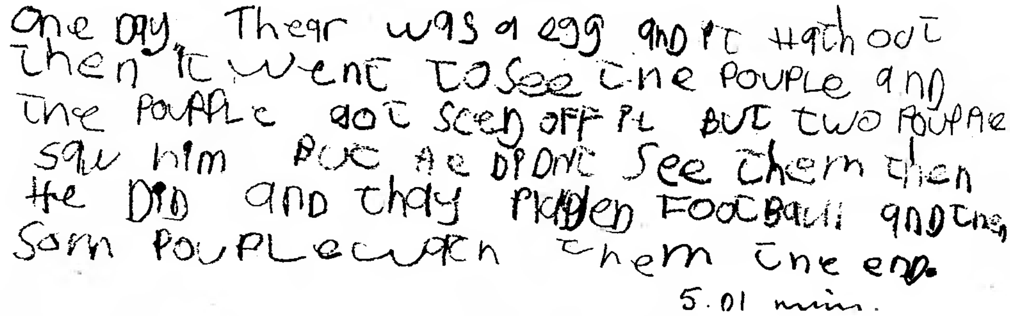

Figure 8.9a Rated 2 points

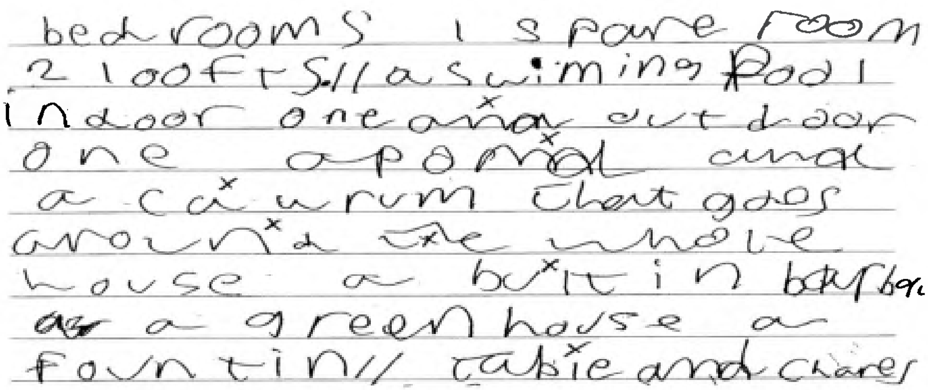

Figure 8.9b Rated 2 points.

The handwriting of this child with DCD has improved very little over 5 years. Both at T1 and T2 he has problems with correct letter formation, sizing and alignment. His script is unjoined and the motor control is poor. Although the words are mostly legible, the writing is inconsistent and untidy. The only noticeable change over time is the omission of unwanted capitals at T2.

Figures 8.10a and 8.10b show handwriting samples of the same control boy at T1 and T2.

Figure 8.10 **Handwriting samples of a control boy at T1 and T2.**

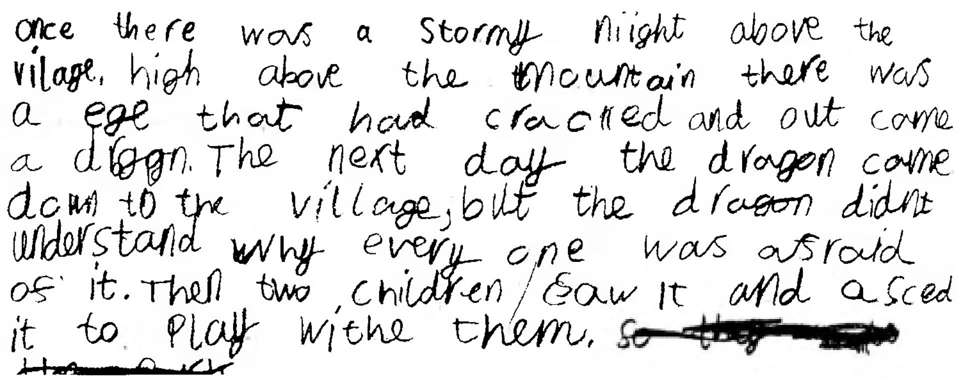

Figure 8.10a Rated 3 points.

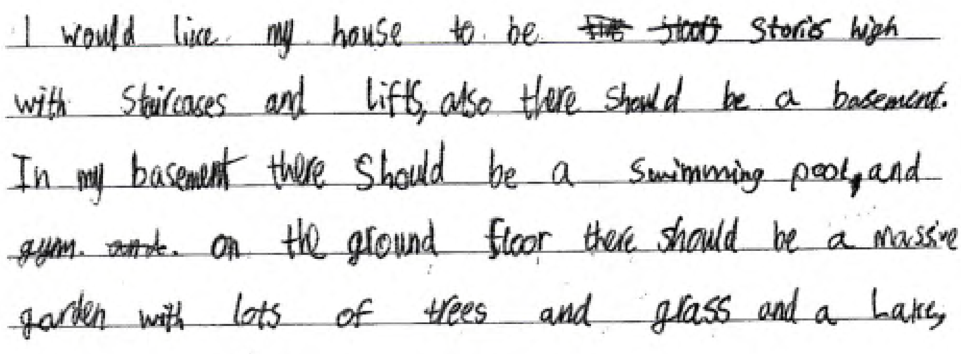

Figure 8.10b Rated 4 points.

Interestingly, the handwriting quality of this control boy has hardly improved either. Both at T1 and T2 the letters are correctly formed and aligned with consistent spacing and the writing is legible. It is partly joined and lacks consistency of line and size, hence scoring still just above average.

Composition quality

Mean scores for rated composition quality for both groups in both modes for T1 and T2 are shown below in Figure 8.11. As with handwriting quality, a Wilcoxon matched pairs test was used to compare performance within groups between T1 and T2 and a Mann-Whitney *U* was used to compare performance between groups at both time points.

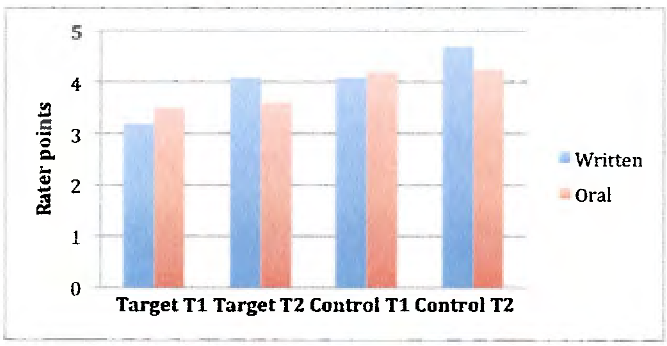

Figure 8.11 Rated composition quality groups in written and oral modes for target and control at T1 and T2.

Results for rated composition quality in both modes showed that there was no significant difference over time in oral compositions across groups ($Z = -1.698$, ns) but that the difference over time in written compositions was significant ($Z = -2.694$, $p < .05$): written stories had improved between T1 and T2.

Results also showed that the difference between children with DCD and controls at T2 was not significant in either rated written composition quality ($U = 43.00$, ns) or rated oral composition quality ($U = 62.00$, ns). Although 7 children from each group improved, in the DCD group 4 of those had gained 2 points whereas the controls had improved by only one.

The following examples in Figures 8.12a, b and c show a typical difference between girls and boys in composition quality.

Figure 8.12 Examples of typical difference between girls and boys in composition quality

Figure 8.12a Example 1 (boy). Rated 1 point.

> "My house will be a penthouse flat in docklands with four bedrooms and very modern fittings."

Figure 8.12b Example 2 (boy). Rated 2 points.

> " I would like the house to have 5 floors, 2 bathrooms, 2 living rooms, 2 kitchens, 2 bedrooms, 1 spare room, 2 lofts, 2 swimming pools, one indoor and one outdoor, a pond that goes round the whole house, a built-in barbeque, a green house, a fountain, tables and chairs and a waterfall."

Figure 8.12c Example 3 (girl). Rated 6 points.

> "... I want an art studio, big and gleaming white – pristine and full of light. I want gardens, too, one at the front of the house and one at the back, which are large and green with a wooden porch and small marble rabbits running through wild shrubs. I want an artificial lake with a pontoon guesthouse barge in the centre, lily pads afloat and any other sort of water plants you can find. The water must be crystal clear and I only want the most exotic of fish, pearly-eyed with long, ornate fins. I want a beautiful bridge, wooden with some sort of majestic balance, almost as if it were floating in mid-air. I would also like a garden on the roof with a pond and small, sleek, quaint benches with Moroccan stools and beanbags. I want a very African theme for the décor of my house. Lanterns will hang from every ceiling. I am very particular about lighting – I like romantic shades of pink, and fiery gold. Dark is something that won't exist in my house! ..."

Examples 1 and 2 (Figures 8.12a and b) were the complete pieces written by boys. The first was assigned 1 point as the content is minimal and barely fulfils the task requirement. The second was assigned 2 points as it covers the basic facts though simply lists what the house requires with no extension, apart from stating that the pond should go round the whole house. In contrast, Example 3 is a selected passage from the writing submitted by one girl which was assigned the full 6 points. Although not shown in its entirety, this piece is well organised and cohesive. It begins by setting out the basic layout required for the house and continues with a more detailed description of each individual room. Then, as illustrated above, it elaborates these ideas for the gardens and for the general atmosphere of the interior. Throughout the piece, as with the passage selected, the writing is descriptive, imaginative and communicated in well-structured text with extensive elaboration and some interesting vocabulary.

Rated quality of the components of composition

After scripts were rated holistically, they were further analysed on the five separate components of composition rated earlier. The means and standard deviations for both groups in both modes are shown in Table 8.8.

Table 8.8 Means and standard deviations for composition components for DCD and control groups in written and oral mode

	DCD				Control			
	Written		Oral		Written		Oral	
	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)	T1 Mean (SD)	T2 Mean (SD)
Ideas	2.75 (0.75)	3.00 (0.74)	2.33 (0.98)	2.42 (0.99)	3.00 (0.74)	3.00 (0.72)	2.92 (0.67)	2.92 (0.69)
Organisation/ cohesion/unity	2.75 (0.45)	2.92 (0.79)	2.58 (0.69)	2.75 (0.75)	2.75 (0.62)	2.83 (0.72)	2.75 (0.75)	2.83 (0.72)
Grammar	3.25 (0.75)	3.00 (0.60)	2.83 (0.72)	2.75 (0.62)	3.83 (0.39)	3.58 (0.51)	3.17 (0.58)	3.00 (0.43)
Sentence structure	2.83 (0.72)	3.00 (0.60)	2.42 (0.90)	2.5 (0.67)	3.00 (0.60)	3.17 (0.58)	2.92 (0.69)	2.92 (0.69)
Vocabulary	2.42 (0.51)	2.25 (0.45)	2.33 (0.65)	2.42 (0.79)	2.67 (0.65)	2.83 (0.58)	2.50 (0.52)	2.50 (0.52)

A Wilcoxon matched pairs test comparing the composition components of written stories with oral stories at T2 found significant differences in the *generation and development of ideas* (Z = -1.90, p = .05) and in *grammar* (Z = -2.829, p = .005): written stories were rated higher for *generation and development of ideas* and for *grammar* than oral stories.

As Table 8.8 shows, on all five measures the ratings for the DCD group were lower than controls. However, Mann-Whitney U tests comparing the children with DCD with the controls in both modes found significant group differences only in written *grammar* (U = 37.00, p = .03) and in written *vocabulary* (U = 34.50, p = .02) where the DCD group were poorer than controls. There were no differences in oral stories.

8.5.2 Does the relationship between handwriting and composition quality remain constant over time?

The handwriting measures from the narrative tasks were correlated with rated composition quality of transcribed written scripts using a Spearman's Rho test. Results are shown below in Table 8.9.

Table 8.9 Correlations between handwriting measures and rated written composition quality across groups at T1 and T2

	Handwriting Speed		Handwriting Quality		Written composition Quality	
	T1	T2	T1	T2	T1	T2
Handwriting speed	1.00	1.00	.25	.38	.42*	.57**
Handwriting quality			1.00	1.00	.72**	.48*
Written composition quality					1.00	1.00

* significant at the 0.05 level (2-tailed).

** significant at the 0.01 level (2-tailed).

At T1 positive correlations were found across groups between rated composition quality and handwriting speed (.42) and handwriting quality (r = .72**). At T2, these two associations with composition were still evident: handwriting speed (r = .57**) and handwriting quality (r = .42*).

8.5.3 Are gender differences evident on any measures at T2?

Results on all standardised and narrative measures for girls and boys at T2 were compared using one-way ANOVA and Mann-Whitney U tests as appropriate. No significant differences were found on any of the standardised tests, or on the number of words produced orally or on total time of production in either mode. However, some gender differences were found on other measures and these are summarised below in Table 8.10

Table 8.10 Gender differences in narrative measures at T2

	F or *U*	*p* value
Parametric data	*F*	
Number of words written	15.11	.001**
Handwriting speed	15.99	.001**
Non-parametric data	*U*	
Handwriting quality	32.00	.016*
Composition quality written	27.00	.005**
Composition quality oral	22.50	.003**

**Significant at a 0.001 level; * significant at a 0.01 level.

The girls' performance was superior to that of the boys on all measures.

Components of composition quality

When the components of composition were compared at T1, both girls and boys in the DCD group were significantly weaker in the written than in the oral stories, though this was not true for the controls. The difference between written and oral stories in the *generation and development of ideas* noted at T1 in all the DCD group had disappeared for the target girls at T2, though differences between modes were still found in the target boys in the *generation and development of ideas* ($Z = -2.24, p < .05$) and also in *grammar* ($Z = -2.27, p < .05$).

8.5.4 Part 2 – Discussion

Are the patterns of performance between groups on the narrative tasks the same at T2 as they were at T1?

Comparisons in performance on a descriptive task in written and oral mode showed that the patterns of performance between groups had changed significantly since the children were assessed five years earlier. First, in relation to the amount of text produced, at T1 children with DCD produced much less in written than in oral mode and less also than controls. At T2 this had disappeared and although more words were produced overall, the children with DCD had increased their written output more than the children in the control group and were now producing as much text as their peers. The time taken on task in both modes had increased over time and so also had production speed. The additional issue discussed in the earlier sections of this chapter was how well children were able to sustain writing over time. It would seem from these results that the increase in handwriting speed of the DCD group enabled 75% of them to continue to write for the whole fifteen-minute task.

None of these results are surprisingly given the impact of age and general maturation, but it was interesting to note that the improvements were greater in the DCD group than the controls. This being the case, a key question to be asked was whether composition quality had improved correspondingly. The answer was clearly yes. T2 results showed that overall it had, in that the two groups no longer differed in this respect, as, whilst the oral results remained the same, significant gains were made in the written scores, particularly in the target group. Looking at the correlational data between handwriting measures and composition quality, strong associations were found between composition quality and both handwriting speed and handwriting quality. This supports earlier evidence of a relationship between the ability to handwrite fluently and the composition quality ratings.

All this evidence gathered from the narrative tasks demonstrates a clear increase in handwriting speed and number of words produced in both the DCD group and controls with a corresponding improvement in rated composition quality. However, the findings on the handwriting quality are worth particular mention for whilst the correlation with composition quality remains at T2, it is clear that in neither group has there been significant improvement in handwriting quality ratings. Thus, it would seem that for both the poorly coordinated children and their peers, the basic form and quality of their handwriting is set by the time they leave primary school and does not change thereafter.

Where there have been increases in performance, the changes noted are more apparent in girls than in boys, suggesting that the gender gap remains well into adolescence, as suggested in the literature (Burgess, McConnell, Propper, & Wilson, 2003; Ofsted, 2003). However, the question asked about the point at which boys "catch up" remains unanswered (Dutton, 1992), as, whilst one boy in the DCD group did increase in handwriting fluency with concomitant improvements in composition, the other five made only slight, if any, gains.

An important question raised by the finding that half the children with DCD made significant gains in written production, both in quantity and composition quality, is what has happened in the time between T1 and T2 which might have affected writing outcomes beyond general maturation? Evidence from the literature would suggest that the gains found in this follow-up study are not typical in young people who were identified with movement difficulties in primary school (e.g. Cantell, et al., 2003; Losse et al., 1991). It is helpful now to look at the responses to the parental questionnaire for possible additional information.

8.6 Part 3: Data gathered from questionnaire

Data was collected from the DCD group using a questionnaire sent to the children's families relating to different aspects of life during the five-year period. Four sections were included and responses to these are reported below.

Home and family stability

No family reported either break-up or trauma during the five-year period.

Health and general wellbeing

All but one of the children had been consistently well during the intervening years. Only one had suffered a major illness and this had resulted in non-attendance at school for two of the five years. For some of the period he had been home-schooled but it was clear that his education had been severely disrupted. However, despite this, it transpired that he was the one boy who had made significant gains in Movement ABC scores and also written performance since T1. This suggests that the missing schooling had not caused the degree of delay that might have been expected, unless, of course, the one-to-one tuition at home had had a greater effect. As regards the diagnosis of developmental disorders, four of the girls and two of the boys had been diagnosed with dyspraxia since the first study, a further girl had been diagnosed with dyslexia and one boy had received a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD) with certain features of Asperger's Syndrome (AS).

Educational issues

An interesting finding was that five of the twelve children in the DCD group had not remained at the secondary school to which they had first transferred. The girl with dyslexia and the boy with ADHD/Asperger's Syndrome had been moved to schools with special provision for their conditions; one other boy had moved as his family circumstances had changed and one had been excluded from mainstream school for deviant behaviour. A further two girls had moved schools being victims of alleged bullying. These changes were in contrast to the experience of the control children, eleven of whom still attended their original schools with only one who had moved and that for family reasons. As regards the writing problems, all but one still felt that handwriting was difficult and eight of the twelve children with DCD used a keyboard instead of handwriting as the primary mode for written school assignments. Reports of achievement levels varied but most children professed still to experience difficulties in keeping up with written assignments. For some the difficulties were reported to be in organization of ideas and for others it was the inability to produce enough.

Intervention

Evidence from the parental questionnaires revealed that all children in the DCD group had received some form of intervention since leaving primary school. Table 8.11 shows the types of intervention received for each child.

Table 8.11 Types of intervention received for each child: DCD group only

	Physio/ Occupational Therapy	Visual Perceptual Therapy	Handwriting Tuition	Touch-Typing	Spelling Tuition
Girls					
1	X	X	X	-	-
2	-	X	X	-	-
3	-	X	X	-	-
4	-	X	X	X	X
5	-	X	X	-	-
6	-	X	X	X	X
Girls Total	1	6	6	2	2
Boys					
7	X	X	X	X	-
8	-	X	X	-	X
9	X	X	X	X	-
10	-	X	X	X	-
11	X	X	X	X	-
12	-	X	X	-	-
Boys Total	3	6	6	4	1

Unsurprisingly, since these children had been recruited with handwriting difficulties, all but one had received specific help for handwriting since they were first tested. Of these, most had received learning support within school and, in addition, had received external help from clinical specialists. Four of the group, one girl and three boys, had received either occupational- or physiotherapy and all had received some form of visual perceptual training directed towards correct letter formation and spatial organisation on the page. Three children, two girls and one boy, had received specific help with spelling, and six had taken touch-typing lessons. The handwriting and clinical interventions had all taken place over a six-week period, children attending individual lessons once a week. The touch-typing tuition had been more intensive on the whole with five of the six children attending a holiday course every day for either one or two weeks. These courses had been repeated in subsequent holidays until speeds of over 30 words-per-minute were achieved. The spelling interventions, though received by only three children, were also more intensive than the handwriting tuition (more than one lesson per week) and for a longer period of time (over two years).

Despite the likelihood of a causal link between the interventions received and the measured improvements in performance in many of the children, an analysis of the impact of different types and degrees of intensity of the support was not possible in this study because detailed records of the interventions were not kept. All that can be reported in these circumstances is that it appears that the gains may be related to the targeted work undertaken in some cases and this suggests that future research into (a) the impact of interventions of different natures and (b) the frequency continues to be important (e.g. Zwicker, 2005). Most importantly, these data show that girls appear to have benefited more from intervention than the boys.

8.7 Conclusion

Following up 24 young people after five years (from 10/11 to 15/16 years of age) produced interesting data on their general development and on their written literacy in particular. First, for the DCD group, despite a slight reduction in measured verbal ability, standard scores for literacy were largely unchanged, with the exception of spelling which was relatively weaker. It has to be acknowledged, however, that all measures of spelling are taken in written form and as such are not independent of the handwriting competence of the speller. This will be developed further in Chapter 9. Movement ABC scores at T2 were found to be higher than those at T1. However, in all, gains were small and most children remained around or below the 15% percentile, confirming what has been found in other studies (e.g. Cantell, et al., 2003; Losse et al., 1991) that for those who are poorly coordinated in childhood there is little real improvement in performance over time. Where changes had occurred, they were confined mainly to manual dexterity and predominantly in the girls.

Looking next at the narrative measures, there is clear evidence of improvements in the writing performance of half the children in the target group. The gains identified brought these children more in line with their peers, particularly in handwriting speed and the amount of text produced, though not so much in quality of handwriting. As had been predicted from the evidence of the Christensen studies (2005), this increase in production has been accompanied by an improvement in rated composition quality of written narratives, so much so that the deficits noted at T1 were largely eradicated. A closer analysis of which children improved points again to marked gender differences in improvement in this particular sample. In order to understand better the reasons for the divide between the improvers and non-improvers, scores on the standardised tests and also the exposure to intervention have both been examined.

First, looking at the scores on the standardised measures, since verbal and performance IQs have remained stable over time these cannot be said to be significant factors in the change. Second, the consistency in word reading and reading comprehension scores, noted in the DCD group at T2, cannot account for the change because, whilst writing had improved in only half of the children in the group, reading scores were largely unchanged. Third, Movement ABC scores were found to have increased in all the children in the DCD group, even if only slightly in some cases. However, though some of the biggest improvements recorded were for boys, it is the girls who show the biggest gains in writing. A more detailed analysis of the Movement ABC-scores and the handwriting measures showed some interesting patterns which will be discussed individually.

First, at T2 there was a mis-match between Movement ABC-2 scores and DASH handwriting speed scores in nine of the twelve children (5 girls, 4 boys) in the target group. The five girls had Movement ABC scores between 5-9% but were on the 30% percentile or above for handwriting speed and, in addition, scored between 3 – 6 points (the maximum) for handwriting quality. Of the four boys, two wrote faster on the DASH than their Movement ABC-2 scores would have predicted, yet two wrote slower. The match for handwriting quality was closer. However, these unexpected speed results invokes questions over what exactly the relationship between motor coordination (as measured by the Movement ABC-2, a well-researched and widely used test) and handwriting skill as demonstrated in this study is. One possible answer lies within the Movement ABC-2 scores themselves, as the pattern of the sub-skill scores gives some possible indicators. The main factor which may have influenced writing outcomes is that manual dexterity scores showed a significant increase, especially among the girls, and these comprise the majority of children whose writing speed have increased.

In an attempt to understand this problem better, it is necessary, next, to examine the part that the interventions may have played in the changes which had been noted. All the children in the DCD group had the benefit of at least one type of intervention between T1 and T2. All received perceptual training with an emphasis on building accurate internal representations of the letterforms and joining strokes. All but one received direct tuition in handwriting, some in school, some outside. Seven out of twelve received some kind of physical therapy, either occupational- or physiotherapy, with a focus on improving motor control for handwriting, and one had intensive specific sports training. In addition, six had received help for spelling and six had learned to touch-type. It is assumed that this targeted teaching approach will have had some impact upon written performance and, indeed, the fact that half the children, five girls and one boy, showed marked writing improvements over the period studied supports this assumption. This evidence, together with the improved results on composition quality in these same children, suggests that it is possible, by using appropriate therapies, to improve handwriting ability enough to eradicate the disadvantage at school. However, it would also seem that this is possible without necessarily changing the underlying motor status of the individual to any real degree. This is a new and interesting idea and one that may in fact suggest that general motor ability and specific handwriting ability may show only partial overlap. There is no evidence from these studies that ball skills are in any way associated with the motor production of text and that the link with balance is tenuous. Only manual dexterity shows any correlation and this is weak and with handwriting quality alone. The therapeutic literature suggests that balance and stability are commonly found in children with DCD (Wann, Mon-Williams & Rushton, 1998), yet there is no evidence in this study to link scores for balance with writing speed.

A further question to which there is no obvious answers at present, is why girls appear better able to benefit from intervention than boys. The exposure to treatment among the young people in this study was shared equally between the sexes, yet the only boy to show significant gains was the one who, through illness, missed two years of schooling during the period concerned. Whilst intervention appears to have accompanied, and probably assisted, marked improvement in the girls, it remains a mystery why five out of six boys have failed to improve their writing skills to a functional level despite receiving considerable levels of help.

This suggests that some central questions posed within this thesis require further investigation and these questions will be discussed in Chapter 10.

Chapter 9

Study 4: The impact of variable workload on handwriting behaviour: an exploration of the effects of changes in motor and orthographic demand on the handwriting of boys with and without DCD.

9.1 General Introduction

One of themes running through this thesis is the question of why poorly coordinated children with handwriting difficulties often show more generalised problems with writing. Focusing on able children who met criteria for DCD, the three studies reported so far explored this question in a variety of ways, producing a number of convergent findings. For example, all three studies found statistically significant correlations between the physical act of handwriting, measured in terms of number of words written, and the quality of composition as rated by independent assessors (average $r = 0.78$). Put another way, these correlations suggest that approximately 60% of the variance in the compositional quality of stories written by the children could be accounted for by the number of words they managed to write.

When this link was examined in a different way, Studies 1 and 2, found that the children with handwriting difficulties not only produced shorter texts than children judged to be competent hand-writers but also wrote stories which were weaker compositionally. This finding was then developed further in Study 3, when the same children were followed up after a period of five years. What then emerged was that those children whose handwritten output was below that expected for their age at 10-11 years of age, continued to produce stories of poorer content quality, *but only if their handwriting difficulties were not resolved*. The reverse position was also true: scripts of those whose handwritten output had improved after five years (with help) were correspondingly rated higher for written composition than they had been earlier and than those whose output was still poor. This outcome is consistent with Christensen's (2005) finding that intensive handwriting intervention improved not only the physical aspects of writing but also the ratings for composition quality.

Another aspect of the findings from all three studies provided different but useful data on the links between the mode of expression and compositional quality. For example, when the written and spoken compositions of the children with DCD were compared, the organisation, cohesion and unity, grammar, sentence structure and vocabulary were very similar. This reflects a basic linguistic competence underlying both modes of verbal composition, as suggested in the literature (Harrell, 1957; Loban, 1976). However, when the ability to generate and develop ideas was examined, this proved to be poorer in their handwritten texts. Additionally, when the handwritten compositions of the DCD group were compared with those of fluent hand-writers, it was this same component which differentiated the two groups. One possible explanation of this particular finding is that generating and developing ideas is a skill which is more cognitively demanding than say, structuring a sentence once the idea is formed, and thus is more demanding of attentional resources. [2]

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[2] In the population studied here, factors such as low verbal intelligence and general literacy problems have been ruled out as possible causes of poor written composition.

Taken together these results suggest that, whilst no causality can be assumed, being able to write enough and at a reasonable speed at very least provides a vehicle through which creative ideas can be expressed. A more specific expression of this idea suggests that those who handwrite with ease can devote more attention to planning the content of what they write. Correspondingly, for those who fail to produce handwritten text effortlessly, the quality of written content is reduced (Berninger et al, 1997; Graham, 1990). Support for this thesis can be found in a study by Fayol (1999) who showed that devoting resources to handwriting and spelling left less capacity for syntactic processing, content retrieval and rhetorical structuring when composing. Similarly, Bourdin and Fayol (2000) showed that the cost of handwriting reduced performance on a written serial recall task compared to an oral recall task. Based on these findings, the question of exactly how lack of competence in handwriting exerts its influence on composition quality needs to be explored.

As discussed in Chapter 3, there are numerous theories and/or models of writing which attempt to specify, in differing amounts of detail, the many processes involved in writing a piece of text along with the ways in which these various processes interact or influence each other (e.g. Hayes & Flower, 1980; Bereiter & Scardamalia, 1987; Kellogg, 1994; Berninger & Swanson, 1994). One theory which is commonly referred to in the literature is the rather general theory of competition for cognitive resources, described by Torrance and Galbraith (2006) and modelled by Berninger and Amtmann in their 'Simple View of Handwriting' (2003). What is missing from this model, however, is precision regarding the processes involved in transcription. Whereas Berninger and Amtmann simply list the options available, i.e. typing, handwriting and spelling, the less well-known but much more specific model of handwriting, proposed by Van Galen in 1991 and modified by Smits-Engelsman et al in 2001 (see Chapter 3, p. 60), suggests that at least four steps are required between the conceptualisation of the spelling pattern and producing the letters on the page. Consequently, this model can be used to test competition between processes within the heading of transcription.

Over the last decade, an increasing number of studies have explored the interaction between cognitive and motor factors during writing, Skilled handwriting performance has been shown to be sensitive to contextual factors (Ellis, 1982; Wing, Nimmo-Smith & Eldridge, 1983; Sovik, Arntzen & Thygesen, 1987; Thomassen, Tibosch & Maarse, 1989); to task change (e.g. Luria & Rosenblum, 2010, 2011), variations in task length (Rosenblum, Parush & Weiss, 2001), task familiarity (Smits-Engelsman, Van Galen & Portier, 1994b) and task continuity (Meulenbroek & Van Galen, 1984; Kosterman, Westzaan & van Wieringen 1994). The following were planned with particular reference to motor output, however. Luria & Rosenblum (2010, 2012) measured the effect on the motor components of handwriting by increasing the complexity of number sequences to be written. They found handwriting was slower, more variable spatially and had lower angular velocity when the mental workload increased from low to high, though pen pressure was not affected. In contrast, the study by Kao, Shek and Lee (1983), found that pen pressure decreased with increase in task complexity as measured by moving from tracing to free writing. In this final study, a clever technique used by Alamargot and Fayol (2009) is adopted in which a child is asked first to copy a short passage and then to continue writing the same story. This manipulation allows comparison between copying which might be considered to carry a moderate level of cognitive load with free writing which is many ways more demanding while at the same time keeping the topic constant and creating a writing task as natural as possible.

Looking at the idea of competition between components within transcription more closely, several studies have demonstrated that the fluency of handwriting can be disrupted by changes in orthographic complexity (e.g. Kandel & Valdois, 2006, Kandel & Spinelli, 2010). In those cited, task manipulation was achieved by comparing written performance in languages with different levels of orthographic diversity, and it was found that handwriting slowed where unfamiliar letter clusters within words were encountered. Other studies have tested this finding with children who find English spelling difficult, e, g. those who met the criteria for dyslexia (Sumner, Connelly, & Barnett, 2012) and had similar results, finding that slowness of production was exacerbated by the spelling impairment. Following this line of thinking, it has also been suggested that becoming a fluent, accurate speller in English requires more time and effort than in other orthographies because of the specific complexity within the language. To test the effect of orthographic load in the present study, the motor response to copying letter clusters of different levels of familiarity is measured.

Addressing this issue from a motor perspective, consistent with the Van Galen cascade model, where motor control lies downstream of spelling and allograph selection, motor demand has been manipulated by different researchers in different ways. In some studies, for example, load has been increased by varying the allograph required during execution e.g. asking subjects to change from lower to upper case (Olive & Kellogg, 2002), or by including an element of motor learning, e.g. by introducing a new form to be copied (Chang & Yu, 2010; Velay et al., 2011) or by changing the script used, e.g. from Chinese to English (Kao, Hong, & Wah, 1986) or from Hebrew to English (Rosenblum, Parush & Weiss, 2003). In the present study, motor load is manipulated at letter level by comparing words comprising letters which involve simple strokes from those which use more complex ones (see later).

From these various studies, it would seem that both inefficiencies in the individual's grapho-motor system and the vagaries of English spelling are likely to confer an excess load on the production of written material. Moreover, where such loads are combined - as with a child with DCD writing in English - the effect seems likely to be exponentially greater. In this final study, it is this issue which becomes the major focus.

As shown in the previous three studies, children selected because they have poor handwriting will manifest their difficulties in different ways. In the literature, for example, the slowness in text production noted in our studies has been reported by several others (e.g. Chang & Yu, 2010; Rosenblum, Parush & Weiss, 2003). Poor legibility is also reported in studies which have looked at accuracy and consistency of line (e.g. van der Plaats and Van Galen, 1990; Velay et al, 2011) suggesting that stroke accuracy might also susceptible to disruption if demand were increased. In addition, although there is some inconsistency between studies in the findings, many studies report impaired force control when grasping (a pen) (Eliasson et al., 2006; Forssberg et al., 1992; Pereira, Eliasson & Forssberg, 2001; Wann and Nimmo-Smith, 1991) something which would affect pen pressure and which might be affected by changes in cognitive demand.

When considering how best to measure the components of handwriting that might reveal the effects of increasing task demands to be employed in this study different approaches were considered. In particular, it was deemed necessary to go beyond the global measures that could be obtained by using a stopwatch or simple rating scales and use a more sophisticated method. As noted in Chapter 5, there are many different computerised systems available which provide data on different aspects of handwriting, ranging from those which measure the kinematics of the movements of the hand, through those which quantify the movement of the pen to those which provide data on say, one measure such as the pressure on the pen. One in particular, ComPET, was chosen because it produces a range of measures which seem likely to be sensitive to changes in task demand and enable the measurement of activity both on and off the page (Rosenblum, Parush & Weiss, 2003).

To summarise, the general aim of this study is to test the idea that increasing motor and cognitive load has a greater effect on the motor output of children with DCD and handwriting difficulties than it does on children who are well coordinated without such difficulties. Specifically three questions will be addressed:

1. What can the standardised tests used in earlier studies tell us about boys believed by their teachers to show (a) a discrepancy between their intellectual and motor abilities, and (b) a difficulty with handwriting which affects their written assignments in school?
2. Are children with DCD and poor handwriting affected more by increasing task difficulty/complexity than typically developing children? Specifically, does a change in task demand from copying to free writing affect children with DCD more than typically developing children? In addition, do any effects that do emerge remain or change with increase in task length?
3. Are children with DCD and poor handwiting more affected than controls by increases in motoric complexity, orthographic complexity or both? If so, what aspects of handwriting are affected?

For ease of reading, the data relevant to each of these questions will be presented in three parts, each with its own brief introduction and discussion. This will then be followed by a general discussion.

9.2 Method

9.2.1 Participants

Thirty boys participated in this study. They were selected in a strict sequence involving the identification of the DCD group first, followed by the control group. The criteria for inclusion of children for each group will be described separately.

Target group. The primary criteria for inclusion adopted in this study were that the children had a handwriting difficulty serious enough to require specialist help, were unexpectedly poor in writing overall and were poorly coordinated. In addition, all must attend a mainstream school, be judged to have high verbal intelligence and be competent readers. A total of 20 children were referred as possible candidates. When tested on the appropriate standardised measures of IQ and reading ability, all 20 boys met the set criteria.

Using data from both the literature and earlier studies as a guide, some details for inclusion in the present study were modified or refined (see Chapter 5, p. 67 for detail). To summarise: (i) girls were excluded as Study 3 found the handwriting of the boys seemed more resistant to change and a proper investigation of gender differences would require many more participants than was feasible for the present study. (ii) the age range of 10-11 used in Studies 1 and 2 was relaxed to 9-14 to ensure enough boys who strictly met the inclusion criteria were found. Careful age- and ability- matching counteracted any possible age effect. (iii) Whilst a cut-off of 5% on the Movement ABC was intended, those who fell between the 5th and 15th percentile were also included as long as manual dexterity was below the 5th. When these criteria were applied, two boys did not comply and were excluded. A further three chose to withdraw from the study. Thus, 15 target boys went forward.

Control group. Once the DCD group was identified, schools were asked to provide a control boy of similar age and ability with no known motor coordination or handwriting problems and these were then tested on the same measures. Where possible, controls were chosen from the same schools as children with DCD. However, where a close age and ability match was not found, boys were recruited from similar schools in the same geographical location. In sum, 15 boys with handwriting and movement difficulties and 15 controls completed testing.

9.2.2 Procedures

All the participants were seen individually in a quiet room, either at school or at home. Only the tester was present. Testing was conducted in two sessions. In the first, children were assessed using standardised assessment tests as before, to ensure inclusion criteria were met. The following standardised tests, described in detail in Chapter 5 (p. 69) were administered:

- General intellectual ability: the short form of the WISC-III R UK;
- Word reading and spelling: the WIAT-II;
- Motor competence: the Movement ABC-2;
- Handwriting speed: the DASH.

Where inclusion criteria were met, a second session was conducted in which the experimental tasks were administered. Two specifically designed experimental writing tasks were conducted using an electronic digitiser tablet and software chosen for its suitability for the purposes of this research and these are described in detail directly below.

9.2.3 Narrative tasks

The tasks for the two experiments were administered as a single narrative task with a simple preparatory activity at the start.

9.2.3.1 Task 1: Single word copying

Children were told that they were going to write a story about three friends living in Kazakhstan. However, as some of the names would be unfamiliar, they would be allowed to practise writing them in advance of writing the story. The single name words to be copied were carefully structured in the following way: first, referring to the motor literature, two names were devised containing letters using simple strokes. Reflecting the developmental sequence in which children learn to perform lines (Beery & Buktenica, 1989), letters such as 'i', 'l' 'y' and 'm' in which the predominant strokes are vertical ones were deemed to be motorically "simple" and therefore less demanding for the writer. In contrast, letters which involved one or more direction changes horizontally, such as 'a', 's' and 'z', were chosen as being motorically more "complex" and therefore more demanding (Wann, 1987). In addition, letters which curved anti-clockwise were selected, since early work by Thomassen and Teulings (1985) found that children naturally choose to circle clockwise, suggesting that those letters which demand anti-clockwise movements take longer to become established.

As well as reflecting two levels of motor demand the names also reflected two levels of orthographic demand. In deciding this structure, reference was made to the single letters and bi-grams which occur most frequently in the English language (Gutenberg Project, 2003). Thus, as 'i', 'e' and 'a' are the most frequently occurring vowels and the letters 'll' and 'ss' are the most commonly found doubles, these were used to construct words which were orthographically simple (i.e. *less* demanding). In contrast, letter clusters such as 'lym' and yzn', because they occur infrequently, were used in composing names which were orthographically complex (i.e. *more* demanding). Thus four words were formulated, all containing the same number of letters (6) and a similar number of strokes (13 -14)[3] but with structures as shown in Table 9.1 below.

Table 9.1 Experimental words

	Orthographically "simple"	Orthographically "complex"
Motorically "simple"	Millie	Guilym
Motorically "complex"	Chassa	Kryzna

Thus: 'Millie' was motorically *and* orthographically simple (henceforth labelled M1/O1);
'Guilym' was motorically simple but orthographically complex (M1/O2);
'Chassa' was motorically complex but orthographically simple (M2/O1);
'Kryzna' was motorically *and* orthographically complex (M2/O2).

The child was presented with four separate cards on which were printed each of the target words and these were copied three times in "normal" handwriting. Each trial was separately timed and the times recorded. Only the data on trial one for each word is reported here.

9.2.3.2 Task 2: Copying the story introduction

Once the four words had been copied three times each, children were given the story introduction on a separate card and asked to copy it in their own time, again in their "normal" handwriting. Each individual time was recorded. The introduction read:

> "Millie, Chassa and Guilym were friends. They lived in Kryzna. It was a fun place to live but one day something very odd happened..."[4]

[3] A stroke was defined as continuous movement on the page until a change of direction or a pen-lift was reached.

[4] The four names were carefully chosen for later analysis. The length and complexity of the introduction was piloted for ease of transcription and adequate stimulus for continuation of the story.

9.2.3.3 Continuing the story in own words (FW1)

Children were then asked to continue the story in their own words after a two-minute thinking period. They were given a minimum of ten minutes and maximum of fifteen to complete writing and individual completion times were recorded. They were timed from when they started to write and an electronic marker was (unknowingly) inserted into the text after exactly the same length of time that each child had taken to copy. This was to allow comparative measures between copying and free writing over an equal time period to be analysed.

9.2.3.4 Further continuation of story (FW2)

The children were unaware that the free writing part of the task had been divided into two parts. From their perspective, they wrote continuously for the allotted 10-15 minutes. However, the electronic marker created a new file in the software so allowing separate measures between the initial stage of free writing to be compared directly with the continuation of free writing. Thus, two separate free writing measures were recorded: the short period (FW1) (equal to the copying time) and the longer period (FW2). As well as the computer analysis, data was collected from the hard copies of the scripts. Results from the hard copies (i.e. the non-ComPET data) and from the computerised data (ComPET) are both presented below.

9.2.4 Data preparation

9.2.4.1 Data collection

The experimental tasks were conducted on a WACOM digitiser tablet. A4 lined paper fixed to the surface of the tablet and children wrote on it with a sensitive ink-pen designed to leave a trace on the paper as well as recording the computerised measures. The tablet was linked to a laptop computer on which the ComPET programme had been installed. The data were collected automatically by the software in real time. After testing, the raw data were returned to the software designers for aggregation. Data files created for each child were then returned to the researcher in visual and numerical form for statistical analysis.

9.2.4.2 Data selection

As was described in Chapter 5 (p.74), the ComPET software yields two types of measures – the child's visible trace plus a number of kinematic variables computed from performance on the digitiser tablet via the sensitive ink-pen. These comprise 14 variables, not all of which were appropriate to measurement in the English language. From the possible variables available, care was taken to select only measures which would apply equally to either joined or un-joined style as children educated in the UK vary in the style they use. Thus, variables such as segment duration 'on paper and 'in air'', which would vary depending on style, were omitted. Those reported, which can broadly be divided into temporal, spatial and force measures, are shown below.

Temporal variables (measured in milliseconds)
Total Duration of task (DUT): separated into time 'on paper' (DuP) i.e. when the pen is touching the tablet, and time 'in air' (DuA) i.e. when it is raised off the tablet.

Mean stroke velocity (VM): calculated by dividing the length of the stroke in millimetres by the time in milliseconds it takes to perform it, averaged out across the whole task. A stroke starts when the movement commences on paper and ends with a change of direction.

Spatial variable (measured in millimetres):

Mean stroke length (SLM) relates to the length of strokes (as defined above). The mean was calculated by dividing the total stroke length by the number of strokes produced by each child for each task.

Force variable (measured in unscaled units from 1-1024).

Mean pen pressure (PPM): represents the mean of the pressure of the pen on the writing surface for the whole task.

9.3 Results: Part 1. "Bright" boys with DCD and (hand)writing difficulties.

The aim of this part of the final study was to describe in detail the profiles of the boys selected by their teachers as (a) being bright and verbally able (b) being poorly coordinated, and (c) having poor handwriting which was affecting their performance on written tasks in school. As before, a series of five standardised tests measuring general intellectual ability, word reading and spelling, motor competence and handwriting speed are employed first, to determine the accuracy of the teachers' judgements and second, to provide objective data on the nature of the difficulties this particular group of children were experiencing.

9.3.1 IQ and literacy

Individual subject data from the WISC and WIAT tests along with means and standard deviations for the DCD group and controls are shown below in Table 9.2.

Table 9.2 Individual subject data on WISC and WIAT for DCD group and controls

Child	Target					Control				
	Age	WISC VIQ	WISC PIQ	WIAT Reading	WIAT Spelling	Age	WISC VIQ	WISC PIQ	WIAT Reading	WIAT Spelling
1	9.5	127	94	104	102	9.67	140	132	113	111
2	9.58	117	77	112	98	9.75	135	102	120	122
3	9.83	124	100	122	99	10.00	118	85	122	122
4	10.33	121	-	120	115	10.00	121	-	121	110
5	10.33	129	77	108	93	10.08	131	104	121	117
6	10.5	135	102	122	117	10.25	116	130	129	117
7	10.5	108	126	109	83	10.33	121	-	110	113
8	10.67	132	114	126	123	10.42	143	114	128	129
9	10.75	135	97	114	88	10.50	127	102	131	129
10	11.00	111	83	110	73	10.50	129	100	129	129
11	11.17	132	88	131	107	11.75	129	105	118	111
12	12.17	127	86	119	98	12.33	135	111	119	108
13	12.42	124	94	104	86	12.33	137	137	117	131
14	13.75	127	102	128	116	12.33	132	117	131	136
15	14.50	132	59	126	120	14.17	127	88	120	99
Mean	11.13	126.87	93.14	117.53	103.13	10.98	129.40	109.77	130.07	127.0
SD	1.47	9.75	16.79	8.94	15.04	1.30	7.97	16.01	10.07	18.33

Table 9.3 shows the results of a series of 5 one-way ANOVAs conducted to compare the differences between groups on the key measures.

Table 9.3 Significance levels for test of the Difference between groups on key measures

	Age	VIQ	PIQ	Word Reading SS	Spelling SS
P value	.80	.37	.01*	.06	.00**

** Significant at the 0.001 level (2-tailed); significant at the 0.01 level..

These analyses confirm that the boys in the two groups were well matched for age, verbal IQ and word reading. As in Studies 1 to 3, performance IQ was lower in the DCD group. Unexpectedly, in this study, however, a paired sample t test showed that the disparity between VIQ and PIQ was significant for both the DCD group ($t = 6.785$, $p < .001$) and the controls ($t = 5.389$, $p < .001$). Spelling was again weaker in the DCD group than the controls ($t = 3.602$, $p = .001$).

9.3.2 Motor competence

The individual percentile rankings together with means and standard deviations on the total Movement ABC-2 score and the individual subtests for each group is shown below in Table 9.4.

Table 9.4 Individual subject data on Movement ABC-2 and its subtests for the DCD group and controls

No.	Target				Control			
	MABC %	MD %	A&C %	Bal %	MABC %	MD %	A&C %	Bal %
1	9	2	50	0.5	98	98	91	91
2	2	1	75	2	63	50	91	37
3	5	1	9	1	50	50	37	50
4	5	5	16	25	91	84	91	63
5	9	1	25	5	95	95	75	75
6	5	2	50	0.1	75	63	75	75
7	5	9	5	0.1	98	95	95	95
8	5	5	16	9	84	63	84	91
9	5	2	9	25	91	91	75	91
10	2	1	5	0.1	84	63	84	91
11	9	2	84	5	91	50	79	91
12	1	2	0.5	0.1	75	75	75	63
13	2	5	0.5	9	91	84	75	91
14	9	5	37	9	91	63	95	75
15	1	0.1	19	0.1	91	50	95	91
Mean	4.93	4.33	29.73	10.19	84.53	71.93	84.40	78.00
SD	2.96	1.59	26.29	13.87	13.53	17.84	15.31	17.76

Inspection of the total scores on the Movement ABC-2 presented in Table 9.2 reveals that there was no overlap at all between the DCD group and controls. Whereas the minimum percentile rank for the controls was 63, the best for the DCD group was 9. Eleven of the 15 boys in the DCD group obtained total scores at or below the 5th. The remaining four boys obtained total scores between the 5th and 15th percentile but met the specific criteria employed in this study of scoring below the 5th percentile for manual dexterity.

As in previous studies, the data suggest slightly different profiles for the two groups. A further analysis was conducted to compare scores on the three sub-tests within and between groups. Mean standard scores for both groups are shown below in Figure 9.1.

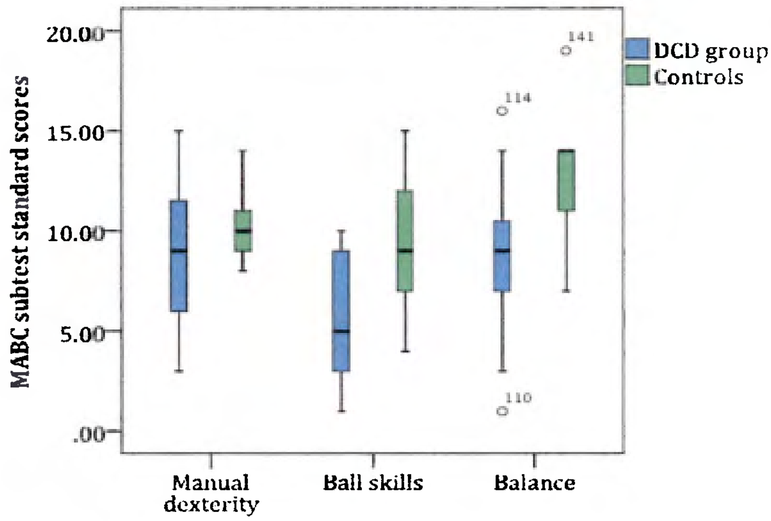

Figure 9.1 Movement ABC-2 standard scores for DCD group and controls by subtest

A repeated measures ANOVA conducted on these data with one between subject factor (*group*) and one within subject factor (*test component*) found there was a significant main effect of group (F (1,28) = 86.538, p = .000) but no significant main effect of test component (F (1,28) = 1.311, ns) and no interaction (F (1, 28) = 2.350, ns). Further investigation of the main effect of group showed that the differences on all three Movement ABC-2 sub-tests were statistically significant: manual dexterity (F (1,28) = 6.210, p = .019), ball skills (F (1,28) = 12.687, p = .001) and balance (F (1,28) = 81.490, p = .000).

In spite of the failure to find a significant interaction between group and component, differences in profile within the DCD group alone were examined. These showed that manual dexterity was significantly poorer than both ball skills (p = .001) and balance (p = .023), the latter two components not differing from each other. For the controls, there were no differences between any of the subtest scores

9.3.3 Handwriting competence

Handwriting speed

Table 9.5 below shows the standard scores and percentile rankings on the DASH together with the means and standard deviations for both groups. Also shown here is the percentage of illegible words produced during the free writing task.

Table 9.5 Standard scores and percentile rankings on the DASH for the DCD group and controls and percentage of illegible words

No.	DCD			CONTROLS		
	DASH SS	DASH %	Illegible %	DASH SS	DASH %	Illegible %
1	90	28	4	135	99.1	0
2	94	36	6	127	97.1	0
3	100	52	0	114	83.5	0
4	70	2.7	3	114	83.5	0
5	108	71.8	5	104	61.7	0
6	92	30	3	114	83.5	5
7	86	18	20	100	52.4	0
8	89	24	20	108	71.8	0
9	80	10	25	119	91.2	0
10	54	2.7	3	111	79.1	0
11	84	15	4	95	39.6	0
12	76	6	9	99	48.5	2
13	72	3.8	4	105	64.3	0
14	80	10	25	122	93.2	1
15	79	8.8	48	108	71.8	0
Mean	83.60	21.05	12.57	111.67	74.35	0.50
SD	13.15	19.87	13.44	10.89	18.35	1.40

As Table 9.5 shows, eight boys in the DCD group fell below the suggested cut off point for low handwriting speed but seven did not. In contrast, all controls were well within the normal range or above, eight scoring in the highest quartile. When the total standard scores were compared, therefore, the group difference was highly significant (Mean target = 83.60; controls =111.67; t = -9.741, p = .000).

The DASH includes 5 subtests each purporting to tap into a different aspect of graphic ability. Since children with handwriting difficulties are known to show different profiles of performance across these tasks, it seemed important to determine how the boys in this study coped with the differing demands.
These data are shown in Table 9.6.

Table 9.6 Individual standard scores for DASH subtests for the DCD group and controls

Child	DCD						CONTROL					
	CB	CF	CB/CF	AW	FW	GS	CB	CF	CB/CF	AW	FW	GS
1	8	7	-1	10	8	7	17	17	-	15	15	15
2	10	8	-2	8	10	12	17	15	-2	14	13	15
3	12	11	-1	10	7	8	12	14	+2	11	13	12
4	3	5	+2	7	5	9	13	11	-2	14	12	12
5	13	8	-5	10	14	4	14	18	+4	10	10	17
6	8	8	0	9	9	13	15	12	-3	13	10	13
7	8	5	-3	11	6	14	14	21	+7	10	9	17
8	9	7	-2	9	7	6	10	12	+2	14	9	16
9	7	7	0	6	7	10	15	13	-2	13	12	13
10	3	6	+3	3	3	7	9	13	+4	13	13	15
11	8	6	-2	8	7	10	10	9	-1	8	10	12
12	8	4	-4	6	6	6	11	10	-1	10	9	8
13	8	4	-4	5	4	9	11	11	-	10	11	10
14	9	4	-5	9	5	9	16	11	-5	16	12	13
15	5	3	-2	12	6	10	12	11	-1	12	10	17
Mean	7.93	6.20	1.80	8.20	6.93	8.93	12.67	12.00	0.67	12.53	11.13	13.33
SD	2.76	2.11	2.36	2.42	2.66	2.73	2.69	2.27	2.36	2.26	1.92	2.53

Table 9.6 shows the individual standard scores for DASH subtests for the DCD group and controls. A two-way ANOVA with one between-subjects factor (*group*) and one within-subjects factor (*subtest*: 5 levels) was conducted on these data produced a main effect of group ($F(1,28) = 32.540$, $p = .000$) and of subtest ($F(4, 26) = 4.155$, $p = .004$). Post hoc analysis of the man effect of group then showed that the difference was significant for all five subtests with the DCD group scoring consistently lower than controls.

Table 9.7 Comparison of standard scores on the DASH subtests for DCD group and controls

	DCD Mean (SD)	Controls Mean (SD)	*F* value	*P* value
DASH ss	84.57 (13.07)	113.15 (10.95)	-4.953	.000**
Copy Best	8.13 (2.47)	12.92 (2.78)	-4.308	.000**
Copy Fast	6.67 (2.55)	12.23 (2.17)	-5.578	.000**
Alphabet writing	8.47 (2.50)	12.54 (2.26)	-3.967	.000**
Free writing	6.80 (2.81)	11.38 (1.94)	-3.352	.000**
Graphic speed	8.87 (2.75)	13.15 (2.48)	-3.458	.000**

** Significant at the 0.01 level (2-tailed)

Pairwise comparisons between subtests then showed that the differences between Alphabet Writing and Copy Fast ($p = .007$), between Copy Best and Copy Fast ($p = .023$), between Alphabet Writing and Free Writing ($p = .022$) and between Copy Fast and Graphic Speed ($p = .011$) were all significant. However, there was no significant difference between Copy Fast and Free Writing or between Copy Best, Alphabet Writing and Graphic Speed.

In addition to the group findings on the DASH the individual subject data for the DCD group revealed considerable variation in profile. Although seven boys scored above the 15th percentile cut-off, a closer look at their scores on the component tasks made it possible to see why their teachers referred them to the study. For example, S 3 who scored on 52nd percentile overall, scored just 7 on Free Writing; similarly, S5 who scored on the 71st percentile overall, scored 5 points lower on copying when asked to copy fast. This suggests that these boys, although appearing to have no problem with handwriting speed, do in fact write slower than the norm under certain conditions. Again, the Copy Best/Copy Fast difference shows that the only two boys whose scores increased in the direction expected in the test were those who scored lowest on both copying measures (standard scores: 3,5 and 3,6, respectively), demonstrating already atypical writing performance. When the scripts were rated for legibility all but one of these six boys had a high degree of illegibility (see later).

Load differences affecting handwriting speed

The individual tasks within the DASH were designed to carry different cognitive or perceptual loads. Three in particular have been singled out for comparison: Graphic Speed (a letter-like form repeated), Alphabet Writing (single letters) and Free Writing (orthographic-motor integration with composition). Standard scores for the speeds on each of these three tasks for both groups are represented below in Figure 9.2. A repeated measures ANOVA was conducted with one between-subject factor (*group*) and one within-subject factor (*task*) comparing the standard scores recorded for these three tasks.

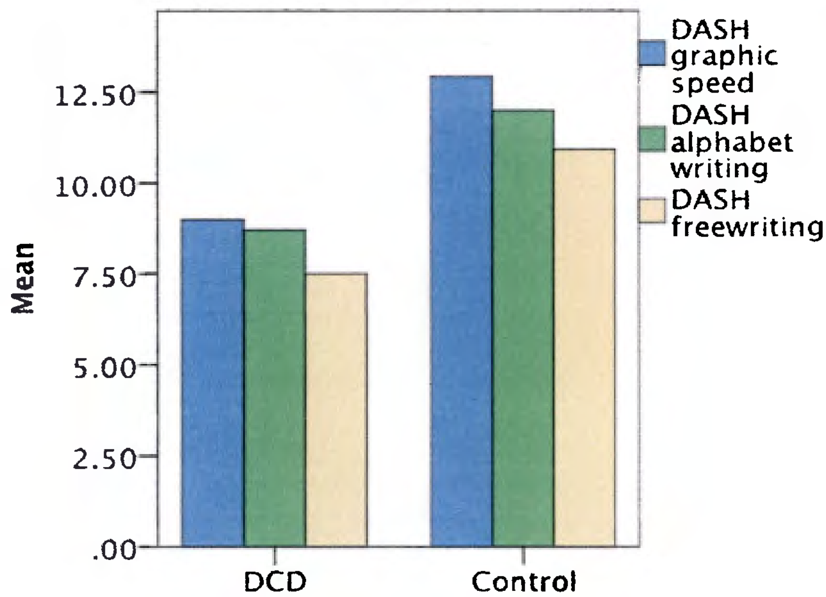

Figure 9.2 Standard scores on Graphic Speed, Alphabet Writing and Free Writing for the DCD group and controls

There was a significant main effect of group (F (1,26) = 42.687, p = .000) and of task (F (3, 26) = 8.294, p = .008) but there was no group x task interaction (F (1,26) = .050, ns): handwriting speeds were lower for the DCD group than controls across all three tasks and for both groups, standard scores for handwriting speed decreased as the task became more demanding. Further analysis of main effect of task showed that the difference between Graphic Speed and Alphabet Writing was not significant. Free Writing speed differed significantly from both Graphic Speed (p = .008) and Alphabet Writing (p = .012) being significantly slower. This finding was unexpected.

Handwriting legibility

The only measure of legibility obtained from the DASH is the percentage of illegible words in the free writing task. The individual subject data on percentage illegibility is shown above in Tables 9.5 and the means and standard deviations are shown below in Table 9.8 together with outcome of *t* test between the two groups.

Table 9.8 Means and standard deviations for percentage of illegible words for both groups.

	DCD	Controls	*T* value	*P* value
Percentage illegible words				
Mean (SD)	12.57 (13.44)	0.50 (1.40)	3.342	.003**

** Significant to a .001 level

As Table 9.5 shows, 12 controls scored 100% legibility with a mean score that was actually less than zero. If we were to use the mean score for the control group as a rough measure of legibility only one boy in the DCD group would fulfil that criterion. For the remaining 14 boys in the DCD group, illegibility ranged from 3% - 48%.

Figures 9.3a and 9.3.b shows samples of handwriting of free writing from the DCD group, illustrating the type and levels of illegibility which was typical of those who were rated low. The first boy scored on the 18th percentile for speed with 20% illegibility; the second scored on the 8th percentile for speed with 48% illegibility. A one-way ANOVA comparing the groups on this measure found a significant difference on percentage of illegible words in the DASH free writing task (F = 11.18; p = .003): the DCD group overall wrote less legibly than controls.

Figure 9.3 Samples of handwriting of free writing from the DCD group

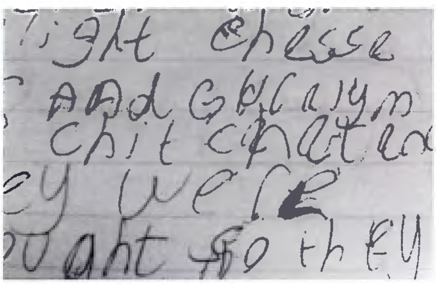

Figure 9.3a Sample of a boy with DCD who scored 18% on the DASH with 20% illegibility

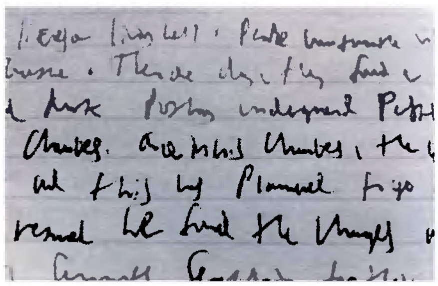

Figure 9.3b. Sample of a boy with DCD who scored 8% on the DASH with 48% illegibility

Correlations between Movement ABC-2 scores and DASH scores

Results of a Pearson's Product Moment run on standard scores on the Movement ABC-2 and DASH are shown below in Table 9.9

Table 9.9 Correlations between total standard scores for Movement ABC-2, DASH, WIAT II spelling and percentage of illegible words

	MABC ss	Manual Dexterity ss	Ball Skills ss	Balance ss	DASH ss	WIAT Spelling ss	Illegibility %
MABC ss		.94**	.55**	.92**	.75**	.54**	.52*
Manual Dexterity ss			.36	.84**	.68**	.53**	.47*
Ball Skills ss				.38	.32	.41*	.63**
Balance ss					.70**	.41*	.41*
DASH ss						.60**	-.47*
WIAT Spell ss							-.54**

The above table shows a strong correlation between the Movement ABC-2 total and DASH total standard scores (0.75) with more moderate but statistically significant correlations between the Movement ABC-2 subtests and the DASH. A strong correlation was also found between standard scores for WIAT Spelling and both the DASH standard scores (0.60) and the percentage of illegible words (-0.54).

9.3.4 Discussion

Taken from mainstream schools, the 15 boys nominated for this study were considered to be of high verbal intelligence and with no reading problems, their only known difficulties being in motor coordination and the production of handwritten work. On testing, all fifteen were found to be of at least average general ability and to read well. However, spelling scores were lower than controls, as in the former studies, and it will be necessary to look more closely at the implications of this finding later.

As far as the children's motor competence was concerned, the Movement ABC-2 confirmed teachers' views that the two groups of children were well separated. Whereas all of the control children obtained scores above the 84th percentile on the formal assessment, all of the children with DCD obtained scores below the 5th. Although the children with DCD were not assessed by a paediatric neurologist (to rule out possible neurological or medical conditions) their Movement ABC-2 scores taken together with the acknowledgement from teachers that poor handwriting skills were affecting academic performance, suggest that all the children in DCD group meet the criteria for Developmental Coordination Disorder (DCD) as specified for this study.

A handwriting difficulty was the focus for selection of participants, as well as other dimensions which will be examined later. Therefore, it was not surprising that there was a significant difference between the groups on handwriting speed and this was true on all five subtests of DASH. There was also a marked difference on one measure of legibility – the percentage of illegible words in the free writing task. It was, however, the case that not all target boys met criteria for a handwriting speed impairment, as measured by their *total* score on DASH. If one were to take the 15th percentile, for example, seven scored above this level and would not therefore be included in the study had that been a specified requirement for inclusion. But teachers were not asked just to judge speed and for some, there were other reasons for selecting children. For example, close examination of the boys' profiles across the various tasks and measures suggested an explanation for each one. For several, speed and legibility, especially under the pressure of being asked to write fast (Copy Fast and Free Writing), was an issue where they tended to score worse than when speed was not mentioned. Also, all but one of the DCD group wrote illegibly for a significant amount of the time whereas this was true of only one of the controls. Issues with levels of accuracy which impact upon the legibility of the scripts is another factor which has been shown to affect teacher rating of composition quality (Graham et al., 2011) and cannot be ignored as possibly contributing to a generally poor handwriting profile.

During informal discussion with the teachers involved in the study concern regarding the inability to 'get work down' often emerged as both a *perceived* problem and, as was shown as a result of the DASH, an *actual* one in terms of slow production speed. DASH scores for the DCD group were significantly lower than controls across all five subtests.

Low productivity, measured by counting the number of words written, was again found in the DCD group. However, on closer scrutiny, an interesting picture emerged. Despite output being much reduced for the majority of the DCD group, they did in fact take *as long* as the controls to produce their scripts in most cases. Unlike several children in Study 3, they did not necessarily "give up" before the end of the task but continued to the end, or near the end, as instructed. However, this pattern highlights an equation which does not add up: if the boys were taking the same amount of time as controls to produce significantly less text, how can what was happening during that time be accounted for? The data provided in Parts 2 and 3 of this chapter can provide some, if not all, answers to this question, as at least some potential factors were measurable.

9.4 Results: Part 2. The effect of different task demands on handwriting performance

In the section above, the handwriting problems the selected children experience in school were quantified using the DASH. Difficulties with both legibility and speed were evident, with the latter appearing to vary systematically with task demand. However, the tasks within the DASH are not directly comparable with each other as they have different content, are of different lengths, and involve slightly different instructions from the tester. In addition, the measures taken were limited to those which can be measured with a stop watch. In this part of the study, therefore, the aim was to test the effect of "demand" or "cognitive load" on performance directly, by manipulating task difficulty in a more controlled way and by measuring electronically a number of aspects of performance, which are not visible to the naked eye.

9.4.1 Copying versus free writing for the same amount of time

The data gathered on these tasks were analysed first non-electronically and then, where appropriate, using the ComPET system.

9.4.1.1 Non-ComPET data

Starting with the non-ComPET data, the total time taken, total number of words and word-per-minute speeds for copying and the short free writing task for both groups were calculated from the hard copies of the written scripts and are set out below in Table 9.10.

Table 9.10 Means and standard deviation for total time taken (in seconds), number of words and wpm speeds on copying and free writing for DCD group and controls

	DCD Copying	CONTROLS Copying	*F* value (*p* value)	DCD FW1	CONTROLS FW1	*F* value (*p* value)
Total time (in seconds)	91.80 (20.40)	72.60 (13.20)	7.93 (009**)	91.80 (20.40)	72.60 (13.20)	7.93 (.009**)
Number of words	24	24	n/a	18.67 (4.08)	22.62 (3.84)	6.88 (.014*)
Wpm speed	18.00 (4.30)	23.74 (5.19)	10.15 (.004**)	13.40 (5.40)	19.16 (4.24)	9.61 (.005**)

** Significant at .001 level; * significant at .05 level.

Time taken

As Table 9.10 shows, the DCD group took significantly longer to complete the copying task than their controls (F (1,28) = 7.926, p = .009). Since the time each child took to copy the passage became the set time for comparison, the duration of free writing on this part of the task is the same and therefore no comparison is needed.

Number of words

By definition, the number of words to be copied was identical for the two groups. However, when each child was allowed to continue writing for the same amount of time as it took him to copy the 24 words, the DCD group were found to produce significantly fewer words - on average three words less- than the controls (F (1,28) = 6.879, p = .014).

Word-per-minute speeds

Table 9.10 also shows the word-per-minute speeds on the copying and short free writing (FW1). A two-way ANOVA was conducted on these scores with one between-subjects factor (*group*) and one within-subjects factor (*task*). There was a significant main effect of group (F (1,28) =14.478, p = .001) and of task (F (1,28) = 19.369, p = .000): the controls wrote faster overall than the DCD group and all the children wrote faster when copying than when free writing. Although the decrease in the word-per-minute score was greater for the DCD group than the controls, there was no significant group x task interaction.

To summarise so far, handwriting performance for all children was different between copying and free writing. This confirms that this manipulation had an impact. More specifically, when free writing, all children, regardless of which group they were in, produced fewer words than when copying and wrote more slowly. In addition, the children in the DCD group wrote consistently slower than controls during both tasks.

9.4.1.2 Analysis from ComPET software

As noted above, two types of data are available from the digitising system used in this study - a visual trace of the pathway of the pen both on and off the page and numerical readings from the software. Visual evidence is shown first followed by analysis of the numerical data.

Visual evidence

Figures 9.4a and 9.4b show samples of script by a boy from the control group, first as it appears on paper and second, as the computer-recalled image, showing lines (i.e. movements) both on the page and off it.

Figure 9.4 Samples of script by a boy from the control group

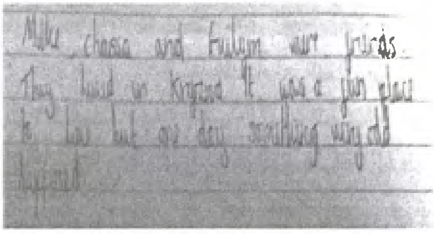

Figure 9.4a. Sample of the copied sentence as seen on ComPET

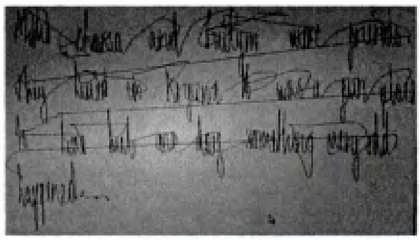

Figure 9.4b. Sample of the copied sentence control group boy

The computer image (Fig. 9.4b) shows both the main traces where the pen has touched the page (recognisable when compared with the 'on paper' script) and the lines between words, indicating short, direct movements of the pen in the air during pen-lifts. Air movements from the end of one line to the start of the next are visible as direct, diagonal lines. A small number of additional lines are apparent where some further movement has occurred 'in air', possibly as a result of returning to dot an 'i' or cross a 't'. However, in general, the lines represent an array of efficient, directed writing movements.

Figure 9.5 Samples of handwriting

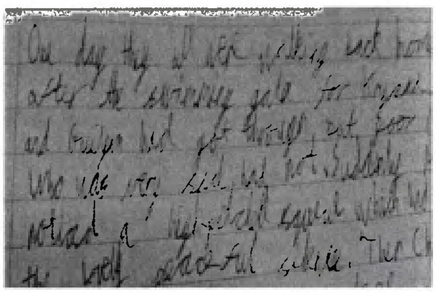

Figure 9.5a. Sample of hand-written free writing on paper of a boy from the DCD group

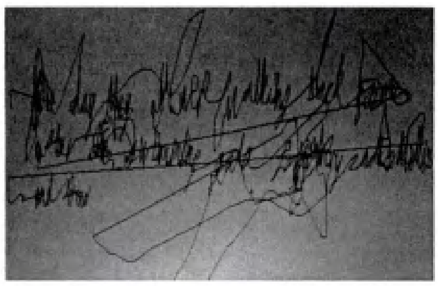

Figure 9.5b. Sample of the same piece of free writing as seen on ComPET

When examining the two versions of this boy's script, it is difficult from the computer image to distinguish lines which have been performed 'on paper' and which are 'in air'. However, several lines (representing *movements*), superfluous to the writing of the actual text, are clearly visible, particularly around the unusual name "Kryzna" on line 2. The computer image shows this excess movement, much of which appears unproductive in terms of the writing task, both on the page and in the air. One can see that movements between words and between lines are less direct than those in the first boy's sample and there appears to be much "overwriting", something not obvious to the naked eye. Overall, the sample from the second boy demonstrates a greater amount of motor activity, less control of the pen and less purposeful movement than the sample from the first.

Statistical analysis

Copying versus short free writing (FW1) - temporal

The copying and free writing tasks were timed first using a stopwatch. The computerized analysis now provides information on how much of that time was spent 'on paper' and 'in air'. The means and SD are shown in Table 9.10, along with the mean stroke velocity. Figure 9.21 then illustrates the proportion of time in seconds spent 'on paper' and 'in air' visually for the DCD group and controls for copying and FW1.[5]

(i) Proportion of time 'on paper' and duration 'in air'.

Table 9.11 Means and standard deviations of temporal measures for copying and FW1 for the DCD group and controls

Temporal	DCD		CONTROLS	
	Copying Mean (SD)	FW1 Mean (SD)	Copying Mean (SD)	FW1 Mean (SD)
DuT	94.53 (31.12)	90.11 (21.45)	77.89 (22.92)	71.88 (14.45)
DuP	60.91 (17.68)	48.27 (16.24)	49.35 (18.36)	41.81 (7.13)
DuA	33.62 (12.37)	41.84 (15.65)	28.54 (12.30)	30.07 (7.33)
VM	5.50 (1.33)	5.10 (1.50)	5.49 (0.73)	5.21 (0.62)

Figure 9.6 shows the duration of time in seconds 'on paper' and 'in air' on copying and FW1 for DCD and controls.

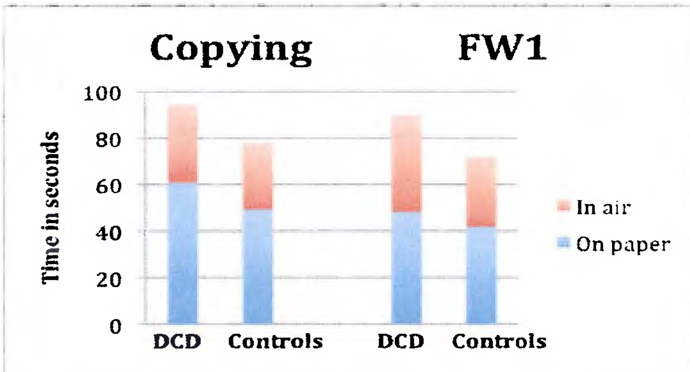

Figure 9.6. Duration of time in seconds 'on paper' and 'in air' on copying and FW1 for DCD group and controls

A repeated measures ANOVA was conducted with one between-subjects factor (*group*) and two within-subjects factor, *task* and *pen location* (i.e. on or off the paper). Results show there was a significant main effect of group (F (1,28) = 7.635. p = .01) and of pen location (F (1,28) = 30.781, p = .000) but not of task (F (1,28) = 1.75, ns). Thus, the DCD group took longer than the controls overall and more time was spent 'on paper' than 'in air'. There was a significant two-way pen location x task interaction (F (1,28) = 32.02, p = .000) and also a three-way group x task x pen location interaction (F (1,28) = 4.975, p = .033).

In order to investigate the three-way interaction in more detail, separate analyses were first conducted on each task component separately. For copying there was no significant difference between groups for duration 'on

[5] Although the copying and short free writing tasks were intended to be of equal duration, the tasks were measured using a stopwatch. The electronic software has recorded slight human error in the timing (see Fig. 9.21). However, the difference was found to be insignificant.

paper' (F = 3.289, ns) or for duration 'in air' (F = 1.356, ns): both groups performed similarly on copying. In other words, both groups performed similarly on copying. For the short free writing there was no significant difference between groups for duration 'on paper' (F = 2.120,ns) but the group difference 'in air' was significant (F = 7.428, p = .011): the DCD group spent longer than controls in the air. To show this finding in a different way, the 'on paper' and 'in air' times were calculated as a percentage of the total task duration and are shown below in Table 9.12.

Table 9.12 Percentage of total duration of time 'on paper' and 'in air'

	DCD		CONTROLS	
	Copying %	FW1 %	Copying %	FW1 %
DuP	64.43	53.57	63.36	58.17
DuA	35.57	46.43	36.64	41.83

This shows that when copying, the proportion of time spent on the page and in the air is similar for the two groups. However, when free writing, although both groups spend less time on the page and more in the air, this change is greater for the DCD group.

(ii) Mean stroke velocity (VM)

Figure 9.7 shows the mean stroke velocity for the two groups across the two tasks.

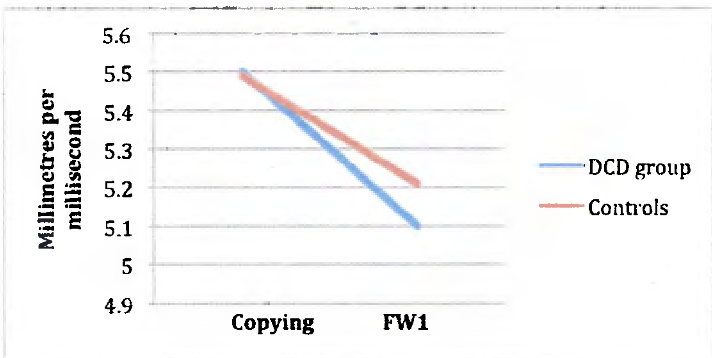

Figure 9.7 Mean stroke velocity on copying and free writing tasks for DCD group and controls

Results showed no effect of group (F (1,28) = .002, ns) but a significant main effect of task (F (1,28) = 7.538, p = .001) with stroke velocity decreasing between copying and FW1. Although the DCD group produced slower strokes than the controls when free writing, the group x task interaction was not significant.

Spatial measure: Mean stroke length (SLM)

Data for mean stroke length across the two task conditions for both groups are presented in Tables 9.13 and Figure 9.8.

Table 9.13 Means and standard deviations for mean stroke length for copying and FW1 for the DCD group and controls.

	DCD		CONTROLS	
	Copying Mean (SD)	FW1 Mean (SD)	Copying Mean (SD)	FW1 Mean (SD)
Spatial Mean stroke length (SLM)	184.50 (133.09)	164.80 (140.00)	148.99 (77.74)	149.65 (85.67)

Figure 9.8 shows the mean stroke length across copying and FW1 for the DCD group and controls.

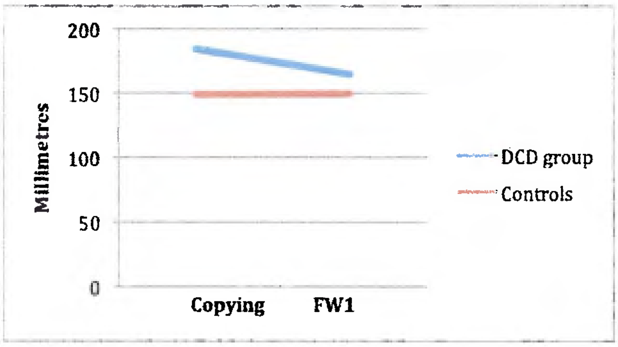

Figure 9.8 Mean stroke length across copying and FW1 for the DCD group and controls

A repeated measures ANOVA conducted on these data revealed a significant main effect of group (F (1, 24) = 4.721, p = .038) and of task (F (1, 28) = 24.363, p = .000): plus a significant group x task interaction (F (1,24) = 6.145, p = .019): the stroke length decreased for the DCD group with the change of task but hardly at all for controls. Looking at this more closely, an independent t test showed that the difference between groups in stroke length was significant when copying (t = 2.587, p = .015) but not when free writing (t = .207, ns).

Mean pen pressure (PPM)

Table 9.14 shows the means and standard deviations for pressure for copying and FW1 for the DCD group and controls.

Table 9.14 Means and standard deviations for pressure for copying and FW1 for the DCD group and controls.

		DCD		CONTROLS	
		Copying Mean (SD)	FW1 Mean (SD)	Copying Mean (SD)	FW1 Mean (SD)
Pressure	PPM	802.49 (175.31)	792.71 (174.99)	651.26 (189.52)	621.36 (187.98)

Figure 9.9 shows the mean pen pressure for the two groups across the two tasks.

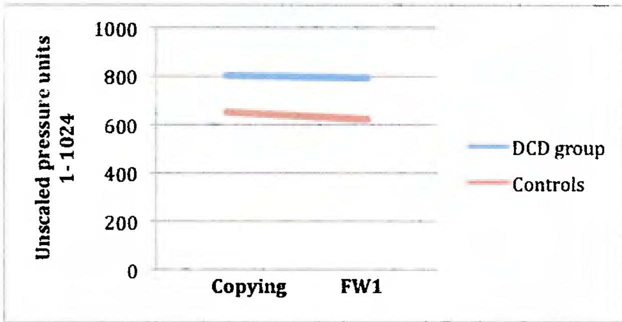

Figure 9.9 Mean pen pressure on two tasks for DCD group and controls

There was a significant main effect of group ($F(1,28) = 6.394$, $p = .017$) and of task ($F(1, 28) = 4.488$, $p = .016$) but there was no significant group x task interaction: the boys in the DCD group consistently used more pressure than the controls but pressure decreased as the task complexity and length increased. Again, the lack of an interaction shows that both groups were equally affected by task changes.

Summary of main effects for copying and free writing tasks

Table 9.15 shows a summary of the main effects for group and task on all measures for the narrative copying and free writing task.

Table 9.15 Summary of the main effects for copying and free writing for group and task

Variable	Group	Task	Interactions
DuT	.01*	ns	Task x pen = .000; Group x task x pen = .033
DuP	ns	ns	
DuA	ns	ns	
VM	ns	.001**	None
SLM	.038*	.000**	Group x task = .019
PPM	.017*	.016*	None

** Significant to .001 level; * significant to .01 level.

Significant main effects of group were found in total task duration, stroke length and pen pressure, the DCD group exceeding the controls in all three measures. In contrast, there were significant main effects of task in stroke velocity, in stroke length and in pen pressure but not in task duration. This suggests that changes in task demand from copying to free writing have an impact on certain aspects of handwriting behaviour in both groups.

9.4.2 Short free writing (FW1) versus continuation of free writing (FW2)

9.4.2.1 Non-ComPET data

After copying the 24-word passage, each child was allowed to continue the story for up to 15 minutes. Within this time frame, it was possible to distinguish two time elements – (i) the point in time which was equivalent to the child's copying time and (ii) the amount of time they carried on for after that point. This distinction not only provided the direct comparison between copying and free writing reported above, it also allowed further evaluation of how the child performed over a longer time period.

Total time taken

In order to make a reasonable comparison between free writing tasks, the total task duration scores are here reported in minutes as opposed to seconds (as above).

Table 9.16 below shows the total time in minutes for both tasks for both groups.

Table 9.16 Total time in minutes on free writing tasks for DCD group and controls

	DCD Mean (SD)	CONTROLS Mean (SD)	*F* value	*P* value
FW1	1.53 (.34)	1.21 (.22)	9.257	.005**
FW2	7.25 (1.65)	8.06 (0.76)	-0.804	ns
Total	8.81 (2.96)	9.27 (1.30)		

One-way ANOVA was used to compare groups in total time taken for the writing tasks. There a significant difference between groups for the short free writing task ($F = 9.257$, $p = .005$) but not for the long free writing task ($F = -.804$, ns).

Number of words

The number of words written on the short free writing task (FW1) and long free writing task (FW2) are shown below in Table 9.17.

Table 9.17 Number of words on free writing tasks for DCD group and controls

	DCD Mean (SD)	CONTROLS Mean (SD)	*F* value	*P* value
FW1	19.33 (5.02)	22.62 (3.84)	6.967	.013*
FW2	103.73 (42.99)	127.54 (41.59)	4.681	.039*
Total	123.06	150.16		

Results showed that the DCD group wrote significantly fewer words than controls on both the short free writing task (FW1) ($F = 6.967$, $p = .013$) and the long free writing task (FW2) ($F = 4.681$, $p = .039$).

Word-per-minute speeds

Table 9.18 below shows the word-per-minute speeds on the short free writing (FW1) and long writing task (FW2) for both groups. A two-way ANOVA was conducted on speed scores with one between-subjects factor (*group*) and one within-subjects factor (*task*).

Table 9.18 Word-per-minute scores on free writing tasks for DCD group and controls

	DCD Mean (SD)	CONTROLS Mean (SD)	*F* value	*P* value
FW1	13.23 (1.34)	19.18 (3.93)	9.286	.005**
FW2	14.46 (4.81)	15.90 (3.17)	1.027	ns
Total	13.88 (3.08)	17.54 (3.55)		

** Significant to .001 level.

The word-per-minute scores for both free writing tasks for both groups are illustrated below in Figure 9.10.

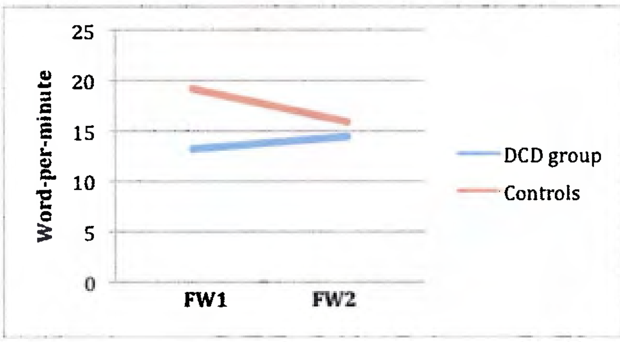

Figure 9.10 Word-per-minute speed scores for short and long free writing tasks for the DCD group and controls

There was a significant main effect of group (F (1,28) = 5.062, *p* = .033) but not of task (*F* (1,28) = 3.618, ns) There was also a significant group x task interaction (*F* (1,28) = 12.432, *p* = .002): Post hoc analysis of the interactions showed that the speed difference between groups was significant in FW1 (*F* = 9.286, *p* = .005) but not in FW2 (*F* = 1.027, ns). Within the two groups the difference between FW1 and FW2 was not significant for the DCD group (*t* = -1.043, ns) but it was for the controls (*t* = 4.625, *p* = .001). Thus, whereas speed remained constant for the DCD group with the longer task (FW2), there was a *decrease* in speed for the controls.

Sustainability

The number of boys able to sustain writing for the required length of time was next examined for both groups and the times at which they stopped writing are shown in Figure 9.11 below.

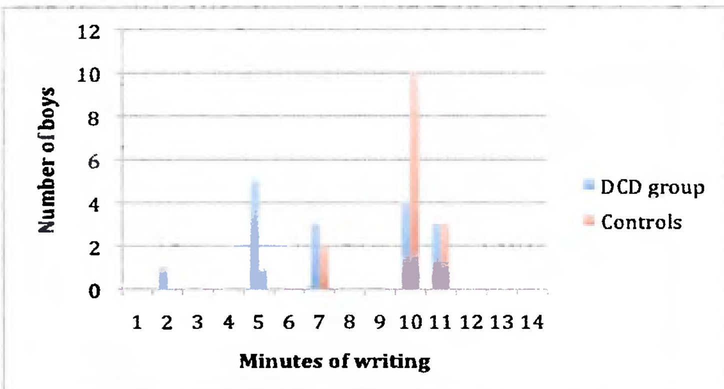

Figure 9.11 The number of boys stopping writing at each minute

This shows nine of the DCD boys as opposed to three of the controls gave up writing before the required ten-minute minimum and only three from each group wrote for longer, none writing for the maximum fifteen minutes.

Spelling

The number of spelling errors in the total free writing task was calculated as a percentage of the total number of words written (omitting the four name words). Results are shown below in Table 9.19.

Table 9.19 Percentage of spelling errors in the total free writing task for DCD group and controls

	DCD	CONTROLS	*F* value	*P* value
Percentage of spelling errors				
Mean (SD)	3.15 (4.23)	1.33 (1.63)	2.285	ns

Overall, differences between groups were not significant but there was great variation within the groups, particularly where only one child in the DCD group wrote with 100% correct spelling in contrast to twelve of the controls.

9.4.2.2 ComPET data

Table 9.20 shows means and standard deviations for temporal, spatial and force measures for short and long free writing tasks for both groups. Because of the structure of the experiment, comparisons of tasks duration and its separation into time on the paper and in air were not applicable.

Table 9.20 Means and standard deviations for temporal, spatial and force measures for FW1 and FW2 for the DCD group and controls

		DCD		CONTROLS	
		FW1	FW 2	FW 1	FW 2
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Temporal	VM	5.10 (1.50)	5.76 (1.34)	5.21 (0.62)	5.60 (0.87)
Spatial	SLM	164.80 (140.00)	165.88 (152.24)	149.65 (85.67)	145.47 (109.89)
Pressure	PPM	792.71 (174.99)	787.26 (176.65)	621.36 (187.98)	610.54 (191.46)

Repeated measures ANOVAs with one between-subjects factor (*group*) and one within-subjects factor (*task*) were conducted on the three sets of measures and these are reported below. For mean stroke velocity, there was no effect of group (F (1,28) = .002, ns) but the main effect of task was significant (F (1,28) = 7.538, p = .001): stroke velocity increased between FW1 and FW2. There was no significant group x task interaction showing that both groups were equally affected. On the spatial measure – mean stroke length (SLM) - the difference between groups was significant (F (1,28) = 4.721, p = .038) but there were no differences between the tasks and no interactions. The DCD group wrote with longer strokes than the controls and this did not change from the short to the long task. As far as pressure was concerned, there was a significant main effect of group (F (1,28) = 6.394, p = .017) but not of task and there was no group x task interaction. The DCD group wrote with more pen pressure than the controls and this did not change from the short to the long task.

9.4.2.3 Summary

The task duration for the short free writing tasks was set by the copying times. There was no difference between groups in the length of time they spent on the free writing tasks overall. However, the DCD group produced fewer words than controls on both free writing tasks. Whilst the DCD group wrote slower than controls on the short free writing task, this difference had disappeared in the long free writing task. However, more boys in the DCD group than controls gave up writing prematurely. There was no difference between groups in the percentage of their free writing which was mis-spelt. When data were analysed using ComPET, mean stroke velocity increased for both groups as the length of the free writing task increased. The DCD group wrote with longer strokes and greater pen pressure than the controls and this did not change with the increase in task length.

9.4.3 Discussion

The aim of this part of the study was to employ increase in task difficulty as a means of testing competition between transcription and other aspects of writing which might be contributing to reduced composition quality reported by teachers in children with DCD. Essentially this is a test of the 'Simple View of Writing' model proposed by Berninger & Amtmann (2003) (see Chapter 3, p. 39).

First, handwriting performance was compared between groups on two different tasks of the same length, copying and composing. It was hypothesised that changes in task demand, i.e. when the generation of ideas was required, would elicit changes in handwriting behaviour, particularly for the DCD group. Specific measures, identified with reference to the literature as susceptible to change in task, included task duration (Olive & Kellogg, 2002; Olive et al, 2009), proportion of time spent 'on paper' and 'in air' (Luria & Rosenblum, 2010, 2011; Rosenblum et al, 2003), stroke velocity (Smits-Engelsman et al., 1996; Schoemaker et al., 1994b), stroke length (Smits-Engelsmann & Van Galen, 1997) and pen pressure (Kao, Shek, & Lee, 1983; Wann, 1986).

As a baseline measure, group comparisons were made on the copying task and this revealed that, as expected, the DCD group took significantly longer than controls, thus producing a slower word-per-minute score. When the task changed to free writing, although both groups wrote slower when composing than when copying, the DCD group's speed decreased significantly more than the controls, though only at the start of free writing, and they produced fewer words. The slowing of production with increase in task demand is consistent with the capacity theory being tested, i.e. that free writing is cognitively more demanding. The fact that the DCD group wrote even slower than their typically developing peers when they were asked to start composing supports Dockrell's (2009) finding that the impact of increase of task complexity is felt more acutely by children who are already struggling to write (see Chapter 3, p. 50).

Looking next at the computer analysis on these two tasks, the visual readings suggested that the DCD group were producing a greater amount of 'in air' activity than the controls, much of it seeming to lack focus. Analysis of the numerical data confirmed this to be the case and showed that although both groups spent longer 'in air' when composing than when copying, this was even greater for the DCD group. Time spent off the page would appear from the literature to be a natural corollary of composing, during which ideas are generated (e.g. Alamargot et al., 2007) (see Chapter 3, p.65), but the excess time spent in the air by the DCD group over the controls, together with the visual record of the degree and complexity of the 'in air' activity, suggests that there are additional factors in play for children with motor control difficulties. One possible explanation for this delay might relate to the planning and organizing of movement required prior to the execution of a motor act (Hill, 2005) - something which takes time in this group.

Analysis on pure stroke velocity showed that although the DCD group took longer to complete both tasks, the physical production of strokes was not significantly slower for them than for the controls on either task. The stroke measure was achieved by averaging all the strokes performed during the tasks and calculated by dividing the total amount of time taken in milliseconds by the number of strokes made (not shown here). The fact that the speed of performing the individual strokes did not differ between groups suggests that activity other than motoric stroke-writing speed (Meulenbroek & Van Galen, 1989) accounts for the greater length of time taken on task (see main discussion). In contrast, stroke *length* was found to be greater in the DCD group across both tasks suggesting, as one would expect, less fine control of the pen for these children (Schoemaker et al., 1994; Smits-Engelsman et al., 1994a).

With regard to pen pressure on the page, DCD children used consistently more pressure than controls but this did not vary with task. This finding is consistent with research evidence identifying poor force control as a common characteristic of writers with DCD (Pereira, Eliasson & Forssberg, 2000; Wann, 1987; Wann & Nimmo-Smith, 1991).

Following the comparison between copying and free writing for the same time period, handwriting was compared between the short and long free writing tasks. As well as introducing the possibility of fatigue effects, this might also serve to separate the idea *generation* from the idea *development* in terms of demand. The same measures as before were tested, first without, and then with the computer analysis. In contrast to the short tasks, groups did not differ significantly on total task duration. The mean group scores for both fell slightly short of the ten-minute recommended length. However, within the groups individual differences in the length of time children chose to continue to write were evident. Only six from the DCD group as opposed to twelve controls to continued writing to the end or near the end of the minimum period, suggesting that as in earlier studies, many of them "run out of steam".

Since the WIAT II spelling test reported in Part 1 found that boys in the DCD group scored significantly lower than the controls, the number of mis-spelt words was calculated as a percentage of total text produced in the free writing task. Surprisingly, there was no significant difference between the two groups in this respect.

9.5 Results: Part 3. The effect on motor and/or orthographic demand on handwriting performance

In this part of the study, the aim is to measure the effects of varying the loads imposed by handwriting and spelling complexity on motor output directly through further task manipulation at word level. In order to do this, specific words had to be constructed for the children to copy which produced two levels of complexity within each type of demand, motor and orthographic. The way in which these words were designed is described in detail above. As a reminder, the four words were: 'Millie' which was motorically *and* orthographically simple (M1O1), 'Chassa' which was motorically complex but orthographically simple (M2O1), 'Guilym' which was motorically simple but orthographically complex (M1O2), and 'Kryzna' which was motorically *and* orthographically complex (M2O2).

9.5.1 Comparisons between the four words - Visual evidence

Before turning to the quantitative data, the hard copy traces of the children's words were examined to see whether any effects of variations between the words might be evident qualitatively. Figures 9.12a -9.12h below show the traces of the movement of the pen in the air in addition to the movements on the surface of the writing tablet for both groups on two examples of the name words: first 'Millie', then 'Guilym'. They illustrate first, the diffference between a well-coordinated writer and one with DCD in general pen control, and second, how changes in orthography were expressed motorically for the boy from each group.

Figure 9.12 Samples of movement of the pen

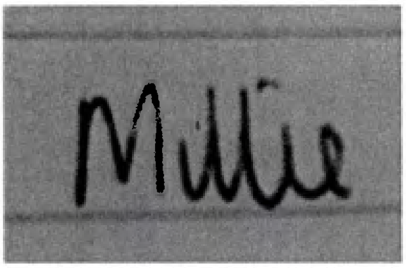

Figure 9.12a 'Millie' copied by a control boy on paper'.

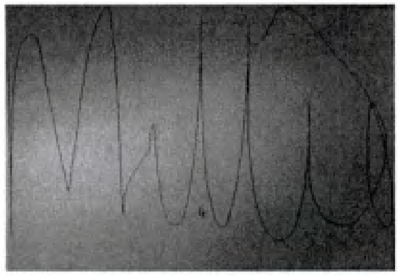

Figure 9.12b the same sample on ComPET

This boy has copied the name 'Millie' using continuous cursive handwriting. He has written the whole name without lifting the pen from the paper and the trace shows a fluent pathway without deviation. This is also reflected in the computer image of the same event, shown in Figure 9.12b, though, in addition to the traces 'on paper', the 'in air' stroke used to dot the 'i' is also visible.

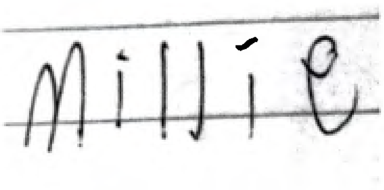

Figure 9.12c. 'Millie' copied by a boy from the DCD group

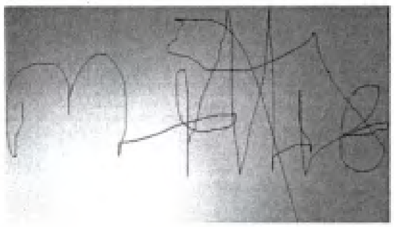

Figure 9.12.d. The same sample on ComPET

The ComPET image shows that this boy from the DCD group, writing in un-joined script, has produced many more general movements in the air than his control.

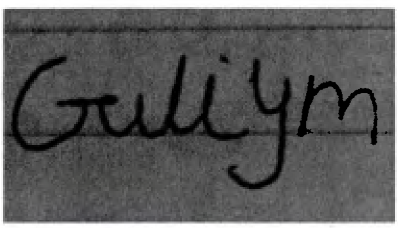

Figure 9.12e 'Guilym' copied by a control boy

Figure 9.12f The same sample on ComPET

Figures 9.12e and 9.12f show a control boy copying the name 'Guilym', again using part- cursive script. However, Figure 9.12d shows the computer image which reveals that excess movements have been performed 'in air' around the letters 'ly' in the second half of the word, presumably in response to the unexpected orthography. This demonstrates a disruption to the fluency of the handwriting at this point in an otherwise fluent writer. This disruption would probably be invisible to the naked eye but the pathway of the pen 'in air' during the penlift and the length of the 'in air' pathways are recorded visually but are also measured numerically by the software (see later).

The following examples, in Figures 9.12g and 9.12h below, taken from the copying of a boy with DCD, show a contrasting pattern of motor activity for this name.

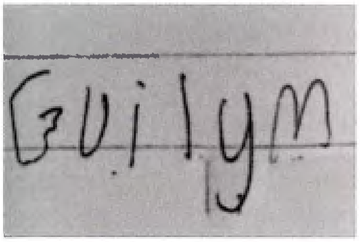

Figure 9.12g. 'Guilym' copied by a boy with DCD

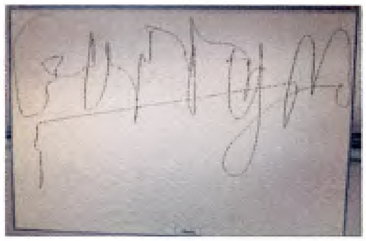

Figure9.12h. The same sample on ComPET

In contrast to the sample in Figure 9.12e and 9.12f where the interruption to the flow of handwriting is confined to the exact location of the orthographic irregularity, the sample in Figure 9.12g and 9.12h shows excess motor activity *throughout* the writing of the word, both 'on paper' and 'in air'. This may reflect poor general control of the pen or it may indicate the level of the effort required to accommodate any unfamiliarity of the word by disrupting the whole flow of the writing. Either way, it is clear that this boy is producing more movements off the page than his control, many of them unproductive, in addition to the strokes produced on the page.

Having observed differences in the computer-generated visual images of the responses to the copying of the single names, the next step was to determine whether these differences were systematic across groups and could be attributed to the particular manipulations involved.

9.5.2 Statistical analysis of single name words

Since the four words employed in the study were "invented" to meet certain criteria with regard to motor and orthographic complexity, it seemed necessary to check that there were in fact differences between them before examining particular comparisons. To achieve this, a repeated measures ANOVA was conducted with *group* as between subject factor and *word* as a within-subjects factor using total task duration (DuT) as a representative measure. (see Figure 9.13 below and Table 9.21).

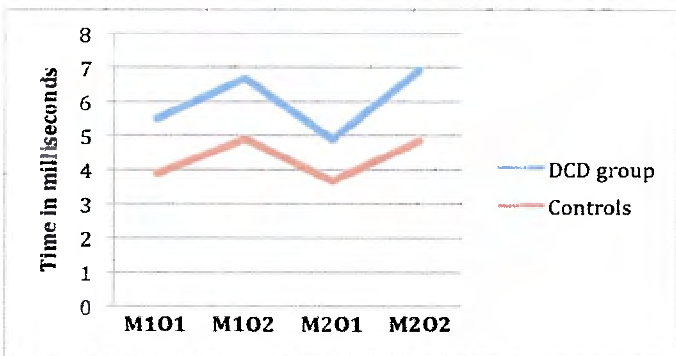

Figure 9.13 Total time taken for each word for both groups

This analysis revealed a main effect of group ($F (1,28) = 4.675$, $p = .039$) and of word ($F (1,26) = 13.360$, p .001) but no group x word interaction. The DCD group took longer than the controls and more time was taken for certain words than others for both groups. In what follows, therefore, the separate affects of type of load and degree of difficulty are investigated.

9.5.2.1 The impact of type of load and degree of difficulty on the production of copied words.

Table 9.21 shows the means and standard deviations on temporal, spatial and force measures for the four words for both groups. In a complex factorial design like the one used here, it is difficult to separate the effects of orthographic versus motor variation and level of difficulty visually. However, from simple inspection of Table 9.21, two things stand out as of interest. The first is a positive outcome. For every single comparison possible – 6 measures, 4 words – the DCD group perform less well than their controls. In contrast, the other observation is slightly problematic. The word "Millie" which was designed to be the simplest as far as motor complexity was concerned actually takes longer to write than "Chassa" which was designed to be motorically more demanding. This effect is evident in both the total time and 'in air' and it seems likely that it is due the fact that dotting the two 'i' s in "Millie" took time that was not attributable to complexity of letterform per se. The spatial and force measures are, of course, unaffected by this problem. Nevertheless, it will have to be kept in mind when interpreting the outcome of the following analyses.

Table 9.21 Means and SDs on temporal, spatial and force measures for each of the four single word names for DCD and control groups

	DCD Mean (SD)				CONTROLS Mean (SD)			
	M1/O1	M1/O2	M2/O1	M2/O2	M1/O1	M1/O2	M2/O1	M2/O2
Temporal								
DuT	5.50	6.68	4.88	6.91	3.90	4.90	3.67	4.84
	(2.52)	(2.24)	(1.94)	(3.12)	(1.06)	(1.03)	(0.91)	(1.35)
DuP	4.25	4.84	4.05	5.51	2.85	3.71	3.05	3.61
	(2.24)	(1.91)	(1.97)	(2.68)	(0.88)	(0.85)	(0.69)	(0.76)
DuA	1.17	1.78	0.77	1.32	1.06	1.13	0.58	1.17
	(0.81)	(1.76)	(0.71)	(1.47)	(0.65)	(0.92)	(0.62)	(1.05)
VM	4.61	4.25	4.85	4.42	4.24	4.19	4.18	3.86
	(1.82)	(1.39)	(2.10)	(1.51)	(0.97)	(0.96)	(0.73)	(0.89)
Spatial								
SLM	15.76	18.57	16.25	21.21	11.51	14.60	12.42	13.86
	(4.66)	(5.20)	(5.33)	(8.35)	(2.36)	(2.98)	(2.13)	(2.30)
Force								
PPM	821.19	851.32	815.99	875.79	615.73	683.50	638.53	649.22
	(206.62)	(146.75)	(188.68)	(114.79)	(177.15)	(176.05)	(192.96)	(210.89)

Temporal measures: proportion of time 'on paper' (DuP) and 'in air' (DuA)

The total time it took to complete each word is shown for each group in Figure 9.14 with each block divided to show the proportion of time of time 'on paper' and 'in air'.

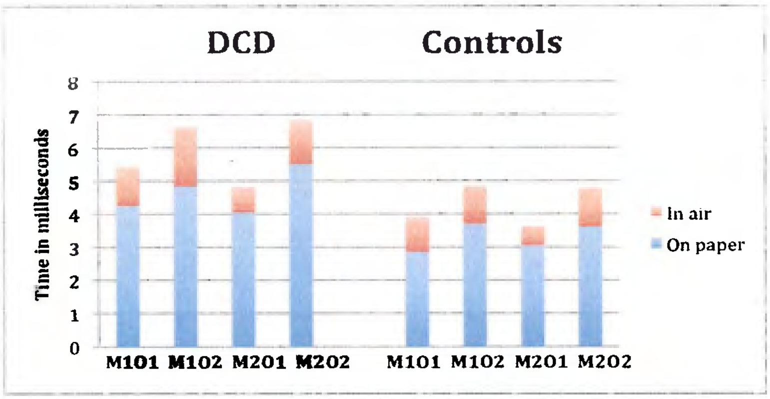

Figure 9.14 Total duration of task 'on paper' and 'in air' for DCD group and controls

Starting with the duration of time spent on the paper, analysis of variance revealed a significant main effect of group (F (1,28) = 8.737, p = .006) of load-type (motor vs orthographic) (F (1,28) = 96.170, p = .000) and of degree of difficulty (simple vs complex) (F (1,28) = 28.522, p = .000). There was also a significant load-type x degree of difficulty interaction (F (1,28) = 53.157, p = .000) and a significant three-way group x load-type x degree of difficulty interaction (F (1,28) = 5.238, p = .030).

In order to explore this interaction further, the effect of load type (motor/orthographic) and degree of difficulty (simple vs complex) were analysed for each group separately using repeated measures ANOVA (see Figure 9.15).

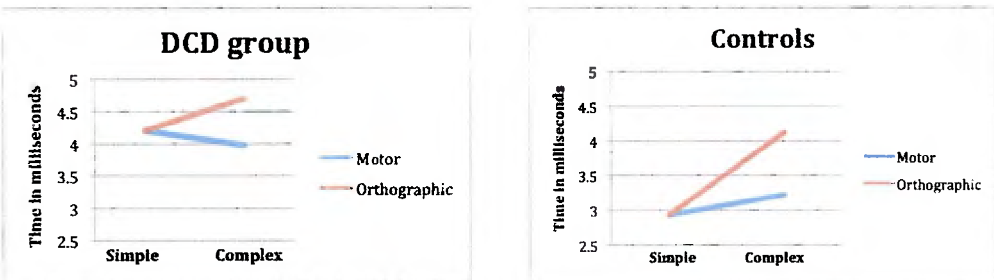

Figure 9.15 Interactions between level of demand and load-type (motor/orthographic) for the DCD group and controls

For the DCD group, there was no significant effect of increasing difficulty either in the motor or orthographic domain (motor: F (1,14) = .246, ns), (orthographic: F (1,14) = 1.943, ns): the children took equally long on the page whether the difficulty increased either motorically or orthographically. For the controls there was no significant effect of increasing difficulty motorically (F (1,14) = 2.286, ns) but there was orthographically (F (1,14) = 10.682, p = .005): the children took longer on the page when orthography became more complex.

When comparisons were made between groups, the difference was significant when the level of difficulty was simple (motor: F (1,28) = 4.666, p = .039), (orthographic: F (1,28) = 4.660, p = .034)) but not when it was complex (motor: F (1,28) = .778, ns; orthographic: (F (1,28) = 1.990, ns).

When the amount of time spent 'in air' was analysed, ANOVA showed no significant main effect of group (F (1,28) = 0.911, ns) but there was a significant main effect of load-type (F (1,28) = 12.860, p = .001): length of time spent 'in air' was affected more by motor than by orthographic factors and both groups were similarly affected. The effect of degree of difficulty only neared significance (F (1,28) = 4.095, p = .053). There were no significant interactions.

Temporal measure - mean stroke velocity (VM)

The mean stroke velocity for each name word for both groups is shown in Figure 9.16.

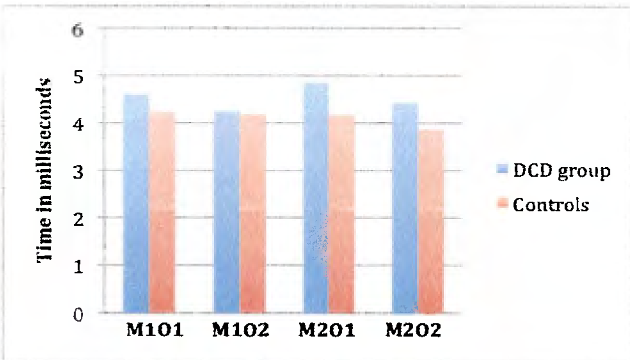

Figure 9.16 Mean stroke velocity for each word for DCD group and controls

Analysis of this measure, showed no effect of group (F (1,28) = .803, ns) or of load-type (F (1,28) = .001, ns) but there was a significant main effect of degree of difficulty (F (1,28) = 6.695, p = .015): when the words became more difficult the stroke velocity decreased (i.e. slowed) for both groups, regardless of whether the change was within the motor or orthographic domain. There were no significant interactions.

Spatial measure: mean stroke length (SLM)

Mean stroke length in each word for both groups is show in Figure 9.14 below.

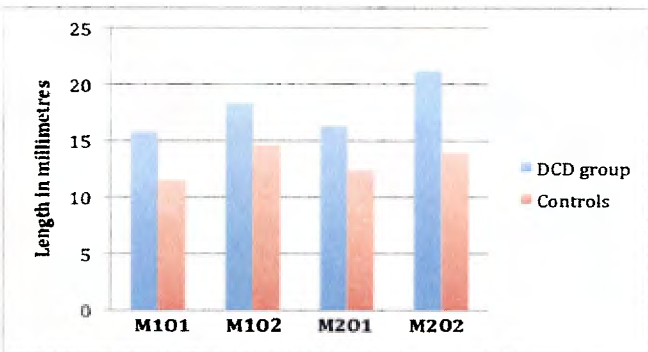

Figure 9.17 Mean stroke length in each word for DCD group and controls

On this measure, the main effect of group was significant (F (1,28) = 15.528, p = .000) as was degree of difficulty (F (1,28) = 27.228, p = .000) but there was no difference between load-types (F (1,28) = 1.017, ns): mean stroke length was greater in the DCD group than controls overall and increased with an increase in degree of difficulty for both groups in both motor and orthographic conditions. There were no significant interactions.

Pen pressure

Mean pen pressure for each word for both groups is shown below in Figure 9.18

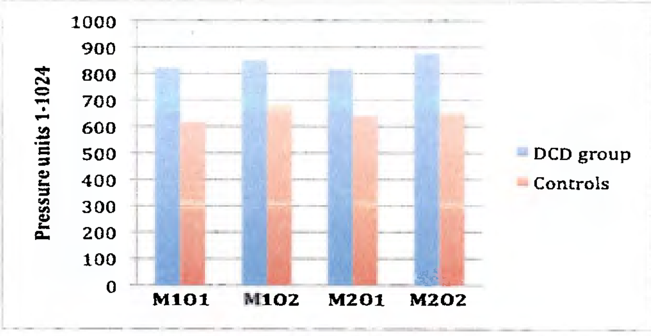

Figure 9.18 Mean pen pressure for each word for DCD group and controls

ANOVA on these data revealed a main effect of group (F (1,28) = 9.650, p = .004) and of load-types (F (1,28) = 9.551, p = .004) but not of degree of difficulty (F (1,28) = 1.304, ns): the DCD group always exerted greater pen pressure than the controls; pen pressure increased more with changes in orthographic than motor factors.

Summary of statistical analysis: main effects (p values)

Table 9.22 below shows a summary of the main effects for group, type of load and degree of difficulty on temporal, spatial and force measure for the the single words.

Table 9.22 Statistically significant main effects for group, demand and mode on temporal, spatial and force measures for single words

Variable	Group	Type of load	Degree of difficulty	Interactions
DuP	.006**	.000**	.000**	Group x load x difficulty .03*
DuA	ns	.001**	.053	None
VM	ns	ns	.015*	None
SL	.000**	ns	.000**	None
PPM	.004**	ns	.004**	None

** Significant to the .001 level; *significant at .01 level.

Overall, the DCD group took longer to write the four words than their controls. This difference was mainly accounted for by the time spent 'on paper', although the time 'in air' was more difficult to interpret, given the problem with the name Millie. Although the average length of the strokes made by the DCD group was longer than the controls, the groups did not differ in stroke velocity. The DCD group exerted greater pen pressure than controls overall.

Change in the type of load affected total time spent on task, both 'on paper' and less so 'in air'. Degree of difficulty also affected the stroke velocity and stroke length but not and pen pressure.

for the controls, in the single word as in the longer tasks, and were influenced by increase in task demand. This suggests a possible reduction in the fine control of the pen during the execution of these strokes and it may be that the increase in stroke velocity experienced during the longer free writing task (see above) was accompanied by a corresponding reduction in stroke control - a speed-accuracy trade-off (Schmidt & Lee, 2005).

Finally, the results of Part 2 found greater pen pressure in the DCD group than controls. The same was found here in the single word tasks. Looking at pressure responses to the varying task conditions, both groups *increased* pen pressure with increase in task demand irrespective of the type, suggesting that the already greater effort exerted by the DCD group was compounded further when tasks became more demanding.

9.6 General discussion

The act of writing involves the physical expression of language. As a skill, therefore, it belongs to a rather small set of activities which require the integration of the many dimensions of language with the complex perceptual and motor aspects of execution. In the mature writer, the cognitive and motor components of writing are more or less in balance as spelling is not a problem for most and relatively little attention is needed to produce legible well-organized handwriting on the page. In children, however, where spelling may not be fully mature and the motor elements are still being refined, increases in difficulty in either area might affect performance adversely. In this final study of children with DCD and handwriting difficulties, the aim was to test the idea that increased cognitive and/or motor load during writing would have a greater effect on the output of children with difficulties than on those without.

Question 1: What can the standardised tests used in earlier studies tell us about boys believed by their teachers to show (a) a discrepancy between their intellectual and motor abilities, and (b) a difficulty with handwriting which affects their written assignments in school?

Before reporting the findings on the experimental tasks, a summary of how the children chosen for the study performed on the standardized tests used throughout this thesis seems appropriate. In the main, the children with handwriting difficulties in this, as in all four studies, presented similar profiles, scoring high on verbal IQ and word reading. Consequently, this confirms that none of the results obtained on the experimental tasks could be attributed to a generalised learning difficulty in the target group. On the spelling tests administered, however, the children with poor handwriting obtained consistently lower scores than the controls, a finding which warrants some discussion. It is generally assumed that reading and spelling are two sides of the same coin which develop together along similar lines, so the disparity found here was somewhat unexpected and the possibility that some of the writing difficulties encountered might be related to spelling problems had to be considered. This argument has been addressed, however, in three different ways. First, it is often over-looked is that the term "spelling" is most frequently used to describe *written* spelling and the possible influence that the manner of production– i.e. handwriting - may have on the accuracy of the transcribed letters, has to be considered particularly for children with handwriting difficulties. Second, in this fourth study spelling scores were entered as a co-varying factor in the analysis of written composition and was found not to be significant. Third, when the spelling errors of the two groups in the free-writing task in the final study were compared, there was no significant difference between them. Thus, it can be said that no evidence has been found in these study to attribute any difficulties of written expression specifically to levels of spelling.

As in previous studies, all of the boys taking part in the present study met set criteria for DCD and their scores on the Movement ABC 2 correlated highly with their scores on the DASH, suggesting a strong link between generalised movement difficulties and failure to acquire adequate handwriting skills. Going beyond a total score, however, some interesting patterns within the test emerged, which seem relevant to the broader discussion of how DCD might be diagnosed. Several boys showed an uneven profile across the three test components. Whilst their scores for manual dexterity were on or below the 5th percentile, they displayed unexpected competence with aiming and catching (see Part 1 of this chapter, p. 212). This unevenness of profile, noted also in Studies 1 and 3, leads to questions over whether a low performance score across all subtests is necessary for diagnosis. This, also, of course, questions the reliability of using this particular test-item for diagnosis, something which has been noted in other studies (e.g. Junaid et al., 2000). Although the DSM-IV does not separate the different aspects of motor ability, the ICD10 allows for the distinction between gross and fine motor skills, stating that performance of 2SDs below the mean on either could be considered as evidence of a motor disorder. This is an issue which has debated at the European Academy meetings (EACD, 2012) and which is ongoing. Also, given the suggestion that there is only partial overlap between handwriting competence and total Movement ABC-2 scores, the question over where to place handwriting diagnostically is still an issue, given that problems with mastery of this skill appears with so many different disorders.

Another observation from a motor perspective was that quantitative scores *on their own* don't paint the full picture. As suggested in the Movement ABC test manual, (Henderson & Sugden, 2007), much can be learned by looking at qualitative aspects of performance. To take one example, on the aiming and catching tasks, the movements of several boys with DCD appeared awkward and dysfluent, even though targets were achieved. It would not be irrational to expect this dysfluency of movement to translate also into awkwardness with handwriting which requires, arguably, a higher level of skill to perform such fine movements. A further observation made during testing focused on differential use of the trial phases on the Movement ABC tasks. The control boys appeared to maximise these trials to their own advantage, adjusting aspects of their performance which could be improved. In contrast, it appeared that the DCD boys did not to use the trials to any purpose, and this may be linked with impaired potential for motor learning often reported in this group (Hill, 2005). Qualitative observations such as these help a tester to understand more fully the underlying motor *ability* of the child, separate from possible motor *competence* demonstrated on any one task at any one time and this supports the argument that a single test score alone cannot reliably diagnose a disorder (see Chapter 4, p. 56).

At present, no standardised measure of handwriting quality or legibility is available for UK use. The few that do exist are designed for testing in cultures where a specific handwriting style is taught, such as in Holland or the US, and these are normed with Dutch or American children. In this series of studies, therefore, a simple rating scale was used which showed quite clearly that the boys with DCD wrote less legibly than controls. In the present study, the percentage of boys achieving legibility was shown to be lower in the DCD group using the DASH as a measure as well as measuring group differences experimentally which will be described below.

As noted on page 213, the DASH served its purpose as a measure of speed of handwriting in that there was very little overlap between the DCD and control group on their total scores. With just two exceptions from each group, the lowest percentile in control was equal to the highest in DCD - around 50%. As with the Movement ABC-2 test, however, observations made beyond the total score were every bit as informative as the total score itself. For example, in the case of no.3 and no.5 whose overall scores were within the normal range, they scored low (7 and 8 respectively) on two items where increase in speed was required – copying fast and free writing. When all the data taken together, however, it was possible to see why their teachers had judged their handwriting to be poor.

Question 2: Are children with DCD and poor handwriting affected more by increasing task difficulty/complexity than typically developing children?

To date, there have been few studies which have measured the interaction between cognitive and motor load in children with DCD and handwriting difficulties. Those there are have used either a drawing task (Smits-Engelsman, 2007), number sequences (Luria &Rosenblum, 2011), different scripts (Rosenblum et al., 2010; Chang & Wu, 2010) or alphabetic languages other than English (Velay et al 2011). None have been conducted in English although it is considered to contain complex orthographic codes.

As transference between languages, let alone between different scripts, cannot be assumed (Tseng & Hsueh, 1997), it became a requirement of this study that the children included met certain criteria and wrote in English. An additional factor which conditioned the structuring of the experimental tasks was that, although models of handwriting describe output at word level (Van Galen, 1991), more recent research has suggested that within-word complexities may influence output (Kandel & Spinelli, 2010). This highlighted the importance of testing output not only at sentence and word level but at a level within words.

In the second part of the study, the children performed two tasks which were similar in some ways to the DASH tasks but the nature of data collection changed allowing the various dimensions of each child's handwriting to be examined in much more detail. Some of the similarities and differences between the copying and free writing tasks in the DASH and in this part of the study are worthy of comment. First, with regard which particular type of handwriting the child should adopt, the instructions across all tasks in the DASH are very specific. For example, the two modes of handwriting requested are 'best' or 'fastest'. In this present study, by instructing children to use 'normal' handwriting, i.e. the style they usually use in school, an additional type of performance can be assessed. Second, the introduction for the experimental task included four sentences, each of which was unfamiliar to the child and contained four unusual names. This contrasts with the DASH repeated use of the "The quick brown fox..." where a child's performance might be influenced by good or poor memory and was designed to present a higher cognitive load. One further respect in which the demand of the experimental task may have differed, was in free writing where it was predicted that constructing a story about Kazakhstan would be more demanding than producing content about "My Life".

Moving now to the findings from the experimental tasks, the main aim of these two parts was to measure how the groups responded to systematic manipulations of the writing tasks. First of all, when copying was compared with free writing for an equal length of time, it was demonstrated that both groups were affected by task change. However, not only did each group take different lengths of time to copy (the DCD group taking longer), but the task change resulted in a change in the 'on paper'/'in air' balance differently for the two groups. More specifically, the DCD group spent longer than controls 'in air' when the task became cognitively more demanding (i.e. involving composition). Additional evidence to help interpret how the increased 'in air' time was provided by the visual traces of the pen-pathways. This suggested that much of the motor activity off the page was not focused and may have been unproductive. This finding also goes some way to addressing an issue raised above relating to the fact that, when free writing, the DCD children were on task for as long as the controls but produced significantly less text. Again, referring to the motor literature, motor planning, not only motor execution, can be an issue for the poorly coordinated child (e.g. David, Deuel, Ferry, Gascon, Golden, Rapin, et al., 1981; Dewey & Kaplan, 1992; Hill, 2005) and this may be a possible explanation for how the unaccounted-for time was spent.

With regard to the spatial and force measures during copying versus free writing comparison, the results showed that copying, though seemingly easier than free writing in certain respects, is not without its stresses for some children. On both measures the group performance differed and the boys with DCD produced longer strokes with greater pen pressure. These findings are consistent with the evidence quoted earlier that accuracy and force control are difficult for children with generalised motor impairments.

Turning now to how these findings changed when the children were required to write for longer, surprisingly it appears that the group differences were not as marked in the extended task as in the shorter tasks. For example, although the DCD group produced fewer words, several sustained tasks nearly for the required duration, stroke velocity remained the same, word-per-minute scores were not dissimilar from the controls and the percentage of spelling errors were no different. Only in greater stroke length and pen pressure for the DCD group did not vary significantly with the longer task.

Taking the Part 2 findings together, the general picture painted of the DCD boys is one of children who are slow to initiate writing activity, then seem to 'get into gear' as the tasks gets underway, but perhaps fade as the task continues or give up prematurely. When individual profiles are examined it becomes clear that the variability, noted in earlier chapters, is extensive and there are a number of children whose performance was affected by the task extension in very specific ways relating to sustaining levels of effort. To give some examples, one boy from the DCD group wrote for less than three minutes on the ten-minute task, having completed the short task satisfactorily; for another, 48% of the longer piece was illegible although on the short task he had managed to maintain clearer script; a third misspelt 15% of his words as became more engaged with his narrative although he spelt most words correctly at the start of the piece. All these changes seem to have been induced by the additional demand imposed by making the assignment longer. These examples also serve as reminders that individual data are as important as group data in gaining a fuller understanding.

Question 3: Are children with DCD and poor handwriting more affected than controls by increases in motoric complexity, orthographic complexity or both? If so, what aspects of handwriting are affected?

In the final part of the study, the copying of the structured single name words was examined to understand better how motor and orthographic types of demand vary and inter-relate. The comparison between the purposely-constructed names showed that the planned manipulation did in fact affect the handwriting measures analysed. However, contrary to expectation, increase in orthographic demand alone influenced how both groups wrote; the motor demand appeared to have no effect. Given the levels of impairment of both general motor competence and of handwriting in the DCD group, this finding seems unlikely. However, as was discussed in the Part 2 discussion, the method used for measuring motor demand could have been more sensitive to the age and experience of the children tested and this is something which may need to be considered for further research. Something which did emerge clearly was the extent to which handwriting speed and fluency were disrupted by orthographic complexity and this replicates the Kandel findings (2006) whilst more specifically demonstrating this impact in terms of motor execution. The interactions on the four-word analysis showed that, as predicted in the introduction, the DCD group were differentially affected by the disruption, particularly in terms of task duration. This is something which few studies consider and which none, to date, have tested.

Chapter 10

Conclusions

10.1 Answering the research questions

This thesis opened by asking why many children who have handwriting problems (despite being intelligent, literate and orally fluent) experience difficulty expressing themselves in writing, far beyond the pure physical act of putting pen to paper. Questions were raised over the extent of the problem and exactly how the difficulties manifest themselves, so the aim was to explore the phenomenon both theoretically and empirically. Also, as this difficulty has frequently been reported in children with generalised motor difficulties, in the course of exploring the issues, the motor status of the children and adolescents who participated was assessed. Two distinct groups were identified – those with DCD and those without – and thus the performance on written tasks for these two groups could be compared.

One purpose of the studies undertaken was to explore not only the general cognitive and literacy ability of the children who share the characteristics identified, but also to look in greater detail at their motor coordination and handwriting profiles. It emerged that not all those recruited for the four studies who met the criteria for DCD had had their motor problems formally recognised in school. Teacher awareness of the motor impairment seemed to be lacking in a number of cases. However, as all those referred for handwriting difficulties were found also to be poorly coordinated, the motor impairment was seen to play an important role in the way the children respond to writing tasks. Indeed, the children with DCD were found to perform quite differently from their well-coordinated peers on the majority of measures suggesting, as expected, that the presence of DCD strongly influences performance.

The nature of the handwriting difficulties was also examined and it is clear that not all those who found writing difficult had problems across all areas or necessarily with the same aspects of the skill. A number of different components of handwriting seemed to be problematic whilst still having a major impact on the writing outcomes. In the empirical work of the four studies, certain factors were all found to constrain children's writing – i.e. reduced output, illegibility, slow handwriting speed and lack of sustainability. In addition, when tasks became more demanding, as in the manipulations of the final study, the impact of the problems was compounded.

The exact relationship between poor handwriting and general motor difficulties was also explored. While fine motor control was most closely associated with poor handwriting, not all poor writers showed in-coordination in all areas. Some children proved themselves well able to catch a ball or balance on a board. This suggests that the overlap between DCD (as tested) and the handwriting issues is not total, despite the incidence of co-occurrence being high.

Acknowledging that writing is a form of language, it was felt important that children should be linguistically competent and it was decided that assessing oral as well as written ability was crucial. Therefore, in the course of planning for the studies, the question arose of what was reasonable to expect of children at a particular age in terms of written and oral language. The 10-11 years age group became the focus of testing because this is the age at which the literature suggests the two forms of language should be developed to a comparable level. Thus, using oral language as a comparator, children were asked to speak stories as well as to deliver them in handwritten form. This provided a general linguistic baseline from which to assess performance more specifically in writing.

The second research question asked at the outset focused on a possible link between the physical act of handwriting and the quality of the written compositions ensuing. Evidence from the two early studies, testing a total of sixty-four children, found strong correlations between the quality of compositions as rated by independent assessors and several factors - the amount of text children produced, handwriting legibility and speed - and this provided a strong case for exploring these relationships further. Furthermore, the compositions these same children produced orally were of equal quality to their peers, highlighting the specific nature of their difficulty with writing. Still more evidence of this association emerged when the children from the first study were re-tested after five years. It was found that those whose handwriting was still poor in adolescence, were still rated below average for composition quality. And to add weight to the argument linking these different aspects of writing, those whose handwriting had improved after intervention demonstrated commensurate improvement in composition.

The third question raised sought to find reasons for the poor composition noted, drawing on theories of competition for cognitive resources from a limited resource pool. Thus, it was suggested that, for those whose handwriting was not automatic, valuable attention and memory resources, needed for producing and developing ideas, were being diverted from composing in order to produce handwritten script. As this theory was central to the thesis, it needed to be tested empirically and thus it provided the rationale for the final study. Whilst the findings of no one study can ever claim that a single factor is responsible for the breakdown in a process as complex as writing, this last study yielded ample evidence to support a theory of competition within limited cognitive capacity. The handwriting presented by the DCD group demonstrated high levels of effort and certain aspects of handwriting deteriorated when written tasks increased in cognitive demand. Although all children were affected to some degree, the change was felt more acutely by the DCD group, suggesting that the impact of their motor impairments was even greater than predicted. This was expressed not only by a slowing of production, increased pen pressure and decrease in stroke accuracy but also by an inability to continue writing to the end of the time allocated in several cases.

10.2 Implications for teachers

The findings from these four studies have several implications for teachers for how children, such as those studied, need to be supported in school. The first focuses on raising awareness of motor impairments in those in mainstream education, and this includes better identification of the impairment, the importance of rigorous assessment and an appreciation of the way the difficulties may impact on academic success. The children studied here had, in the main, high intellectual potential yet were known to be underperforming in the classroom. This waste of talent was causing teacher and parental concern but there was little evidence of real understanding of ways by which to ameliorate the difficulties.

The second implication relates to managing expectation of children's performance in the classroom. Children with DCD are known to be variable, with performance between and within individuals in constant flux, yet few teachers seem to recognise the need to vary their demands of the child according to factors such as fatigue, and the strictures of the curriculum provide little flexibility for possible fluctuations in performance. Although limitations of space prevent the reporting here of variability measures from the studies, suffice to say that there were clear indications of intra-individual variation in all measures.

A further important area for teachers is an understanding of the complex nature of handwriting and how difficulties in specific aspects require a very targeted approach to intervention. This relates to how highly handwriting is valued in schools, how any difficulties are conceptualised, how they are assessed and the basis on which intervention strategies is devised. It is of interest that as a result of the evidence presented at the US Handwriting Summit in 2012 promoting handwriting, several states, which had been considering ending the teaching of handwriting, reversed their decision in the light of what the research had shown.

Looking at more specific implications for teachers from the findings from the studies in the thesis, the first point regards the importance of regular and consistent handwriting teaching for all children. Without good teaching the automation of this skill, vital for subsequent academic achievement, is unlikely to be achieved. The second critical point relates to those who find handwriting difficult to master. The evidence from Study 3 that written content quality increases in those whose handwriting improves, highlights how important it is that teachers do not allow any handwriting difficulties identified early in the primary school to go unaddressed. As the recent National Curriculum guidelines (DfE, 2012) expect children to be using cursive script by lower KS2, this would seem to be an ideal point at which initiate interventions for those who are not writing to that level.

Study 3 raises a third issue concerning the mode and frequency of intervention. All the children in that study received some support for their handwriting difficulty yet 50% of them failed to improve significantly. Details from the parental questionnaires showed that the interventions for these children were neither intensive (more than once a week) nor sustained (for longer than six weeks). Evidence from the Christensen study (2005) showed positive outcomes as a result of intervention but on *daily* practice (for 30 minutes) and over eight weeks. Thus, the clear message is that teachers should act to remediate poor handwriting early on and that intervention programmes should be both intensive (i.e. daily) and sustained (i.e. for at least 6-8 weeks) for maximum effect.

Within the teaching programmes themselves, the importance of speed over neatness, above a certain level of legibility, emerges from these, as from other studies, as a priority yet few schools specifically encourage children to write fast. Tools are currently available to test handwriting speed in a whole-class context but again, few schools make the time to assess which children cannot write fast enough to access the curriculum. Related to this is the evidence from the thesis that teaching *from a movement perspective* is essential for increasing fluency. Establishing sound motor patterns that can be performed faster when appropriate is a necessary forerunner to learning to write at speed. Too great an emphasis on accuracy and neatness in the classroom, currently commonplace in primary schools, leaves children unhappy about writing faster in case neatness is sacrificed. Teaching which included grapho-motor exercises and practice of letters within their movement groups all help to encourage the motor fluency required. This would be a useful approach for all children but would have particular relevance for those with motor coordination problems.

The findings of the studies also have implications for the *testing* of handwriting speed for exam concessions. More specifically, the third study demonstrated that a ten-minute task does not necessarily differentiate the good writers from those who struggle, whereas a task of fifteen minutes might. Given that the majority of school assignments and public exams require writing to be sustained over much longer periods than a short test demands, further empirical work is needed to find the optimum length of task for testing.

A further issue of relevance to teachers in school is the way handwriting problems have been shown in the fourth study to interact with spelling irregularity to create a double constraint to fluency. The evidence on the impact on the motor production of the complex orthographic patterns suggests that spellings should be taught and practiced motorically, using the delivery mechanisms which children use in class to produce work. The idea that handwriting supports spelling is frequently quoted by teachers but that the converse applies – that difficult spelling disrupts handwriting fluency - may not be as widely understood. The combined teaching of these two transcription skills would seem an obvious approach to ensure the maximum benefit to the child.

The final implication for teachers relates to possible ways to adapt their approach directly to actual writing tasks. On the evidence shown that getting started in free writing seems to be where children with DCD (and possibly many others) are most vulnerable, support strategies to minimise the cognitive load at the outset could be helpful. One possible approach might be to encourage the vocalizing of ideas before attempting to write and to provide single words or phrases to act a memory cues.

10.3 Future research

The thesis has additionally raised several issues which could be developed in the future. The work undertaken here is modest and therefore replication of the studies with much larger samples would bear fruit. However, beyond this, there are some key areas where further research could be conducted. For example, all twelve children with DCD in Study 1, recruited on the basis of their handwriting difficulties, were found to meet the criteria for DCD. Yet, in Study 4, on testing, two boys with poor handwriting scored too high on the Movement ABC to be included. There obviously are children whose handwriting difficulties are not related to a motor impairment and further exploration of the qualitative differences between theirs and those with DCD would increase our understanding.

A second area for research relates to the possible benefit which handwriting confers on narratives written, something hinted at in Study 1. The National Handwriting Association collects anecdotal evidence from professional authors who choose handwriting over keyboarding when producing early drafts, claiming it encourages ideas to flow. For children impaired by poor handwriting, keyboard use is now a real alternative for writing. However, studies systematically comparing the composition quality produced in the two modes have not yet been conducted with children who are fluent both with handwriting *and* on the keyboard so this is one area which should be further explored.

The third and last line of research to be followed up relates to the attempt made in Study 4 to quantify the impact of increased motor demand on the fluent production of text. The tasks devised for the 10-11 year olds may have a much greater impact on younger children who are still learning their letterforms, and this way any who might be vulnerable to generalised writing problems later on, could be identified early.

In conclusion, the principal finding of this thesis is that the motor coordination difficulties experienced by young people with DCD appears to have an impact on the execution of some cognitive tasks. For this research, one particular motor task was chosen– handwriting – and one cognitive task- written composition. However, it has to be considered that future research will find that the physical-cognitive relationship in these children extends into other, hitherto unrecognised, areas. This would further increase our understanding of the scale of the challenges they face academically in school and in life later on.

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Appendices

Appendix 1. Ethics approval form

Leading education and social research
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25 November 2011

To Whom It May Concern

This letter is to confirm that Mrs Angela Webb has successfully obtained ethical approval for the project titled '*The Relationship between Poor Handwriting and Written Composition in Children and Adolescents with Developmental Coordination Disorder*', as part of the requirements of the Doctor of Philosophy in Psychology programme conducted under the joint supervision of Professor Morag Stuart and Dr Sheila Henderson)

Yours sincerely,

Appendix 2. Letter to head teachers about Studies 1 and 2

Dear Headteacher,

I am a specialist teacher studying for my PhD at the Institute of Education, London University. I am researching children's writing difficulties, particularly in those who are good readers but have trouble putting their ideas on paper. I am focusing on children at the top of primary school (aged 10-11 years) who have handwriting difficulties, and may also have problems with motor coordination.

If you know of any child in your school in Years 5 or 6 who fall into this category and whose parents might allow them to take part in the study, I would be very pleased to hear from you. For testing, all the children will need to spend two sessions with me of approximately an hour each. They will first be asked to complete standard tests of intelligence and literacy, and I will also assess their motor coordination. Next, they will be set two story tasks, one spoken and one written. The results between the two will be later compared.

The design of the study meets the ethical requirements set out by the Institute of Education and the results will be kept completely confidential.

The children can be seen at your convenience, either in school, at their homes or at my teaching room in Islington, whichever you and they prefer. After testing, if you are interested, you will be able to see both your children's results and the overall findings of the study.

I am extremely grateful for your help in this study and hope that you will find it both useful and interesting.

Appendix 3. Letter to target parents for Studies 1 and 2

Dear Parent,

I am a specialist teacher studying for my PhD at the Institute of Education, London University. I am researching children's writing difficulties, particularly in those who are good readers but have trouble putting their ideas on paper. I am focusing on children at the top of primary school (aged 10-11 years) who have handwriting difficulties, and may also have problems with motor coordination.

If you would allow your child to take part in the study s/he would need to spend two sessions with me of approximately an hour each, completing standard tests of intelligence and literacy. I will also assess his/her motor coordination. The children will be set two story tasks, one spoken and one written and the results between the two will compared.

The design of the study meets the ethical requirements set out by the Institute of Education and the results will be kept completely confidential. If you are interested, you will be able to see both your child's results and also the overall findings of the study.

Your child can be seen at your convenience, either in school, at home or at my teaching room in Islington, whichever you prefer.

I am extremely grateful for your help in this study and hope that you will find it both useful and interesting.

Yours sincerely,

Appendix 4. Consent form for Studies 1 and 2

PhD Writing Difficulties Study
CONSENT FORM

Name of participant……………………………………………………………………

Date of birth……………………………………………………………………………

Name of current school…………………………………………………………………

Year of Schooling………………………………………………………………………

Current main address: ……………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Telephone number……………………………..........Mobile: …………………………………...

Email: ………………………………………………………………………………………..

PARENTAL CONSENT
I am willing for my son/daughter* …………………………………………………
to take part in the PhD Writing Difficulties Study.

Signed……………………………………………………………………………………..

PARTICIPANT CONSENT
I am willing to take part in the PhD Writing Difficulties Study

Signed……………………………………………………………………………………..

*Delete where necessary

Appendix 5. Picture stimulus and instruction for narrative task for Study 1

Story Task – Dragon Picture Sequence

Instruction:

"Write/tell a story based on these pictures. Make it as exciting as you can so that it can be read/told to other children."

Appendix 6. Criteria for Rating Handwriting Quality for Studies 1, 2 and 3

Points

Handwriting which:

6 is clear, consistent, neat and easily legible, and with all letters correctly formed.

5 lacks total consistency but which is legible with all letters correctly formed.

4 is irregular in form, where some letters may be incorrectly formed but which is mostly legible.

3 is irregular in form, where the majority of letters are incorrectly formed and where legibility is adversely affected.

2 is poorly controlled, in which most letters are ill-formed and which is largely illegible.

1 is totally illegible.

Appendix 7. Criteria for Holistic Rating of Composition Quality for Studies 1, 2 and 3

Points

6 For cohesive story line, imaginative extension of story, mature grammar and sentence construction and interesting use of vocabulary.

5 For cohesive story line, some extension of story, correct grammar and sentence structure and some interesting vocabulary.

4 For an accurate interpretation of the story, with limited extension or imagination and with a basic sentence structure, grammar and vocabulary.

3 For a simple recounting of the story, with few embellishments and limited vocabulary, though grammatically correct.

2 For work where the story lacked sequence and cohesion, or did not reflect the picture stimulus, where grammar and sentence structure were sometimes incorrect and vocabulary was very limited.

1 Where there was no cohesive story line poor or no sentence structure and was grammatically incorrect.

Appendix 8. Elements and criteria for Analytic Rating of Composition Quality for Studies 1, 2 and 3 (from WOLD)

Ideas and Development

4 Points	Extensive development of idea(s) with extension and elaboration of all or most of the points. Look for uniqueness, interest to audience and strong support of the main idea. Can be exceptional writing or extremely thorough.
3 Points	Good development of ideas, with many details elaborated and extended. Ideas are fairly well supported.
2 Points	Adequately supported idea(s), with some details extended or elaborated. May be an extensive list.
1 Point	Weak idea(s), minimally supported, with little or no extension of details, or incoherent.

Organisation, cohesion and unity

4 Points	Completely organized, with smooth flow from one to the next through the use of transitions and sequencing. Unity is strongly evident, with no wandering from the primary theme or plan.
3 Points	Fairly well organized with good unity of plan. Some transitions may be used. Little or no digression from the main idea
2 Points	Small amount of organization. Weak plan that may not be well unified. Ideas may be only minimally connected.
1 Point	Lack of plan. May be incoherent.

Vocabulary

4 Points	Precise, appropriate, accurate and specific work choices that convey the correct meaning and appeal to the audience. May be vivid and imaginative.
3 Points	Good word choices that are appropriate, specific and varied and have some appeal. May lack 'sparkle' but the meaning is clear.
2 Points	Fair use of words. May be specific and have a little variety but approach a very elemental. May be simplistic but effective.
1 Point	Very simplistic. Lacks variety and precision. Meaning may be unclear. May be inappropriate.

Sentence Structure

4 Points	Excellent control and formation of sentences. Variety of sentence structures and sentence lengths contribute to fluency. Few, if any, errors of structure.
3 Points	Adequate amount of sentence variety. Good mix of sentence length and structures. May contain a small number of errors that do not interfere with fluency. Error-free papers with no variety.
2 Points	Sentences constructed fairly well. May have some variety of length and structure or may be somewhat monotonous or choppy. May contain several errors and lack control.
1 Point	Poor sentence structure with many errors that may inhibit fluency or clarity.

Grammar and Usage

4 Points	Error free or very few errors, in approximate proportion to length of the paper.
3 Points	Good grammar and word usage. Errors that do not detract from the overall quality of the paper.
2 Points	Fair grammar and word usage. Errors may interfere with meaning.
1 Point	Poor grammar and word usage, with frequent or serious errors.

Appendix 9. Letters to parents for Study 3

Dear

PhD Research Project

You may remember that in 2005, ...took part in a study which was part of my PhD research looking at children's writing difficulties. In that study, the children were assessed for reading and spelling ability and their motor coordination and attention levels were also tested. They were then asked to write and tell stories which were analysed anonymously for length, and handwriting and composition quality. The results of that study showed that children who wrote *more* tended to score higher on measures of composition quality than those who less.

We are now conducting a follow-up study of all the children tested to see if, and how, their writing ability has developed over time. We are tracing all the children from the original study, and asking them if they would mind being retested, hence the reason for this letter.

The retesting would involve approximately 2 hours and would be arranged at a time and venue to suit you.

The project has been accepted by the ethics committee at the Institute of Education, London University All story samples will be coded for anonymity and complete confidentiality will be kept at all times. If you are interested in the outcomes, you will be sent a summary of the findings once testing and analysis are completed.

If you would be willing to allow ....to take part in this further part of the study, please would you complete, sign and return (in the sae provided) the attached consent form, including your contact details, and I will get in touch with you make an appointment.

I am extremely grateful for your help with this project as it is crucial to the outcome that as many as possible of the original participants are retested. I look forward to hearing from you.

Yours sincerely,

Appendix 10. Consent form for Study 3

PhD Writing Difficulties Follow-Up Study
CONSENT FORM

Name of participant...

Date of birth...

Name of current school...

Year of Schooling...

Current main address: ....

....

....

Telephone number..............................Mobile: ....

Email: ....

PARENTAL CONSENT
I am willing for my son/daughter* ....
to take part in the PhD Writing Difficulties Follow-up Study.

Signed...

PARTICIPANT CONSENT
I am willing to take part in the PhD Writing Difficulties Follow-up Study

Signed...

*Delete where necessary

Appendix 11. Questionnaire for parents for Study 3

QUESTIONNAIRE FOR FOLLOW-UP STUDY

Educational

1. What type of school does your son/daughter attend now?
   a. Comprehensive…………………………………………………….
   b. Grammar……………………………………………………………
   c. Independent…………………………………………………………
   d. Other (please state type…………………………………………….)

2. Has s/he changed secondary school from the one originally attended after primary school?
   a. Yes…………………………………………………………………
   b. No…………………………………………………………………

   If yes, please give reasons…………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………

3. How would you view his/her attendance record?
   a. Good………………………………………………………………
   b. Average……………………………………………………………
   c. Poor…………………………………………………………………

   (*Please give reasons*………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………

4. What levels of literacy and numeracy did s/he achieve at 11 years of age?
   a. Literacy……………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………
   b. Numeracy…………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………

5. Has handwriting ever been a problem for your child at school?

   a. Yes...

   b. No..

   (If yes, please say in what respect)..

   ....

   ....

6. What is the medium used for recording school work currently?

   a. Handwriting..

   b. Keyboard...

   c. Voice activated software...

   d. Combination (please state which)...

   ....

7. If a keyboard is mainly used, how fast can s/he type?

   a. 10-20 wpm..

   b. 20-30wpm...

   c. More than 30 wpm..

8. How many subjects which require a considerable amount of writing is s/he taking for GCSE or equivalent?

   a. 1-2..

   b. 3-4..

   c. More than 4...

Physical

9. How tall is your son/daughter?

....

10. How would you describe his/her body build?

    a. Below average...

    b. Average..

    c. Above average...

11. Has s/he had any prolonged illness or medical condition since leaving primary school? (If yes, please describe)

....

....

....

....

....

12. Is s/e currently taking any medication or supplements? (If yes, please describe)

....

....

13. Have any developmental disorders been diagnosed at any time?

(If so, please state, with dates if possible) ....

....

....

....

14. Has s/he received any intervention for any difficulties identified?

(Please indicate when, with dates if possible, how often and what type.)

a. Learning support within school..

....

b. Tutoring outside school...

....

c. Physio/occupational therapy..

....

d. Other (please state type)..

....

Personal

15. Has s/he moved house/school/area since leaving primary school?

a. Yes..

b. No...

16. Has s/he experienced any of the following since leaving primary school?

a. Family break-up..

b. Family trauma...

c. Serious illness...

d. Other experience which might affect school performance?......................

....

....

17. How would you describe his/her general happiness/well-being?

a. Very happy..

b. Generally unhappy..

c. Somewhere in between...

18. Are there any other comments you would like to make on your son or daughter's general progress or well-being?

....

....

....

....

Thank you for completing this questionnaire. Please return it to:

Angela Webb at 25 Lonsdale Square, London N1 1EW. ***The contents are for research purposes only and will be kept strictly confidential. No names will be attached to the data at any time.***

Appendix 12. Narrative task and instructions for Study 3

Open the Response Booklet to the Written Expression pages. Give the child the booklet and the pencil. Say **I want you to write a letter. Here is what I want you to write in the letter.** Point to the text on the child's Stimulus Booklet page as you read the following instructions aloud.

Imagine that you could have someone to design a place for you to live in and create it to your *exact* wishes. Write a letter to that person. Describe how you want your ideal place to look. Be sure to include all the details the person would need to know about your ideal place.

You may either print or use joined up writing. You do not have to fill both pages. Just concentrate on what you have to tell this person, not on how many lines or pages you are filling. You do not have to include an address, salutation or closing in your letter. You may not use a dictionary, but don't avoid using words you might misspell. You will not lose marks for spelling mistakes. You will have 15 minutes to write your letter. I will tell you when you have 5 minutes left and when you have 1 minute left. Do you have any questions?

Answer any questions the child has about the task, but do not give any specific instructions about what to write. When ready, tell the child to begin and begin timing.

Remind the child when 5 minutes are left and when 1 minute is left.
Do not allow the child to write for more than 15 minutes.