An investigation into the prevalence of non-tripod pengrip and its implications for secondary school writers

A thesis submitted to Middlesex University
in partial fulfilment of the requirements for the degree of Master of Philosophy

May 2011

Elizabeth Bladon

Middlesex University

School of Arts and Education

ABSTRACT

This research addresses the twin issues of whether non-tripod grips are becoming more common and whether young people who adopt any of these grips experience greater problems than their peers. Existing research into writing grip focuses on young children, leaving the long-term consequences of an unorthodox grip poorly reported.

The initial demographic survey investigated changes in penhold. The survey was conducted in a single secondary school, its satellite primary schools and adults in West Wales. This established a high frequency of non-tripod grips occurred among children and young adults that were not replicated in older adults. Statistical analysis of the data indicates that this change in grip happened quite abruptly to young people who began school in the early 1980s.

The research also identified ninety-three secondary school pupils, using a range of non-tripod grips and matched each to a pupil using an orthodox grip. Thirteen non-tripod grips were identified, three for the first time, while the severity of others appears greater than in the existing literature. The effects of each grip were considered statistically, using the null hypothesis that groups of matched pupils sharing a grip, will have similar characteristics.

Several consequences of the different grips were established, some of which can adversely affect performance and attitudes. These consequences include high levels of pain after even very short writing periods, a high number of adjustments needed to maintain writing, as well as different writing speeds, some of which fall below generally accepted norms. There is thus support for the initial hypothesis that those using non-tripod grips are affected by their choice of grip, which may negatively affect their education.

This research ascertained, for the first time, the suitability of a range of unorthodox grips for the demanding writing tasks required by secondary schooling. It also identifies some grips that should be avoided if unnecessary difficulties with writing are to be prevented.

ACKNOWLEDGEMENTS

First, I would like to thank the all the adults and pupils in the many schools who helped me in this research. These are too numerous to mention but include the headteachers of all the schools, both primary and secondary, that I visited; all the teachers who allowed me to visit their classrooms or permitted pupils to miss a lesson and especially the pupils without whom there could have been no research.

I would also like to thank Catryn for helping me with the Welsh translation and spelling assessments as well as assessing the photographs allowing reliability calculations. Thanks also to Ranji and Ibrahim for assisting with this and other parts aspects of the research.

Huge thanks are also due to James Ogunleye for helping me access SPSS as well as answering my many questions, all of which was far outside his professional remit.

Thanks are also due to my two Director of Studies Diane Montgomery and Victoria de Rijke. Diane for helping though the long hard slog and Victoria for assisting in the final stages, without you both this thesis would never have been finished. Thanks also to two other Middlesex staff without whom the production of this thesis would have been much harder, my second supervisor Ruth Green and Charmain Alleyne, administration officer.

Finally, I would like to thank all my six children who have inspired and humoured me at various times. Especial thanks are due to my youngest, Hamza and Abdullah for assisting me with graphs and other technical aspects of this work, often at times which were extremely fraught.

INDEX OF TABLES

INDEX OF PHOTOGRAPHS

INDEX OF GRAPHS

INDEX OF HANDWRITNG SAMPLES

INDEX OF DATA COLLECTION MATERIALS

STATEMENT OF RESEARCH PURPOSE

This research aims to investigate two related issues: the types of grip currently used by children and adults and the consequences for writers of using a range of unorthodox grips. This study is thus centred on the frequency of non-tripod grips and the way unorthodox grips may affect their users' ability to progress in secondary school. Handwritten work is a way in which children are placed in groups within schools, often impacting on the GCSE tier and the grades possible at the end of their education. A child handicapped by poor writing, whether in terms of speed or because they are suffering an abnormal amount of discomfort might never achieve what he or she is capable of, and without this underachievement being appreciated.

It will be demonstrated there has been relatively little research into the types of grip used by older people although the development of grip through childhood is well-established. Indeed it appears to be believed that if older children or adults use a grip then it is an acceptable alternative to a tripod grip.

Although grip may be only one reason for poor writing skills, the consequences of unorthodox grips have not been established with recent research considering that the effects of pengrip are yet to be resolved (Rosenblum, Goldstand & Parush 2006). This is an important area of research as the effect of grip on handwriting performance is often considered as an afterthought to contemporary research into the factors affecting school performance (O`Mahony, Dempsey & Killeen 2008).

RESEARCH AIMS AND QUESTIONS

This research intends to expand on a preliminary study undertaken as part of an MA degree (Bladon 2004). This research suggested the key questions:

- What is the prevalence of unusual grips in secondary schools and in the wider population?
- Are secondary school pupils with atypical grips were underperforming in comparison with their peers?

The importance of this in secondary school environment is dependant on both the rate of non-tripod grips and the actual grip adopted by individual pupils. Thus an additional research aim seeks to ascertain the prevalence of unusual grips both in secondary school pupils but also in the wider population. This is important as it seeks to discover whether the use of an atypical grip is a recent practice, not observed in older people, as well as if it has been a transitory phenomenon not replicated in younger pupils who have experienced more explicit handwriting instruction. The preliminary research question concerning demographic handwriting grips is addressed in Phase One of the research.

The first phase of the research will attempt to ascertain broad demographic grip patterns and provide a context for the consequent investigation into difficulties experienced by the adopters of non-tripod grips. It seeks to build on Bergmann's 1990 American research into the incidence of atypical grips in non-dysfunctional adults. This research surveyed three population groups, two separate subject specific student groups and voters in a US election. It is intended that this research will be not only more representative of the British population but also link grip and the age of the writer.

Following a literature review highlighting the range of non-tripod grips already identified it is intended that the second phase of the research will investigate and categorise atypical grips within secondary schools in a single geographical area. This part of the research will not only seek to identify the consequences for writers of using a range of unorthodox grips but also to categorise any previously unidentified atypical grips.

This research will thus ascertain the frequency of non-tripod grips and the way these unorthodox grips may affect their users' progress in secondary school. It is intended that the research will not be prescriptive but proactive and highlight the problems with their writing identified by the users of non-tripod grips. It is anticipated that a number of the unorthodox grips identified will have multiple users thus allowing for statistical analysis and providing sufficient adopters of a grip are identified it will be possible to determine whether certain grips should be recognised as disadvantaging their users. If the incidence of atypical grips in the preliminary survey described above is replicated, it is expected that a substantial number of secondary school pupils do not use a tripod grip and the consequences of this choice have not been researched. It is thus the purpose of this research is to investigate whether and in which ways these children's experience of writing differs to that of those using more orthodox grips.

CHAPTER ONE

AN OVERVIEW OF HANDWRITING DIFFICULTIES WITH SPECIAL REFERENCE TO PENGRIP

INTRODUCTION

Handwriting is in essence a physical mechanical skill and failure to acquire this skill can have a dramatic impact on the whole of a child's school career as well as impacting on their eventual success in examinations. Considering that relatively short periods of writing during examinations at the age of sixteen have such a disproportionate effect on young people's futures, comparatively little research has been done into what may disadvantage certain pupils.

Alston (1983 and 1985) in a survey of seven to nine year-olds' writing designed to be representative of England found that 21% of nine year-olds had difficulty producing legible writing and were considered to be `unlikely to progress sufficiently to cope with the requirements of secondary schooling' (1985, p 70). She reported that pencil grip was one of the factors that teachers thought were affecting their ability to write (1985, p 70). Sovik, Arntzen and Karlsdottir (1993) found that fifteen year-olds with good writing wrote significantly more slowly than their peers with poor handwriting but had poorer coordination and were more likely to be using an awkward grip. A different link between handwriting quality and pen grip had been made by Schneck (1991, p 702) who considered that `an awkward grasp may not affect handwriting when minimal amounts are required, but when large amounts of written work are required, a poor grip may lead to fatigue as well as to the slow, poor formation of letters'.

The origin of this research lies in personal experience. Having observed that occasionally children seem to experience extreme difficulty in developing an orthodox tripod penhold, preferring a whole fist dagger like grip, I subsequently taught a sixth form pupil who used a very similar grip. Her fist grip only varied from that used by the younger children in that the pen was held between her third and fourth fingers, a grip that gave her cramp. She found it difficult to write quickly and had performed poorly in her GCSE examinations. Once curiosity had been aroused, it became automatic to register the range of ways that pupils held their pens. It seemed that at least one in ten right-handed secondary school pupils used non tripod grips. These unorthodox grips did not seem to be related to pupils who were struggling to learn, indeed, three of the six pupils in an A level geography examination invigilated had unusual ways of holding their pens.

The automatic observation of grips then became extended to adults: their incidence of usual grip seemed much lower. If unusual grip had only become common quite recently, what would be the consequences of this new unorthodoxy? Given the complexity of identifying pupils with any type of learning difficulty it seems possible that young people with unusual penholds may be displaying slight developmental coordination difficulties.

Thus the starting point of the research project was an awareness of the difficulty of diagnosing the child with writing difficulties. This chapter will consider how grip develops in young children, together with an examination of the literature concerning atypical grips.

DEVELOPMENTAL CO-ORDINATION DIFFICULTIES

Learning difficulties encompasses not only difficulties with language-based learning but also disorders of motor function. These difficulties may occur as a symptom of a recognised congenital or acquired neurological disorder. However, when motor difficulties are not linked to general intellectual impairment then the problem becomes much less easy to recognise and identify. A wide variety of terms have been used to describe such children, some purely descriptive such as `physically awkward' or `clumsy', while others indicate the presence of a distinct disorder such as `dyspraxia' (Henderson and Barnett 1998, p 451).

Although developmental dyspraxia has been much researched it remains an imprecise term to describe children with a lack of motor skill and there has been a great deal of confusion over the precise definition and description of the disorder (Dewey 1995, p 255; Henderson and Barnett 1998, p 452). The term developmental coordination disorder is often considered synonymous with dyspraxia, although the use of the terms also conveys subtle differences often related to the background of the user. Dyspraxia has medical origins and is more commonly used in the UK than elsewhere (Peters, Barnett and Henderson 2001, p 410). However, in the interests of standardising researchers now prefer the phrase developmental coordination disorder (Henderson and Barnett 1998, p 453; Peters et al 2001, p 408).

The term dyspraxia has within its meaning a deficit in movement planning (Henderson and Barnett 1998, p 453) and although the preferred term is developmental coordination disorder it is worth considering earlier research that has focused on dyspraxia. Dyspraxia was defined as an `inability to learn how to perform a skill motor action which is appropriate to a child's age' (O`Regan and Brown 1998, p 258) and manifests itself in a variety of ways. These include impaired fine motor skill performance; left/right confusion; poor tactile perception; poor hand-eye co-ordination; and finger agnosia or a lack of intuitive knowledge of the fingers (Yeo 2003, p 11). Dyspraxic children move in an often noticeably uncoordinated way and are frequently involved in minor accidents – the clumsy child syndrome.

In addition to delays in achieving motor milestones, developmental coordination disorder also affects a wide range of skills notably daily living activities. These include tying shoe laces, fastening buttons and using a knife and fork, but also sports and poor handwriting and presentation of written work (Henderson and Barnett 1998, pp 454-5, 459). Of these skills, handwriting most affects education and may result in under achievement. Barnett and Henderson (2005) considered developmental coordination disorder can affect writing in a number of ways including letter formation, spacing and alignment, as well as writing speed (p 170). This research only briefly considered the effect of grip on handwriting. Although they implicitly recommended the dynamic tripod grip they acknowledged that there are a range of grips that may be employed and merely recommended that a grip that could be used comfortably over a prolonged period be adopted. Other aspects of the way a pen is held were also discussed in relation to pain: too distant and too close positioning of the fingers to the writing tip, posture and too much pressure being exerted onto the paper (pp 183-5). The role of the grip in causing difficulty in a prolonged writing task was not considered but since grip is believed fixed by the age of eight or nine (Jarman 1993a, p 43; Taylor 2001, p 50) before prolonged writing tasks are demanded of children it is an aspect that seems worthy of discussion in relation to children with developmental coordination disorder. For although teachers are aware that some children may have learning difficulties, they fail to appreciate the difficulties that some children experience with handwriting. Poor writing, especially when compared to performance in other areas, is easy to attribute to carelessness or lack of attention. Sometimes the inability to write frustrates leading to disruptive behaviour and this is considered to blame for the poor written work rather than the converse (Barnett and Henderson 2005, p 172).

Henderson considered that children with developmental coordination disorder `do not grow out of it' (1993, p 292) and while Bowens and Smith provided an estimate of the overall incidence of dyspraxia at approximately 6% (1999, p 5), the causes of these difficulties remains unclear. However, research suggests that the cerebellum is implicated in dyslexics with motor learning difficulties. The cerebellum lies at under the cerebral cortex of the brain and is primarily responsible for the coordination of movement. Investigations using positron emission tomography shows that there is poorer blood flow through the cerebellum in such subjects when compared to controls without dyslexia. These results occurred in all three circumstances investigated, at rest, during a pre-learned activity and while learning a novel sequence of activities. The reduced blood flow indicates that the dyslexic cerebellum is less active during both the `execution of acquired skills and the building up of new skills' (Nicholson et al 1999, pp 1663-1666).
Coordination difficulties may be linked to either general or specific learning difficulties (Pumfrey and Reason 1991, pp 84-5) as dyslexics show significantly poorer performance than control groups on some manual manipulation and balance skills (Nicholson and Fawcett 1994, p 157). Furthermore developmental coordination disorder coexists with other specific disorders involving problems with attention, language and reading (Henderson and Barnett 1998, p 465). If the cause of developmental coordination disorder is minor brain damage then it is unlikely that such damage will be restricted to only a single aspect of development and thus 'co-

occurrence should be the norm and specificity the exception' (Henderson and Barnett 1998, p 466). The implication of co-morbidity is that when children are being assessed and supported for developmental coordination disorder the presence of other problems must be considered (Dewey 1995, p 270).

DYSGRAPHIA

Dysgraphia, which may be viewed as an aspect of developmental co-ordination difficulties, although `only manifested in fine motor skills' (Montgomery 2003, p 73). Since handwriting is the most important motor skill to acquire during schooling (Ripley, Daines and Barrett 1997, p 34), these fine motor skill deficits are most evident in poor handwriting, or very low productivity (Deuel 1995, p S7) hence the term dysgraphia which is succinctly defined as a `learning disability related to mechanical writing skill' (Hamstra-Bletz 1994, p 121). Dysgraphia may occur in the absence of other learning difficulties or in association with dyslexia, with at least a third of dyslexics having problems with writing (Montgomery 2003, p 73). Levine, Brooks and Shonkoff (1980, p 87) believed that `inefficiencies of fine motor performance may directly affect the ability to write, to copy from the blackboard, to draw and to cut with scissors' adding that `pencil control in particular may be adversely affected'.

Deuel (1995) identified three types of dysgraphia. The first, which she termed dyslexic dysgraphia, is linked to poor oral spelling while other aspects of writing such as drawing or copying of text are relatively unaffected. The child with dyslexic dysgraphia will be reluctant to write or hand in very brief written work and is often believed not to be trying. The second form is linked to severe motor clumsiness, and displays the reverse with near normal oral spelling, but poor drawing and copying skills. The child with this form of dysgraphia is often clumsy and has difficulties with all fine motor activities and is uniquely characterised by an abnormal finger tapping ability. The third form of dysgraphia is the result of poor spatial awareness. This type of dysgraphia has similar characteristics to that associated with motor clumsiness although drawing will be more severely affected (p S7). Other children have writing difficulties linked to ADHD or tremor.

Schneck (1991 pp 704-5) linked poor handwriting in six year-olds to decreased finger or proprioceptive-kinesthetic awareness as well as immature grip while O`Regan and Brown suggested that dysgraphia will develop when the `pen held insecurely with a palmar or abnormal tripod grip' (1998, p 259). Although, as with all learning difficulties, early identification is beneficial, and awkward pencil grasp has been used in paediatric assessment protocols (Levine et al 1980, p 90), poor motor control is likely to be a residual problem and many affected adolescents may never have good enough best writing, especially to record information at speed (Kirby and Drew 2003, p 78). As a child progresses though the education system the curriculum makes ever-increasing demands for speed (Ripley et al 1997, p 36) that the dysgraphic child cannot fulfil.

Difficulties with handwriting are not generally viewed sympathetically by schools (Montgomery 2003, p 75) as writing avoidance strategies are all too often employed by pupils for other reasons. Finally, as a pupil finishes school poor handwriting may result in examination scripts being given lower marks than those in which the handwriting is neat and easy to read (Soloff 1973, pp 44-5; Cohen 1976, pp 186-7), thereby affecting a young person's further or higher education prospects.

Even if schools fully appreciate pupils' individual skills, or lack of them, this does not solve the dilemma but rather creates new quandaries. It is difficult to decide where to place pupils with limiting writing skills for they are `too bright for the slowest groups and couldn't cope with the written work of the top groups' (Hughes and Dawson 1995, p 183). In streamed schools the placement of these children is going to have to be a compromise. Either they will be placed according to their writing ability or according to their intellectual ability. A decision to place a child in a group, which they have not accessed on written merit, can seem unfair, even to the very teachers whose job it is to teach them. Alternatively, a contrary decision may in an era of tiered examination offer a limited curriculum. Portwood (1999, p 161) in considering this dilemma, recommended placing a child according to his or her intellectual ability as an inappropriate placement would be likely to cause the child to fail to be motivated by the lesson content leading to behavioural difficulties. Adults with learning difficulties describe how their feelings of frustration were vented through misbehaviour and made comments indicating they felt they would at least have felt happier, if not been better educated, if only someone had recognised and understood their difficulties (Hughes and Dawson 1995, p 183).

ACQUISITION AND DEVELOPMENT OF PENHOLD

Turning to the interaction between penhold and dysgraphia, O`Regan and Brown (1998, p 259) linked incoordination dysgraphia to a `pen held insecurely with a palmar or abnormal tripod grip' while Poustie et al (1997, p 91) believed that penhold could be diagnostic of graphomotor dyspraxia. In order to appreciate the differences between the types of grip it is important to consider how grip develops.

The new born child displays a range of involuntary reflexes, most significantly for this research, the primitive grasp response in which all the fingers are held tightly against the palm (O`Regan and Brown 1998, p 249). This innate reflex is inhibited, to be superseded by voluntary control that begins at the age of three to four months when the child develops the ability to grasps objects with the whole hand, flexing all the fingers against the palm (Cutkosky and Howe 1990, p 108), employing a grip that Manoel and Connolly (1998, p 180) described as a `palmar grip'. The earliest palmar grasp is formed with three fingers closing against the palm and this primitive dagger grip (O`Regan and Brown 1998, pp 252, 255) often adopted by young children when first given a pen seriously curtailing control. The development of more sophisticated hand actions continues with, first the independent control of the thumb which develops at around eight months followed approximately two months later by the ability to use the index finger independent of the other digits thus permitting a pincer movement to develop (O`Regan and Brown 1998, p 253). This greater control with the independent finger movements allows children to begin to grasp between the tips of the fingers (Cutkosky and Howe 1990, pp 107-108), which Forssberg (1998, p 108) described as `delicate'.

It is only with this development of independent finger movements that the skilled use of the hand for manipulation becomes possible. Napier (1956) comprehensively described two categories of grasps, differentiating them as power and precision, while other authors describe how precision grips using the fingers develop later than the power grips that generally involve the whole hand. The crucial difference is that power grips immobilise the object in the hand, the grip used on a hammer is an example, thus allowing maximum force to be employed whereas precision grips between the pulp of the thumb and the index finger permit manipulation.

Writing, the subject of this research, requires both extrinsic and intrinsic movements, for the pen must be guided across the paper as well as allowing fine motor control to shape individual letters. Thus, as Van Galen described, handwriting is produced by the `coordinated stretching or flexion of the distal parts of the digit finger, middle finger and thumb' (1993, p 219) producing the vertical components of the letters while the movement of the lower arm positions the script in the left-right axis. So for effective writing, the grip must permit a variety of movement and if the grip adopted limits this then there is a commensurate decrease in manipulative ability (Manoel and Connolly 1998, pp 179-80; Elliot and Connolly 1984).

Yakimishyn and Magill-Evans (2002) assessed the grasp of 51 children aged 23-24 months according to Schneck and Henderson's 1990 developmental definitions of grip posture (p 895). None of the children displayed a consistent grasp pattern although the most frequently observed grasps were the digital pronate, a palmar grasp with the index finger extended along the pencil and the more mature `grasp with extended fingers' in which the pencil is held between the thumb and finger tips. Interestingly, Yakimishyn and Magill-Evans's research found that more mature grips were elicited with short crayons and vertical surfaces (p 571).

Manoel and Connolly (1998, p 181) described how individual digit movement allows a simple synergy to be created with a pinch between the pulp surfaces of the oppositional thumb and index finger. Rosenbloom and Horton's early (1971) research with children over a wide age range, described how the precision dynamic tripod grip, which is so important to writing, develops. Initially `the posture of the fingers is acquired' (p 3) but movement is initially located at the shoulder. Over time the lower joints of the arm become involved in controlling the pencil's movement until eventually the movements are isolated in the fingers resulting in the fully developed dynamic tripod grip. In Rosenbloom and Horton's study of children aged one and a half to seven years, the static tripod grip was observed in children from the ages of two and a half to almost six years while the finger movement for the dynamic grip was first seen just after four years. Significantly, in this 1971 study no grips without tripod positioning of fingers was observed after the age of approximately four years and seven months (p 5). Ziviani (1987, p 32) concurred with many of Rosenbloom and Horton's observations, and in describing the static tripod grip identified it as a less mature grip, most commonly seen in children aged three and a half to four years while Erhardt (1994, p 14) considered it the modal grip between the third and fourth birthdays.

However, the crucial difference between the static and dynamic tripod grips is the way the pen is moved to shape the letters. Once it is the fingers controlling the movement of the writing implement rather than the shoulder, elbow or wrist then the tripod grip is considered to be dynamic. The static and dynamic variations of the tripod grip cannot be distinguished by still photography but can be differentiated by watching the child write or video analysis. The dynamic tripod grip is considered to develop between the ages of three and a half and six years of age (Taylor 2001, p 49), by the age of six years (Schneck 1991, p 702) or by the age of about six and a half years (Ziviani and Watson-Will, 2006, p 219) although Manoel and Connolly found that 80% of children can imitate the dynamic tripod grip by the ages of 52 to 57 months (pp 185-6) [four years four months and four years nine months].

Further evidence of the way in which children's grips matured was evident when the range of grips displayed by 320 non-dysfunctional Boston children between their third and seventh birthdays, thus aged three to six, was investigated in drawing and colouring exercises by Schneck and Henderson (1990). Ten different grips were identified, and considering the results for the drawing task, which more closely approximates to writing, the two palmar grips were not observed after the age of five. Three other grasps were grouped with the palmar grips as `primitive'. Each of these involved extended fingers but none were observed after the age of five and a half. Three grips were considered transitional: the static tripod; four fingers, in which the index, middle and ring fingers were placed above the pencil and a cross thumb grip in which the `fingers fisted loosely into the palm, pencil held against index finger with thumb crossed over pencil toward index finger'(p 895). The cross thumb, with the pen is held between the clenched fist and the side of the thumb, was observed until the age of five and a half, while the other two transitional grips were observed until age of seven, albeit in a single case or 2.5% of those surveyed. The final two grips were described as mature, the dynamic tripod and the lateral tripod, described by Bergmann in 1990 (p 736), which differs from the dynamic tripod in that the thumb is crossed over the pen. In Schneck and Henderson's north-east US research these two grips, the dynamic and lateral tripod grips comprised 77.5% and 22.5% respectively of the six and a half to seven year-old age group. Thus, although using cross sectional rather than longitudinal research the maturation of grip was clearly demonstrated `through the decrease in the use of the primitive and the transitional grips and the increase in the use of the two mature grips' (1990, p 897). In this research the hand which the child was using was not reported and, considering gender differences, there did not appear to be a significant difference between the maturity of grip employed by boys and girls after the age of four and a half, although girls were more likely to use the lateral tripod.

Writing with Elkins in 1986, Ziviani drew attention to the importance of pad to pad opposition, and considered it as one of their four variables, exemplifying its absence in a photograph (Figure 6 (b) p 255). This was not named but is clearly a variation on the lateral tripod the pen held between the index finger pad and the thumb knuckle, as was the illustration of the thumb avoider in Cole's 1955 analysis of left-handers and a grip illustrative of leading to significant problems with written output in Levine et al 1980 (p 92). This lateral grasp, linked to lax finger joints, is considered to restrict finger movement (Summers 2001, pp 132-3). Ziviani and Elkins investigated whether finger and thumb positioning affected writing using separate tasks for speed and legibility. The various components of pencil grip analysed identified four groups. The first two groups had index fingers flexed more than 90° (distal joint bend back), with the two groups varying in the degree of rotation of the forearm. The third group lacked the pad to pad opposition (lateral tripod) while the final group had a relaxed forefinger with pad to pad opposition (tripod grip). The research results displayed no overall evidence of a relationship between grip and speed or legibility although the two children that had both fast (58 letters/ minute) and legible (5+) writing had `what most educators define as a desirable grip (i.e. thumb and index finger opposed on the shaft of the pencil, the pencil resting on the distal phalanx of the middle finger, index finger in relaxed flexion, and the forearm held in more than 45 degrees of supination)' (1986, p 252).

While Schneck and Henderson (1990) found that 22.5% of six to seven and a half year-olds used a lateral tripod grip, higher incidences, 44% of six year-olds, was found in Tseng's 1998 Taiwanese research (p 216); 38% of Summers' (2001) Australian seven-year-olds (p 137) and in Tuckett's 2006 South Wales research (p 31) – 58% of five year-olds. 86% of the children South Wales investigation used one of the three grips which Tuckett considered mature: the lateral tripod; the dynamic tripod and a quadrupod grasp, similar to the dynamic tripod except the index and second finger are positioned in opposition to the thumb. The lateral tripod was the most frequently observed grip, although as with Schneck and Henderson's research the lateral tripod was again much more often observed amongst girls, again with girls demonstrating a much higher incidence of mature grip than boys at the age of five, approximately 95% compared with 60%. These figures have to be inferred from the graph as raw data for gender is not included.

Further information on the type of grips used by young children was revealed by Carlson and Cunningham's 1990 research involving children aged four to five and a half years of age. This research (primarily focused on the effect of pencil diameter on the children's skill) used a ten grip categorisation based on the number of digits in contact with the pencil and the way in which they were placed. These grips were condensed into three groupings for analysis (Carlson and Cunningham 1990, p 283). The least mature group included 5C and 4A, which had three fingers (index, middle and ring) in opposition to the thumb the difference being whether the little finger supported the pen. The middle group included the lateral quadrupod and dynamic quadrupod grips while the most mature group comprised only the lateral tripod and dynamic tripod grips. The lateral quadrupod grip is characterised by four digits in contact with the pen, the index and middle finger on the upper surface of the pen, with the pen resting on the ring finger and the thumb moved across so that the thumb pad is not in opposition. The numbers of children using each pencil grip were not reported although the authors noted that `most of the children in the sample used a grip type consistent with expectations of children between the ages of 4 years, 0 months and 5 years , 5 months' (p 289). However, the maturity of grip utilised, together with finger movement was a predictor of performance on several of the drawing and simple writing activities investigated.

Another grip pattern was first reported by Dennis and Swinth (2001) in their research comparing the performance of US fourth grade pupils with atypical and dynamic tripod grips. They identified as a separate grip pattern the lateral quadropod grasp (pp 176, 178). Dennis and Swinth observed this grip more frequently (p 179) than the lateral tripod and although this was a newly identified grip they acknowledge (p 180) that other researchers may have been included this grip in their lateral tripod grouping. Koziatek and Powell's (2003) investigation into fourth grader's grip reported similar levels of lateral tripod and lateral quadrupod grips (22 and 21% respectively) in their sample of fourth grade children. This sample appears representative as it consisted of the all pupils that had agreed to participation in the research; approximately 44% of all pupils in the participating schools.

Burton and Danisak (2000, p 13) linked the use of less mature grips to the use of wider pencils, and in addition observed that girls aged three to five tended to display significantly more mature grips than boys. Their definition of mature grips comprised Schneck and Henderson's (1990) lateral tripod and dynamic tripod grasps. Burton and Dancisak also established that the dynamic tripod grip produced greater accuracy than the lateral tripod grip in their line following task (56.8% vs 43.5%). However, this result was not statistically significant and they concluded that the lateral tripod remains an acceptable alternative to the dynamic tripod although they cautioned that they had not tested its suitability over prolonged writing tasks or its resistance to fatigue (p 16).

Although several researchers including Schneck and Henderson (1990); Carlson and Cunningham (1990); Tseng (1998) and Tuckett (2006) have considered that the lateral tripod is a mature variant this seems to be based on observation of its use amongst older children (Schneck and Henderson 1990) and adults (Bergmann 1990) rather than on empirical evidence of its effectiveness. Myers (1992, p 54) expressed these reservations very succinctly when she wrote `further research should be done in order to establish whether or not the lateral tripod grasp is a desirable grasp, particularly since it does not include the open web space component of the static and dynamic tripod grasps`.

Until recently a tripod grip, and right-handed at that, was the only way that a child was allowed to write. The employment of the tripod grip for writing has been accepted as conventional for centuries as this quote from Peter Bales writing in 1590 (cited in Jarman 1993a, p 108) explains:

> Betweene your thumb and your two fingers place
> Your pen to write with comlines and grace.
> Your thumb first aloft, as highest bestowe,
> Your forefinger next, your middle belowe,
> Hold softly your pen, lean tightlie thereon
> Write softlie therewith, and pause thereupon:
> For swiftness will come of itself anon.
> Ill tricks are soon caught, be not so soone gon.

The importance of the tripod grip here described with its salient warning that `ill tricks' are easily acquired is that the tripod grip provides the ability to exert the fine motor control that is important for handwriting. The important feature of the tripod grip is the ability of three digits to exert control over the movement of the pen. Unquestionably there are other grips that also provide the necessary control, as was explained by Bentley when she made clear that an effective grip needed to provide control and comfort, suggesting that holding the pen between the index finger and long finger gives many writers greater control with less stress (Bentley 1990, p 4). The same penhold was also advocated by other handwriting authorities, including Sassoon (1990a, pp 34-5).

Before the introduction of the National Curriculum in the UK standardised all aspects of the curriculum including handwriting, very little time was spent on specific instruction in writing. This is different to the situation that exists in other countries such as France where the teaching of handwriting is a major part of the curriculum for five or six years (Thomas 1998, p 44). The QCA in 1999 formulated the early learning goal (for the Foundation Stage of the National Curriculum) that children should be able to use a pencil and hold it effectively; this was subsequently incorporated into the National Literacy Strategy, (DfEE 2001, p 31). The meaning of the word `effectively' remains open to subjective interpretation. However, the appendices of this document did clarify the nature of the grip to be used by children who `should be encouraged to hold the pencil between the thumb and forefinger with the pencil resting on the third finger' (p 161). Publications instructing teachers (Taylor 2001, p 49) emphasised the efficiency of a tripod penhold and advise that it be encouraged although it was previously considered that `there is not one correct way of holding a pen' (Bentley 1990, p 4).

Young children need to be able to hold a pencil comfortably (Alston and Taylor 2000, p 6), although the ultimate goal is for children to be able to produce writing that is legible and sufficiently fast to allow educational progress (Ziviani 1987, p 36). When a pen is held in dynamic tripod grip, the writer has very good fine motor control over their writing, with effectively three digits able to influence the direction in which the marks are made. Many children develop this method of holding the pen naturally, although some younger children may have to be encouraged into adopting this method of holding their pencils by use of a plastic mould that encourages the development of a tripod grip (Ferriell et al 1999, p 58; Pascoe, Gore and McLellan 1993, p 50). Such interventions should be timely for it is considered difficult to change the grip if an incorrect pencil hold is initially adopted (Alston and Taylor 2000, p 15). Some researchers have been very precise as to the age up to which changes can be achieved, with Taylor (2001, p 50) suggesting eight years, Jarman (1993a, p 43) nine years and Amandson and Weil (2005, p 603) American second grade with the latter authors emphasising that the child's cooperation in important if any change is to be achieved.

In view of Manoel and Connolly's opinion (1998, pp 185-6) that it is only by the ages of four years four months to four years nine months that 80% of children can replicate a tripod grip it must be considered when children should be beginning to write or the concept of writing readiness. Sassoon (1995, p 64) advises against pushing children into writing before they are mature enough and mentions the twin skills of hand-eye coordination and the ability to perceive and copy; furthermore (p 72) suggesting that five years is the age at which most children are writing ready. Benbow (2006, p 319) considered that `many (girls) begin to `write' as early as two and a half, often without proper adult attention or supervision' and that this may be a cause for their adoption of inefficient or even harmful grips. Tseng (1998) also considered that one reason for the high incidence of lateral tripod grip might be due to Taiwanese children beginning to use a pencil in preschool education at the age of three, and that such early writing activity predisposes them to adopt the lateral tripod grip (p 220).

While most authorities, including Ziviani (1983) and Erhardt (1994), believe that it is maturation that permits the development of an effective mature grip there are dissenters. Newell and McDonald (1997 p 249) argued that the shift in grip resulted from the interaction of the child with its environment rather than as an inevitable part of maturation. Furthermore, they emphasise the importance of scale, with an injunction to consider the type of childlike grip that might be produced if adults were to write with implements of a scaled size. This view was expanded and refined by Newell and Cesari who held that children are now raised with only limited experience of small objects `due to the tendency of parents to avoid placing small objects in the workspace of the infant for fear that the child will swallow them' (1998, p 74).

Indeed it may be observed that children learn to write with adult writing implements although frequently they are provided with thick wax crayons or oversized pencils with which to begin writing (Ziviani 1987, p 35), although empirical evidence does not support their use (Amandson and Weil 2005, p 604; Burton and Dancisak 2000, pp 13-14; Carlson and Cunningham 1990, p 289). The effects on the developing grip appear not to have been thought through, for both the diameter and the weight can affect on the formation of a tripod grip with a fully involved thumb.

CONTEMPORARY VARIATION IN PENHOLD

Before embarking on a consideration of the variety of penholds employed in contemporary society it will be constructive to consider exactly what an effective mature grip requires. When any object is held in the fingers so that the hand itself can manipulate it, then a greater variety of movement can be accomplished (Elliot and Connolly 1984, p 283). Elliot and Connolly also observed `if an object is gripped so that it is held immobile in the hand and cannot be moved within the hand by the digits, then it has fewer degrees of movement.' So a grip which means that the pen is held in a rigid fashion then movement must be moved by the body as a whole, using the wrist, upper arm and body (Elliot and Connolly 1984, p 283). However, when a tripod grip is employed with the pen held between the pulp surfaces of the thumb and index finger and the radial distal surface of the third finger it allows movements of fingers and thumb to create the vertical elongation of the letters while the movement of the wrist permits the horizontal sequencing of letters (Elliot and Connolly 1984 pp 286-287). This conclusion that is remarkably similar to that in an early twentieth century text that considered that fingers shape the letters but the arm moves the pen forward (Freeman 1922 p 62).

Freeman (1922) also provides a very detailed description of conventional grip (p 58), uncluttered by diagrams or photographs:

> The orthodox method of holding the pen is to grasp the hold between the thumb and the first two fingers about an inch to an inch and a half from the penpoint. The pen is mainly held between the thumb and the second finger, against which it rests opposite the first joint. The first finger rests upon the top of the pen and keeps it in place, particularly in the downwards movements. The hold also comes in contact with the hand at the base of the index finger. All the fingers are bent easily, each one from the middle to the little finger being bent slightly more that the one before it. The hand rests on the two outside fingers.

This comprehensive description of a tripod grip is supplemented by the injunction that the fingers should not be bent too much for to do so prevents flexibility and leads to cramping and fatigue (p 58) together with a long and interesting discussion on how much rotation of the wrist is acceptable noting that others advocate that a coin be balanced on the wrist during writing to keep the wrist flat (Freeman 1922, p 61). Alston and Taylor (1988, p 21) amplified this definition by indicating that the tripod grip is most efficient, and least likely to result in fatigue when the pencil lies an angle of 40º to the line of the thumb and forearm.

This early attitude to handwriting has been noted by other authors including Thomas (1997, p 129) and Sassoon (1999, p 159) who in her review of handwriting in the twentieth century considered that `attitudes to the child in the classroom have altered - as have the children's attitudes to school'. Until very recently there was no alternate way of recording information, although even prior to the contemporary technological revolution, the teaching of handwriting was given a low priority as a consequence of the sixties generation of teachers and theorists who believed it to be oppressive (Sassoon, 1993, p 17). Thus children are allowed to write in a way that they find most efficient. Unfortunately the grip that might be appropriate for a thick wax crayon at three is unlikely to be the most efficient for a pupil in the GCSE examinations and although idiosyncratic holds initially cause few problems this is not the situation in secondary school when greater demands are made on speed and legibility (Alston and Taylor 1988 p 21) when the `effectiveness of a child's pencil grip and capacity to thwart `writer's cramp' are ingredients of academic success at the secondary level' (Levine et al 1980, p 85).

Although in the middle of the twentieth century there was uniformity in penhold (Thomas 1997, p 129) prior to this (Wann et al 1991, p 66) and more recently other grips have become acceptable (Sassoon 1990a, p 34), especially when writing implements other than pens are employed and `observers of secondary age pupils tend to agree that a large proportion have unconventional tool grip' (Alston and Taylor 1987, p 84). However, the tripod grip was widely viewed to be the norm with `all others being considered atypical and awkward' (Bergmann 1990, p 736) and Benbow (2006, p 334) considered that `pencil postures that are not held within the pulps of the digits do not lead to economy'. Several researchers have suggested reasons for this variation in mature grip with Sassoon (1990a, pp 34, 36) considering that it is the use of writing materials other than pencils such as felt tips, which require holding at a far higher elevation that is causing alternative grips to be adopted. Wann et al (1991 pp 61-5, 68) suggest that it is this need to increase the elevation that causes many children to adopt a quadrupod grip, a grip that is being reported more frequently, with Benbow noting that seven year-olds employed this grip more frequently than the tripod grip (2006, p 330). This grip seemed awkward to Sassoon writing in 1999 (p 154) and in an earlier work she had (1986, p 11) considered that it slowed writing, a comment unsupported by empirical evidence. Crucially, when considering effectiveness, the quadrupod grip is considered to require an increase in hand and arm control rather than finger control (Ripley et al 1997, p 37) while Benbow (2006, p 330) considered it reduced stability as the hand is balanced on only the little finger rather than two fingers as is the case with the tripod.

In addition to this modification, there remain other ways in which a right-handed person may hold a pen. A second way of increasing the angle of elevation of the pen is to move the thumb across so that it is no longer the ball or pad of the thumb which controls movement but the knuckle or even the base of the thumb. Many researchers have observed this idiosyncrasy as it is commonly seen both in contemporary classrooms (Thomas 1997, p 130; Tuckett 2006, p 30) and in adult surveys (Bergmann 1990, p 736). Bergmann's research conducted in the United States in 1988 and published two years later investigated the incidence of unorthodox grips in 485 adults by observing three groups of adults writing in functional situations namely occupational therapy students signing their names, voters signing to register and medical students taking an examination. She reported that over 10% of those observed used a lateral tripod grip with the incidence being highest in the medical students - 15%. Similar results were found in Summers and Catarro's 2003 research involving university students with approximately 10% using the lateral tripod and 12% the lateral quadrupod grips. Although these incidences were lower than that in the 6 year-olds of Schneck and Henderson's research published in the same year as Bergmann, the reason for this difference is not clear. Bergmann suggested that cultural changes such as the use of the telephone, word processors and even multiple choice examinations curtail the need for handwriting and that certain grips such as the lateral tripod are adequate for the level of writing undertaken in contemporary life.

Opinions differ as how effectively the lateral tripod allows the writing implement to be controlled with Bergmann (1990, p 737) reporting that `teachers reported that children using the lateral tripod grasp showed no detrimental effects on their fine motor performance'. Earlier writers, Levine et al (1980, p 87), however, considered that a way that children in early elementary education could compensate for poor fine manipulative skills may be to develop an `awkward, maladaptive grip' further suggesting that this may be either too proximal, too distal or `over-rely on the webbing between first and second finger', with one of the illustrative grips indicative of leading to significant problems with written output (p 92) being the lateral tripod described above. Most recently, Benbow (2006, pp 330-1) considered that this grip achieves joint stability by using the more powerful adductor and first dorsal interrossei muscles causing the thumb to wrap the thumb over or under the index finger thereby limiting the use of fine motor control over the pencil. Moreover, when the pen held in the webbed circle between first finger and thumb reduces feedback from the digits causing the student to have to stop and release grip and shake out the pain from his/her fingers (p 335).

Although the lateral tripod has been reported in published surveys of grip since 1990 (Bergmann and also Schneck and Henderson) the precise definitions of what is a lateral grip are not always clear. Compare, for example, the illustration in Myers (1992, p 54 Figure 6) in which the grasp labelled lateral tripod grasp shows the pencil held between the length of the forefinger and the ball of the thumb held in a side on position, with the illustrations in Schneck and Henderson 1990 (p 895 Figure 1(i) lateral tripod grasp) in which the thumb touches the pencil below the thumb nail; Dennis and Swinth 2001 (p 176 Figure 1(f) lateral tripod grasp), in which the thumb touches the pencil below the thumb knuckle; and the photographs in Tseng 1998 (p 198 Figure 1-3 (l) lateral tripod grasp) in which the pencil is held in the forefinger/thumb webbing and the thumb touches the forefinger; Koziatek and Powell 2003 (p 286 Figure 3 the lateral tripod pencil grip (Tseng 1998)) in which the pencil is held in the forefinger/thumb webbing and the thumb knuckle touches the forefinger. Although the name lateral tripod had not been coined in 1986 the photograph in Ziviani and Elkins 1986 (p 253 Figure 4 (a) thumb and forefinger not in pad to pad opposition in which the pencil is held by the thumb knuckle would also represent this grip although not in as an extreme form as that in Koziatek and Powell.

Amandson and Weil (2005, pp 590-1) considered that there were `acceptable alternatives to the traditionally preferred tripod grip': the lateral tripod; the dynamic quadrupod, and its variant the lateral quadrupod in which the thumb crosses over the pen. Similar opinions had previously been expressed by Jaffe (cited Bergmann 1990, p 737) and Tseng (1998). These grips formed all but one of the atypical grips investigated by Dennis and Swinth (2001) who found, albeit with a sample size of only 23, that there was no significant difference in letter and word legibility between children with atypical grips and children who wrote with a dynamic tripod grip (p 182). A similar result was found by Koziatek and Powell in 2003 with a sample size of 101. The only grip that was linked to lower writing speed in this research was the one pupil who used a (left-handed) interdigital grip.

Dennis and Swinth (2001) cautioned against an over reliance on their results given the small sample size (23 pupils with atypical grasps) to which the observation must be added the limited categories of atypical grips that were included in their investigation - primarily quadrupod (13), lateral quadrupod (4) and lateral tripod (2). Other researchers consider there is a change in fine motor control with Sassoon (1986, p 11) viewing the lateral tripod as limiting, leading to pain (p 44) and in its left-handed version as offering less control (p 10). Although the written trace may be satisfactory even though a poor grip is employed the writer will be using proximal joints such as the elbow and shoulder joints.

The other grip identified by Dennis and Swinth is the `tripod grasp without web space'. They observed this grip only once in their sample of 23 unusual grips. In this grip the thumb is flexed so the ball of the thumb although on the pen, does not provide opposition to the index finger (2001, p 176).

Tseng (1998) in her survey of Taiwanese children between two and a half and six and a half, identified a variety of interdigital grips in which the fingers are fisted into the palm with the pen projecting ulnarly between the index and middle fingers, the middle and ring fingers or the ring and little fingers (pp 213-4). Tseng only observed these grips in children under the age of four and a half and categorised this grip as `primitive' because of the proximal movement (p 218) although subsequent research into American adults observed a similar grip in 1.8% of adults though it was suggested that it may be an adaptation to long nails (Bergmann 1990, pp 737-8).

A range of other grips have also been identified in the literature. These include the four finger grip which has the tips of four digits controlling the pen Tseng (1998, p 213). This grip was illustrated with a drawing by Tseng and a photograph by Koziatek and Powell (2003). In this grip the tips of the index, second and ring finger are in opposition to the thumb with the hand balanced on the smallest finger.

Benbow (2006, p 334) also described a grip caused by extreme laxity of the thumb's metaphalangeal joint. This `non-functional' grip, which Benbow named the index grip, is characterised by the forefinger being held high on the pen and opposition being created between the thumb and second and third fingers. The pen is thus held in a hooked position so that the tip of the pen points towards the writer's midline. Since writing strokes are caused by wrist flexion and metaphalangeal extension the use of the index grip means that the writer cannot slide the hand across the page so that the forearm must be periodically moved.

In a much earlier work Sassoon, Nimmo-Smith and Wing (1986) described in meticulous detail the variety of penholds they observed in seven, nine and fifteen-year-old children in Kent. The features classified included the individual digit positions, the digits' relationship to each other and the pen; their proximity to the pen tip and the extension or flexion of the digits (Sassoon et al 1986, p 95). In addition to the actual penhold, the position of the hand, upper body and paper were all categorised as the authors felt that these postural factors must also have an effect on the pupils' writing (Sassoon et al 1986, p 96).

The conclusions of this paper indicated that only 38% of 15 year-olds used a classic dynamic tripod grip as described above. By including the quadrupod variation, which Sassoon et al described as a modified tripod grip and those in which the index finger and /or thumb to be positioned above the pen rather than at the side, then 85% of fifteen year-olds had a functionally `tripod' grip. Myers (1992, p 53 referring to unpublished work by Benbow) reported that approximately half of normal children follow this type of four finger static to dynamic progression.

However, the primary conclusion of Sassoon et al's 1986 publication that 85% of children adopt a functionally tripod grip by the age of 15 seems suspect. The 15 year-olds in 1986 had presumably been taught to write around 1976, while the younger children (seven and nine) who had learnt to write more recently showed much lower levels of functionally tripod penhold (71% and 72% respectively) despite the orthodoxy described above that penhold is fixed by the age of eight or nine years of age. Moreover it was over this ten year period (1975-85) that handwriting manuals (Bentley 1990; Jarman 1993a; Sassoon 1990a; Sassoon 1990b and Sassoon 1999) seemed to recommend an increasingly laissez faire attitude to many aspects of handwriting instruction, not least penhold. This increasing laxity seemed to continue until the National Literacy Strategy was implemented in 1998 (Allcock 2001a, p 23) and it has only been with the new millennium that the handwriting manuals offer specific instruction concerning the importance of correct penhold (Taylor 2001). The advice given by Alston and Taylor 2000 emphasised not only the importance of the tripod grip but also the significance of its adoption at the outset of schooling when they wrote `when the forefinger, middle finger and thumb are employed in a tripod hold from the beginning, preferably with the forefinger on top of the pencil barrel, a dynamic pencil hold is able to develop' (p 14). Thus Sassoon's 1993 overview of handwriting now seems to represent a transient point of view, at least with respect to grip for she states (p 35) that her:

> work has not led her to suppose that there is an ideal penhold to recommend. To the contrary it seems to have highlighted that different body proportions and personal pressures when allied to the many differences in size, shape and points of modern writing implements provide such a multiplicity of factors that it is better to suggest a variety of penholds for experimentation.

Sassoon did subsequently subscribe to Elliot and Connolly's 1984 opinion when she (1995, p 15) considered that the grip adopted should permit free finger movement. However, her sympathetic approach is displayed in several other places in the same work when she maintains that the initiators of unconventional penholds may find that they work well and it is the imitators who find them awkward (p 34); that unconventional grips may be faster (p 36); and that unusual grips may be adopted following an accident (p 37).

Sassoon mentioned an interest in investigating the subject of unusual grip writing in 1993 (pp 33-34) suggesting that the numbers required to construct any firm conclusions needed to be greater than the three hundred that she had already included in her survey.

Very little research has been conducted into the types of grips used by adults. Bergmann (1990) investigated adult grip patterns using three different US groups: occupational therapy students, medical students and voters. Of the right handed approximately 86% used a dynamic tripod grip, 10% a lateral tripod grip while the remainder used a variety of other grips although the medical students had a higher rate of lateral tripod grasp (15.0%) than either of the other two groups. Bergmann considered that a mature grasp differs from an immature grasp by dynamic wrist control and distal control of the pen (p 738) although when Ziviani writing in 1983 identified `unusual' and `bizarre' pencil grips' she found it difficult justify such designations as she considered that the `normal' progression of the dynamic tripod grip beyond the age of seven had remained unresearched (p 778) although she considered that maturation involved increasing index finger flexion and forearm pronation (p 781).

The presumption the published literature is that a grip is an alternative to the dynamic tripod if it used by adults (Bergmann 1990, p 738). Indeed Bergmann considered that the lateral tripod grip was not a handicap to educational achievement simply because it was so common in medical students. Although Bergmann's incidence of lateral tripod and other non-tripod grips was lower than observed in Schneck and Henderson's 6 year-olds also published in 1990, the differences in the proportions of the types of grip observed could equally be due to an increasing incidence rather than maturation. Indeed Bergmann suggests that cultural changes such as the telephone, word processors and even multiple-choice examinations curtail the need for handwriting and that certain grips such as the lateral tripod are now adequate for purpose, although she considered that there is a need for further research into how legible and fast specific alternative grips are.

This need for additional research was also encouraged by Dennis and Swinth (2001, p 182), for it is only when grasps that adversely affect handwriting performance have been identified that interventions earlier in individual pupils' school careers can be based on empirical evidence. They observed a higher incidence of atypical grip than previous research had suggested (without giving rates); further suggesting that the prevalence of atypical may have increased (p 182).

Table 1:1 The range of non-tripod grips previously identified in the literature

Grip	**First identified**	**Earliest identification**	**Alternative grip names**
Quadrupod	Carlson & Cunningham	1990	Modified tripod (Ziviani 1983)
Lateral tripod	Bergmann Schneck and Henderson	1990 1990	Untitled illustrations Levine et al (1980, p 92); Ziviani and Elkins 1986 (p 253 Figure 4)
Lateral quadrupod	Dennis and Swinth	2001	
Four finger	Tseng	1998	
Index	Benbow	2006	
Quadrupod grip with middle finger dominance	Dennis and Swinth	2001	
Interdigital	Bergmann (long nail adaptation) Tseng (young children)	1990 1998	
Tripod (quadrupod) grip without web space	Tripod variant Dennis and Swinth	2001	

LEFTHANDED GRIP

The issue of handedness must be addressed in the study of any aspect of handwriting. Although the hand used for writing is the aspect of handedness which is most often employed in a simple right/left categorisation it is only one of a number of skills in which hand preference may be noted. In Annett's 1998 comprehensive study of the subject she identified eleven skills other than handwriting (p 67) and showed that 30% of the population may show some mixed handedness with a small but significantly higher proportion amongst those with reading difficulties (Eglington and Annett 1994, p 1615). The current study is only interested in handedness as it affects writing grip and left-handedness, for this activity, has a rate of around 10% (Bradley 1992). The rate varies according to gender and especially age (Coren 1992, pp 50, 206) as it has been affected by the practice of forcing young children to write right-handedly which was commonplace until relatively recently (Annett 1998, p 65). The issue of handedness will be considered in greater detail in Chapter 3, when it arises in relation to design structure but at this juncture the focus is on left-handedness and the problems that it causes while writing and especially those related to grip.

The problems for left-handed writers of a left to right script and the ways that left-handed children may improve their writing have been described in many texts dating from at least as early as left-handed writing became an acceptable choice (Cole 1955; Enstrom 1962). The main problem is that the grip needs to permit the writer to see what they are writing. In response to this problem and in the absence of specific left-handed instruction some left-handers develop awkward grips if left unattended when they first start school and mirror right-handed writing (Sassoon 1995, p 16). A particular left-handed variation to writing irregularity is the adoption of a hooked grip with the hand held above the writing and `letting a child write with and incurved grip, particularly in the case of left-handers, is storing up trouble for the future' (Sassoon 1995, p 64).

EFFECTS OF PENHOLD

A review of the literature concerning the effects of grip on handwriting is both illuminating and confusing. Illumination is found in the many surveys of style and especially speed but confusing because so little research seems to have been conducted about the causes and consequences of these problems. A prominent contemporary proponent on the importance of handwriting, Rosemary Sassoon acknowledges the work of centuries past in the preface to her 1993 book `The Art and Science of Handwriting' when she wrote `some doctors in the last century (19^{th}) wrote more sensibly about the problems of writer's cramp then many specialists do today' a point enlarged on later in the work when pain and its association with writer's cramp are considered (pp 97-99). Recall Freeman's 1922 warning (p 18 above) that the fingers should not be bent too much as it inhibits flexibility and leads to cramping and fatigue.

The effects of a poor penhold may be numerous, including slowness, distorted writing and pain (Sassoon 1990a, p 35) and it has also been suggested that it may limit handwriting endurance (Bergmann 1990, p 738) and that a negative attitude to writing may be indicative of problems (Ripley et al 1997, p 34). Those of interest to this research are the effect on handwriting speed, which will be considered below, and pain. Painful writer's cramp from an occupational therapist's perspective may be due to a `dysfunctional grip that is placing undue strain on specific muscle groups' (Ziviani 1987, p 33). Pain while writing is not normal, although this is not necessarily understood by children for whom writing has always been uncomfortable or even painful. To ensure that handwriting is pain free, children need to know that pain is the body's warning system (Sassoon 1999, p 159). Pain while writing may be caused not only by the way in which the pen is held but also by an excessively tight grip (Taylor 2001, p 50).

Linked to pressure on the pen is the choice of pen: fountain, ballpoint or gel. Some of these pens make marks more easily than others and when a mark is more difficult to make, as, for example, with a cheap biro then the pressure exerted on the pen must be greater and as observed in the previous paragraph so the pen must be held more tightly. Ziviani (1987, pp 34-5) was not only concerned about this choice of pen but also the nature of its surface, believing that `when learning to write, children should not have their attention diverted from the task by unnecessary concentration on the implement being used' and that an inappropriate choice of pen could exacerbate awkward grips.

There has been limited research into the effects of grip on handwriting speed. Summers and Cattaro's (2003) research established that under some conditions the students who utilized lateral grips (tripod and quadrupod) had writing speeds approximately 3 words per minute slower than those who used the corresponding dynamic grips.

As noted above the actual quality of handwriting may be affected by poor grip. Schneck (1991, p 704) found that six year-olds with poorer handwriting were statistically more likely to be using a less mature grip based the grip categories of Schneck and Henderson (1990). Burton and Dancisak (2000) also demonstrated that the dynamic tripod grip produced greater accuracy than the lateral tripod grip although their result was not statistically significant.

Poor penhold (Sassoon 1990a, p 59) is one amongst the many causes for slow handwriting speed with others including: general learning difficulties, visual impairments, spelling difficulties, poor information processing, problems with motor coordination (Developmental Coordination Disorder), inadequate tuition, failure to use cursive writing (Allcock 2001a, pp 23-4), neatness, deep thinking, dislike of writing due to criticism (Sassoon 1990a, p 59).

The diagnosis of children with learning difficulties is difficult and some children are not identified as experiencing difficulties. The secondary emotional problems can lead to disaffection as well as underachievement. At a time when success in the external examinations taken during secondary schooling is currently a prerequisite to accessing further education underachievement in school continues to affect young people long after they leave school. Given the problems described above in diagnosing children with learning difficulties this research will investigate whether secondary school pupils with an unusual penhold are performing less well than their classmates.

SUMMARY AND CONCLUSIONS

Most children develop a mature penhold in the early years of schooling and this can best be described as `where the tool is held between the pads of the thumb and index finger' (Taylor 2001, p 49) and this finger pad to thumb pad allows maximum fine motor control. According to Ziviani (1987, p 37) it is the lack of fine finger movements that influence children into adopting a more fisted grip with the writing implement being held closer to the palm and movements created at the wrist and knuckle joints. Summers (2001), however, discovered a weak association between inadequate joint stability in children and the lateral and quadrupod grasps (pp 133, 138-9). The conjecture that permeates the literature that children's grip will continue to mature (Ziviani 1983, p 778; Schneck and Henderson 1990, p 897) seems presumptive. The hypothesis referred to in the conclusion of Bergmann's paper (1990, p 739) that of `a societal trend towards atypical grip' has nowhere been formulated in the literature to which access has been obtained but all the data that suggests that children's grip will continue to mature is equally supportive of the proposition of societal shift. The incidence of lateral grip reported has risen over the years. Only tripod grip was reported after the age of four and a half by Rosenbloom and Horton's (1971) but lateral grip rates were to 22.5% and 44% respectively of Schneck and Henderson's (1990) and Tseng's (1998) six year-olds; 56% of Summers (2001) seven year-olds; 43% of Koziatek and Powell's (2003) nine year-olds and 58% of Tuckett's (2006) five year-olds. The reason for this lack of universality of the tripod grip is unclear although Benbow (2006, p 318) considered that inadequate training in the use of the tripod grip might be the cause while Summers (2001) associated it to joint laxity.

There is significant research on the range of alternate grips employed in modern classrooms although sometimes varying as to what is considered a mature grip. The majority of writers including Schneck and Henderson (1990); Tseng (1998); Koziatek and Powell (2003) and Tuckett (2006) consider both the dynamic and lateral variations of the tripod and quadrupod to be mature. The dissenting view was expressed by Carlson and Cunningham (1990) who considered that their grips 4B (lateral quadrupod) and 4C (dynamic quadrupod) were of intermediate maturity. However, these prescriptions are often subjectively arrived for Schneck and Henderson (1990, p 896) classified the lateral tripod as `mature because we observed it in many of the oldest children studied' rather than based on empirical research concerning the consequences of unorthodox grips.

While the pulp surfaces of the oppositional thumb and index finger creates the dynamic tripod grip, the variation in which two fingers are employed in opposition to the thumb creates the grip termed by Ziviani in 1983 the modified tripod (p 780) and reported as quadrupod by Carlson and Cunningham (1990); Tseng (1998); Dennis and Swinth (2001); Amandson and Weil (2005, pp 590-1) and Tuckett (2006). This grip, usually involving the thumb, index and middle fingers, is a grip with arm movements controlled principally by the shoulder and elbow (Erhardt 1994, pp 14, 45, 50).

Thus, although many children eventually adopt a tripod penhold, a significant number do not. The purpose of this research is to investigate whether these children's experience of writing differs to that of other children, particularly in respect of writing speed and pain while writing. The next chapter will consider the range of research techniques employed in previous research and assist in the structuring of the final research.

CHAPTER TWO

CRITICAL REVIEW OF RESEARCH METHODOLOGIES USED IN STUDYING HANDWRITING

INTRODUCTION

The purpose of this research is to investigate whether secondary school pupils with unorthodox grips writing experience differs to that of their peers. This chapter will assess the research techniques used in previous research. The methods by which the validity and reliability of these techniques were scrutinised will also be considered.

Although the way children's manipulative skills develop is well-established, until recently very little research into the range of grips used while writing had been undertaken. Much of this research has rightly focused on young children, leaving the longer-term consequences of an unorthodox grip less well reported. Indeed there is a prevalent attitude that if children use a grip, or especially if it used by adults, then it is a functionally acceptable alternative to the dynamic tripod grip.

New grips are still being reported for the first time with Dennis and Swinth (2001, p 182) commenting on the high incidence of atypical grips observed in their study that this `indicates that the prevalence of atypical grasps may have increased since those previous studies were conducted'.

Research into the appropriateness of unorthodox grip patterns is incomplete since much of it has only involved a few alternatives such as the quadrupod, its lateral variant and the lateral tripod. Bergmann (1990, p 739) argued that since there are so many modern alternatives to writing `the need for extensive handwriting is becoming more limited'. Although the research dealt with adults, her argument questions the importance of handwriting for schoolchildren as `questionnaires and multiple-choice tests are taking the place of essays'. This attitude overlooks the fact that although modern coursework may be word-processed, handwritten examinations are the method by which secondary school children are currently assessed. Handwritten work is the means by which children are placed in groups within the school, often impacting on the GCSE tier, thereby the grades possible at the conclusion of their education. If a child is handicapped by poor writing, whether in terms of speed or because they are suffering an abnormal amount of discomfort while writing, then a child might journey through a whole school career without ever achieving what he or she is capable of and without his or her underachievement being appreciated. Although grip may be only one reason for poor writing skills Ziviani writing with Wallen recently (2006) considered that there was still the need for more research into the relationship between typical and atypical grips (p 220).

RESEARCH METHODOLOGY

It is an important aspect of this thesis that a child with poor or delayed motor skill development may acquire a less efficient penhold during the early years of their education, and that this unusual grip may persist into secondary education.

Although a longitudinal study of individual child's grip development would be desirable, it is generally impractical to follow individual children from reception to secondary school. Indeed the practical difficulties, especially the long timescale and financial implications (Cohen, Manion and Morrison 2007, p 214) mean that very few longitudinal studies of handwriting have been carried out (Sovik 1993, p 243; Barnett and Henderson 2005, p 187). Furthermore, longitudinal studies place a very heavy burden on the individuals involved and there is usually a high attrition rate (Cohen et al 2007, pp 214-6). In addition, the retest effects may affect the validity and reliability of the results (Cohen et al 2007, p 214; Geuze 1993, p 308). This is especially important when the subject of the research is pengrip. Writing for most individuals, after an initial learning stage, becomes an automatic process not requiring conscious thought. However, experience indicates that if pengrip is mentioned then individuals become aware of their grip and become more likely to then pick up a pen and use a tripod grip. This would obviously cause difficulties if a researcher was to observe a pupil's writing on multiple occasions and also indicates the importance of not revealing the exact nature of the research until after the participant has completed all writing tasks. Another consequence of the intense nature of longitudinal studies means that the numbers of individuals studied is inevitably very small (Cohen et al 2007, p 217). Longitudinal cohort studies are particularly appropriate to the study of development (Cohen et al 2007, p 217) and can elicit valuable information that could explain the developmental progression involved in the formation of unusual grip. However, it is not the intention of this research to investigate the chronological development of handgrip of a small number of individuals and thus a longitudinal study is contraindicated as it is an intrinsic aim of this research to identify and classify as wide a range as possible of unusual grips. Thus this research intends to utilise the cross-sectional approach used by the majority of the researchers into handwriting difficulties associated with variation in handgrip. A variety of methodological approaches have been employed in cross-sectional research projects and these are considered in detail.

A refinement of cross-sectional research is to use matched pairs of children. Dennis' and Swinth's (2001, p 177) research involved using matched pairs, where one child used an awkward grip while the other used the dynamic tripod. Dennis and Swinth (2001) also used a comparative method in their study of US fourth graders, although in this research the independent variable was grasp pattern, dynamic tripod and atypical grasps (p 177). The children were from five classes in three schools from Washington State. One researcher identified the children with atypical grasps before they were matched for age, gender and hand dominance with others from the same classroom. None of the children were receiving any teaching or occupational therapy support (p 178). Parental permission was sought from all 118 pupils in the classes involved and consent received from 51 with 46, 23 pairs being included in the final sample (pp 178-179). The writing samples were assessed for legibility. This is discussed below (see p 58).

Groups of participants may be matched with others on the basis of age and other variables. Connelly et al (2006) used control groups in their research into the problems dyslexic university students encounter, considering not only ability but also broadly the subjects studied. The nature of this research allowed the dyslexic students to be matched with other non-dyslexic students of the same age (chronological age match) and a younger group with the same spelling age as the dyslexic group (spelling skill match) (p 181).

A second aspect of the research, which must be considered, is the way that the sample is obtained. Random sampling with a strict sampling frame ensures that every individual (or school) has an equal chance of being included. The advantage of this method is that it allows conclusions to be extrapolated to the wider population (Cohen et al 2007, p 109). However, much of the research reviewed uses opportunity or cluster sampling, that is sampling on the basis of geography and other apposite features in the selection of the classes or schools. Despite an element of deliberate selection of those to be involved in the research, considerable attention is paid to the selection of schools that are as representative as possible. In addition rigorous measures are taken to ensure that the children are within the normal range of ability (Ziviani and Elkins 1986).

Further refinements allow population variables to be considered. Sovik et al employed a stratified random sampling procedure in their 1993 study of handwriting speed and other parameters. They again used matched pairs selecting 16 fifteen year-olds, eight with good handwriting and eight poor writers. The small number of participants permitted the use of a digitising tablet and electronic pen. The subjects were filmed with three cameras. Schneck (1991) in her sample of 60 six year-olds used a similar research methodology, selecting thirty pupils with good handwriting and thirty with poor handwriting but also including equal numbers of boys and girls in each group. There is no reference to a photographic record being made of the children's grip patterns in the publication of this research.

Tuckett (2006) unlike Carlson and Cunningham (1990) and Burton and Dancisak (2000) was not able to stratify her sample according to age and although she included equal numbers of boys and girls in her research the age distribution was uneven (p 29). The children were tested in small groups; the three and four year-olds were seen in pairs while the five year-olds were tested in groups of four (p 30).

A final consideration in considering the sample is who is to be involved in the research. Is it to be all those in a particular setting or merely those who consent? In Rosenbloom's and Horton's study of the development of the tripod grip they analysed the grip of all the children in the selected nursery, nursery school and primary school, with their research including children between the ages of eighteen months to over six years. None had any overt learning or physical difficulties. The children were each observed covertly by two observers for five minutes with a nursery nurse encouraging them to perform an appropriate written activity. Since it was necessary to determine whether the child had developed the localised finger movements of the dynamic tripod grasp the older children were encouraged to write their name while the youngest added small circles as eyes to the drawing of a face (1971, p 3). Dutton (1992) in his research into writing speed, also sought to survey the writing all the pupils in a single school, although time constraints eventually meant that only a sample of ten male and ten female scripts were scored (p 85).

All the pupils for whom consent was received, participated in Koziatek's and Powell's (2003) study investigating handwriting speed and grip in pupils in the fourth grade of four US schools. The test was administered individually to each pupil with photographs being taken as they wrote the alphabet (p 285): these still photographs permitted subsequent grip analysis.

A cross-sectional approach is widely utilised in all types of educational research due to time and cost restraints and because they are `less likely to suffer from control effects' (Cohen et al 2007, p 217). They are frequently employed in research into various aspects of handwriting and would be appropriate for research into the effect of grip during secondary schooling. Opportunity sampling with appropriate restrictions, for example, the exclusion of pupils with learning difficulties, is extensively employed in such research although the use of this sampling method may restrict the conclusions that can be drawn from the results. Carefully matching pairs of pupils for multiple variables is a refinement of opportunity sampling which does permit some statistical inference to be made. However, whichever sampling method is employed the final sample will be affected because not everyone initially selected will be willing to participate. As this issue affects much educational research it is a factor that thoughtful research design can try to minimise rather than eliminate. However, given that the nature of this research is to attempt to identify and classify the various unorthodox grips employed by secondary school pupils a statistically representative sample is unnecessary. Other researchers in their identification of grip patterns have used a variety of classification techniques to convey their findings and it is important to consider these before continuing.

GRIP

While immensely sophisticated methods of describing the way the hand grips all manner of objects have been devised (Jacobson and Sperling 1976), the characterisation of the tripod positioning of the fingers on a pen as ^{1}OMEIFP/^{2}CMFI*FP/^{3}MFIFS/W, for example, does not ease comprehension.

Another early study of grip investigated the way that young children acquired the dynamic tripod grip (Rosenbloom and Horton 1971). As with much analysis of grip the classification is narrowly related to purpose, which in this research was to plot the acquisition of the dynamic tripod grip and thus only three outcomes were recorded. Children were using a dynamic tripod grip, or had a tripod grip without localised finger movements making it a static tripod grip or to be at an earlier stage of development. Although the dynamic/static tripod distinction cannot be determined through still photography, each of the grips referred, including the rudimentary supinate and pronate grasps, is illustrated. These together with additional notes on laterality and the way the children handled their writing tools allowing the developmental process to be fully explained (pp 3-4).

Most recent research [including Burton and Dancisak (2000), Yakimishyn and Magill-Evans (2002)] into grip variation has based their classification on that of Schneck and Henderson (1990). Just as Schneck and Henderson described a new variation, the lateral tripod (referenced to Schneck's 1987 unpublished work), this classification has been added to by others describing previously unreported grips. Tseng's classification of grip in her 1998 study of Taiwanese children between the ages two and half and six and a half was based on that of Schneck and Henderson (1990). Her research involved 326 children from a variety of socio-economic backgrounds from ten nurseries and kindergartens in her research conducted in Taipei. All children were of normal ability and none had any motor or sensory deficits. Children were tested individually, accompanied by a parent or teacher, or if older than three and a half as one of a group of three children. The children copied shapes or drew small circles and were videotaped for three minutes. These videos were used for the purposes of identifying the child's grip pattern (1998, pp 212-7). However, during the course of the research four additional, previously unreported grips were identified, three interdigital grasps in which the pen variously projects from between the index and second fingers; the second and ring fingers or the ring finger and little finger as well as the quadrupod grasp. This is described as 'identical to the dynamic tripod except the at the pencil was stabilized against the radial side of the fourth digit by the thumb pulp with the index and middle finger pulps on the shaft, and the thumb stabilized in full opposition' (pp 213-6).

The lateral variation of the quadrupod grip – the lateral quadrupod and another newly identified variation of the tripod grasp - tripod grasp without web space were first described by Dennis and Swinth although they acknowledged that `these two grasps were possibly included in the lateral tripod groups of previous studies' (2001, p 180). However, just because Tseng (1998) and Dennis and Swinth (2001) first named and recorded the incidence of the quadrupod and lateral quadrupod respectively, does not mean that children had not been using these grips previously. Indeed Carlson and Cunningham (1990) in research on the effect of pencil diameter on preschool children's writing that will be considered in greater detail below, described a grip (4C) in which the `pencil is held with index and middle fingers on one side; thumb is opposite index finger, ring finger supporting the pencil opposite the middle finger' and (4B) `pencil is held with index and middle fingers on one side; thumb is crossed over index finger, ring finger supporting the pencil opposite the middle finger', apparently the quadrupod grip and its lateral variation (p 283).

Not all researchers though, have had to add new grip patterns with Burton and Dancisak (2000) successfully identifying all the grips in the 60 three to five year-olds in their Minnesota research with Schneck's and Henderson's ten categories (1990, pp 9, 13). This research required their three, four and five year-olds to follow a three-sided track, up, across to the left and down. Three different lengths were provided, the length of the tracks being scaled to approximately 40% the length of the children's index fingers. This scaling was done to prevent the children adjusting their hand position as they preformed the task, with a drawing task selected, as it required little prior knowledge. The task was undertaken four times with each of five pens of different diameters; the child's hand recorded on video as they completed the drawings (p 12). Subsequent to her work with Henderson (1990), Schneck condensed the ten different grips described in her work to five groups based on the mean chronological age at which the grip was observed (1991, p 703). This grouping meant that both the dynamic tripod and the lateral tripod grip both have a score of five – the most advanced grip.

Other classification systems also result in different grips being grouped together. Summers (2001) used a binary classification, for example the position of the thumb was either `opposed' (value 0 - most desired) or `thumb contact other than pad' (value 1) resulted in four different thumb positions: `against the radial border of the index: flexed over the index; flexed under the index;' and `held against the pencil shaft along the ulnar border' all being categorised as lateral grasps (pp 137-8).

Two recent studies by Tuckett (2006) based the classification of the grip used by three to five year-olds on that of Tseng (1998). The assessment of grip was carried out as the children drew a picture of a person or, in the second study using different writing tools, copied shapes. All but one child's grip could be assessed using Tseng's 14 grip types a failure rate that Tuckett believed acceptable for generalising grip patterns to permit every idiosyncrasy to be included would curtail comparisons with previous research (p 32). Carlson and Cunningham also recognized that not every grip could necessarily be included in their ten grip type categories for they had a category `other' in which `pencil is held using any grip other than those described above' (1990, p 283).

Another analysis that initially employed that of Tseng (1998) was that into the grip used by fourth grade pupils by Koziatek and Powell (2003). The two researchers independently undertook the task of determining the grip from photographs taken as the children wrote. However, as observed in the previous chapter, they recorded a high incidence (21 out of 101) of the lateral quadrupod first named by Dennis and Swinth (2001, p 285).

Other researchers have adapted grip classifications to suit their sample. Carlson and Cunningham (1990) for their research on the effect of pencil diameter on preschool children's graphomotor skill based their classification on Rosenbloom and Horton (1971). This system coded for the number of digits in contact with the pencil which together with a letter identified the precise grip so that, for example, the tripod grip is `pencil is held with index finger on one side; thumb is opposite index finger; middle finger is supporting pencil opposite index finger' is 3C one of the three variations of a three digit contact (p 283). Forty-eight children from a single private nursery school participated in the research; these were selected randomly from those whose parents consented, with the sample being stratified for gender and in 3 six-month age bands. Initially Carlson identified grip, although subsequently a sample of the 48 participants had different aspects of the research assessed for inter-rater reliability (see p 44) although the ten grip classification was condensed to three for statistical analysis (p 283). The least mature group included 5C and 4A that had three fingers (index, middle and ring) in opposition to the thumb the difference being whether the little finger supported the pen. The middle group included 4B (equated with the lateral quadrupod grip above) and 4C (equated with the quadrupod grip above) while the most mature group comprised only 3B `pencil is held with index finger on one side; thumb is crossed over index finger; ring finger supporting the pencil opposite the index finger' (lateral tripod grip) and 3C (tripod grip – see above). The static or dynamic nature of the grip was considered as another variable.

The process by which a grip is identified has been treated in a number of ways by different researchers. As observed above, Koziatek and Powell independently undertook the task of determining the grip from photographs (2003). However, in Summers' and Carraro's (2003) investigation into the writing of young adults the participants themselves (occupational therapy students) rated the percentage of time each of the four possible grips was used during the each of two 2 hour examinations sustained activities. The four grips were described to them and they were provided with two photographs of each grip upon which to base their decision. They were only able to identify their grip as either the dynamic or lateral variation of the tripod or quadrupod grasp. There are a number of problems with this approach to ascertaining grip. First only four possible grips grip patterns could be reported while other researchers have reported a greater variation in grips used. Only occupational therapy students were involved, meaning that the sample was predominantly female (89%). In addition, there was also a higher than expected number of non-right handed participants (18%). Self-analysis would seem to be a particularly unreliable method of determining grip and no attempt was made by the researchers to check whether or not the grips reported were accurate. The participants were required to report the proportion of time each grip was used in each examination. These examinations appear to have been actual examinations, presumably affecting the students' degree and future career. It would be expected that that in these circumstances the students would be totally engrossed in what they were writing and would be unconcerned about the grip they were using. Moreover, two examinations were reported on. The students reported on the first before they took the second. This means that the grip they used in the second examination may be affected by the fact that they were aware that the research was being conducted. Furthermore these were occupational therapy students who could not necessarily be defined as representative of the population, as they were likely to have some aptitude for manual dexterity. Finally, if they were aware of the research they may have felt that the grip they used, or reported as having used, during their examinations may affect their suitability to become occupation therapy professionals. The eight facets of this research that could each have prejudiced the outcome illustrate the risk of bias in a non-probability sample (Cohen et al 2007, p 110).

Other research has attempted to use photography to record pencil grasp but when this proved ineffective because not all the fingers could be observed a classification form eventually had to be used (Summers 2001 pp 137-8) although others have been more successful. Ziviani and Elkins 1986 (p 249) took photographs from an anterior and lateral angle. They fixed the camera to a board in order to keep the camera position constant with the static grip being analysed from the photographs. The various components of pencil grip analysed using monothetic divisive method of cluster analysis and four groups were identified. The first two groups had index fingers flexed more than 90° (distal joint bend back) varying in the degree of rotation of the forearm. The third group lacked pad to pad opposition (the descriptive illustration (p 255) shows the pen held between the index finger pad and the thumb knuckle while the final group has a relaxed forefinger with pad to pad opposition (tripod grip).

As observed above, obtaining a representative sample can prove difficult. The selection of different subjects at different ages means that sampling procedures can never be comparable, a problem acknowledged by Cohen et al (2007, p 21). While children are gathered together in cohort groups in schools that can be assessed socio-economically, adult sampling is inevitably more problematic. Bergmann's research conducted in the United States, in 1988, and published two years later, investigated the incidence of unorthodox grips in 485 adults. This research was based on opportunity sampling as three groups of adults were observed writing in functional situations: namely occupational therapy students signing their names, voters signing to register and medical students taking an examination. The observations were made by a single researcher (p 737), the grips were not recorded photographically and there is no evidence of any inter or intra-rater reliability assessments being made. The range of grips were reported for right-handers only as writing with the left `appears to stimulate the development of wrist and finger positions distinct from the typical right-handed writing posture (eg hooking)' (p 737), 7.8% of the sample was thus removed. Of the right handed approximately 86% used a dynamic tripod grip, 10% a lateral tripod grip while the remainder used a variety of other grips – the transpalmar interdigital (possibly an adaptation to long nails); cross thumb; dynamic bipod and static tripod. The validity of this sampling technique will be considered below (p 50).

Reliability

This section is going to consider how reliable the assessment of the types of grip described above are and how previous researchers have tackled this issue. If conclusions were to be made about, for example, the speed of writing with a particular non-tripod grip, then such conclusions would be void if another individual were to consider the grip unexceptional. As noted above, over recent years a number of new variants of grip have been described, but it is clear from Carlson and Cunningham's work in 1990 that children have employed many of these grips without being reported as a distinct grip pattern. Dennis and Swinth describe a novel grip: the tripod grasp without web space. This is a grip in which the index finger and thumb are positioned on the same side of the pen, without opposition between index finger and thumb, recognising that this was probably a grip that had been included with tripod grips (2001, p 180).

There are two ways in which reliability may be assessed, either a different rater may view the same writing activity (or photographs thereof) producing a measure of inter-rater reliability or the same rater may subsequently reassess either a still photograph or video, creating an intra-rater reliability score. Such reassessment can, obviously be made from photographs but if reassessment is made of a second writing activity then a potential source of error to the intra-rater reliability result may arise if the writer uses a different grip.

Rosenbloom and Horton (1971) had two observers independently record the grips used by the children while they performed an appropriate written activity. Given the young age of the children and the two adult observers, the observation was done covertly. Only three possible outcomes were recorded; the children were considered to have demonstrated the use of the dynamic tripod, the tripod posture without intrinsic movements or to be at an earlier stage of development. There was no disagreement between the observers as to which of the three stages of grip development any of the 128 children had demonstrated (1971, pp 3-4).

Photographs were initially used to identify the grip used by children in Koziatek's and Powell's 2003 research. There was 76% agreement between the two raters. This is a low level of inter-rater reliability although the two researchers then reviewed their findings and worked collaboratively to finalise the grip used by each child (p 285). A similar approach was used by Ziviani and Elkins (1986) who had two raters view each still photograph and rated them for four criteria in accordance with a previously published set of criteria (Ziviani 1983). Inter-rater agreements (Cohen's Kappa – [observed-chance agreement/1-chance agreement]) were calculated for each variable of interest with the following results: index finger flexion 0.94; forearm pronation 0.87; number of fingers on shaft 0.97 and finger opposition 0.90.

Not every individual in a study need be reassessed in order to establish inter-rater reliability. Yakimishyn and Magill-Evans (2002) had a second occupational therapist double code the trials of every fourth child from videotapes. The agreement using Schneck's (1991) condensed five point scale of maturity was high at 90.1%, although this scale relates to maturity and groups different grips together, for example, the dynamic and lateral tripod grips. As a second check of reliability the trials of every second child were double coded 2 months later, again from video. This produced an intra-rater reliability of 95.1% (p 566).

Tseng also employed videos rather than still photography, where she and an assistant viewed the videos of each child in order that the most mature grip could be ascertained in accordance with Schneck and Henderson's ten categories of grip (1990). It is not clear whether the assessments from the video recordings were made independently or collaboratively. The account of the research reports that in a pilot investigation using 30 children the inter-rater agreement (Kappa coefficient) on pencil grip was 0.96 (Tseng 1998, p 217). In the research proper, involving 326 children, there is no evidence whether there was any disagreement over the categorisation of any of the children's grip pattern. However, as noted previously, four new grips were identified in this research, and it must be concluded that an element of disagreement must have been involved to classify 9 children as using one of the interdigital grasps and 66 the quadrupod grasp (p 212).

Schneck and Henderson (1990) used the ten grip classification that had been piloted in Schneck's 1987 published work with an inter-rater reliability of 0.90. In the 1990 research 20 of the 320 children were retested a week after the initial grip classification with an intra-rater reliability of 0.85. Burton and Dancisak (2000) also assessed the grip forms used by children using Schneck and Henderson's (1990) 10 point scale. Initially one rater assessed all 1200 trials by their 60 participants. A sample of all the trials two children in each age/gender grouping children were reassessed by the same researcher with an intra-rater reliability of 0.75. When a modified five point scale (Schneck 1991) was used this improved to 0.87 with a kappa of 0.67. A second rater coded a sample of the trials the inter-rater reliability using the two scales were 0.67 and 0.80 respectively (Kappa 0.64) (p 13).

An alternative ten grip categorisation based on the number of digits in contact with the pencil and the way in which they were placed was used by Carlson and Cunningham (1990 p 283). Initially Carlson working alone identified grip, although subsequently a sample of 12 and 16 of the 48 participants had different aspects of the research assessed for inter-rater reliability. However, it is unclear how `a second observer record(ed) management information' involving `12 observations of grip type and 2 observations of finger movement for each child' when no photography was involved (p 284). It has to be presumed that a second observer recorded the relevant data by observing the initial interactions; although the way these 16 children were selected is not evident. The inter-rater reliability for grip was 93%, while for finger movement it was 94% (p 285).

Validity

Much of the research into the grip employed in handwriting has not explicitly sought to be representative of the population at large. This is unlike surveys of other types, such as Alston's 1983 and 1985 research into the legibility of children's writing which chose a sample of schools to represent the region and the region to represent the country. Those involved may come from a single school, presumably as an opportunity sample (Koziatek and Powell 2003, p 285) or from several randomly selected schools in a particular area (Ziviani and Elkins 1986, p 249). All those in a cohort from a particular setting may be assessed (Rosenbloom and Horton 1971, p 3), but the more complex the testing procedure involved, the less likely it becomes that parental and / or participant permission will be complete, although this may be ameliorated if the sample is carefully stratified for age and gender as, for example, in Carlson and Cunningham's research (1990, p 282).

One of the few published pieces of research into the type of grip used by adults, and for this reason most interesting, failed to consider the validity of the sample (Bergmann 1990). Three different groups of adults were sampled occupational therapy students, medical students and registering voters. The occupational therapy students were predominately female (96.5%) while the medical students were mostly male (65%). Presumably these two groups were both young while voters may have been more variable in age, although this is not reported. It is also likely that the medical students' ability is at the upper end of the range, a factor that may also apply to the occupational therapy students. Indeed the medical students did have a higher rate of lateral tripod grasp (15.0% compared with 9.1% and 8.4% for the occupational therapy students and voters respectively).

Over the past forty years an increasing number of different grips have been reported in the literature. In 1971 Rosenbloom and Horton described only three, Schneck and Henderson (1990) ten, Tseng (1998) fourteen, while in 2001 Dennis and Swinth added two previously unreported grasps - the quadrupod and its lateral variation. The identification of grip can be undertaken in a variety of ways. While it is undesirable of the participants themselves to ascertain their grip there remains real time determination, video or still images. Each approach has its own problems. If the determination of grip is made during the writing without photography there is no chance of reviewing the decision while either type of photography may risk fingers being obscured making accurate identification difficult. In addition still photography eliminates the crucial dynamic element vital to the handwriting process. Obtaining an appropriate sample of school age children is relatively simple although the published researchers' attempts to provide a balanced adult sample have proved problematic. Bergmann's (1990) analysis of voters signing to register perhaps comes closest, although it would obviously be inappropriate to take photographs in such a situation. Lack of photographs effectively eliminates the possibility of obtaining an assessment of either inter or intra-rater reliability. Although it would seem a relatively simple task to identify grip, when this can be calculated inter-rater reliability generally falls (often) far short of a confidence level of 95% indicating how difficult it is to definitively classify grip.

In this research it is intended to identify the unusual grip during an initial survey stage. The pupils identified will then be matched for age, gender and school ability groups (sets) with pupils using a tripod grip. During subsequent individual appointments with each of the identified pupils, careful notes of the grip pattern will be taken together with still photographs of each pupil's grip. This will allow inter-rater reliability of the grip patterns to be ascertained. These photographs and the detailed notes should allow the identification of a number of sub-groups and permit statistical analysis of aspects these separate sub-groupings handwriting performance. As demonstrated in the preceding survey of literature there appears to be an increasing number of unorthodox grips being identified. It is intended that this research should investigate possible consequences for those who use these grips. It will be instructive to consider how other researchers have approached the assessment of these variables.

HANDWRITING SPEED

Amongst the factors considered to affect handwriting speed are the style, grasp used, the pain or fatigue experienced as well as academic ability. Good handwriting requires both speed and legibility (Summers and Cattaro 2003, pp 149-150) with the need for these increasing over a child's school career (Sovik et al 1993, p 134).

The simplest method of testing handwriting proficiency is to measure handwriting speed (Sovik 1993, p 243). The testing of pupils' handwriting speed is less frequent than the testing of their reading and spelling (Roaf 1998, p 39; Allcock 2001b). Moreover, the standardisation of tests is much less well defined with each test testing a different facet of the writing process in addition to mechanical writing skill. For, in addition, to simple mechanics functional writing includes transcription, handwriting and spelling, as well as executive functions of planning, organising, monitoring, reviewing and revising (Connolly, Campbell, MacLean and Barnes 2006, p 176) and some or all of these become involved in the various tests that are routinely employed to assess handwriting speed. Even straightforward copying of a text requires scanning, locating the place in the text utilising short-term memory, with the poor performance in the latter together with non-word reading and handwriting speed itself, being identified as the three best indicators of dyslexic difficulties by Hatcher, Snowling and Griffith in their research involving university students (2002, pp 129-130).

Task

When it comes to a handwriting task the basic choice is between a copying task, writing a familiar text or a self-generated writing exercise. However, with very young children simple drawing and colouring tasks have been deemed more appropriate for determining grip (Schneck and Henderson 1990) although since the techniques may differ perhaps they ought not to be considered as equivalent. The authors themselves noted (p 897) that the children would use a less mature grip for colouring the centre of the circle than the outside. Casual observation indicates that adults do not always use the same grip for shading or colouring as for writing. Often it is the more artistically skilled who seem to prefer a looser, less controlled grip for these tasks requiring less precision. Generally the choice of task may depend on the precise reason for testing; is it, for example, a test intended to replicate examination conditions with the aim of detecting those who may under-perform or is it testing the mechanical process of writing (Alston 1994, p 8). The use of a familiar sentence involves the use of long-term memory, while a self-generated writing includes both thinking time and spelling decisions thus producing lower average writing speeds.

Mason (1991) used two of these three techniques: copying and free writing. This investigation was carried out in three schools involved pupils who had just begun secondary schooling. The results from one school were reported in 1991 and the handwriting speed results from the second school confirming the pattern of results were included in a second article in 1992 (p 108). The task Mason set was a short copying exercise of a 100 word paragraph about handwriting. This was done twice, first fast (two minutes) and then neatly (three minutes), in addition the children spent five minutes free writing on the subject of `All about Me' (p 43). These tasks were kept short to minimise classroom time on the assignments. Graham, Weintraub and Berninger (1998) similarly used two techniques, collecting three samples of writing from each subject in their research on the handwriting of pupils in US grades 4 to 9. Speed was calculated on only one of the samples: the one and a half minute copying exercise. Style and legibility were assessed on this sample as well as the two five minute composition exercises that are discussed in the section on legibility, below.

The third possible technique of writing a familiar sentence was used in the research Ziviani and Elkins (1986) conducted into the effect of grip on handwriting speed and legibility. They used two separate tasks, two minutes of writing `cats and dogs' which was analysed for speed and `the quick brown fox jumps over the lazy dog' analysed for legibility. The children were from 6.8 to 14 years old and were selected from four randomly selected Brisbane schools. Ziviani again used the two-minute `cats and dogs' test in research with Watson-Will (1998) when it was used to assess both speed and legibility in children aged 7 to 14. Sovik et al (1993) used a similar technique when asked the fifteen year-olds in their research to memorise a sentence and a string of words. This research, like that of Mason (1991) also varied speed, with the subject being asked to write with a slow normal speed, a fast normal speed or maximum speed (pp 136-7). The results indicate that subjects were successfully able to control their speed (p 147).

Lyth (2004) used a two minute writing test of the ten word sentence `I can write quickly and clearly all the day long' for his 1999/2000 research although this was shortened in subsequent research to `I can write quickly and clearly' in order to more clearly discriminate between writing speeds as only completed sentences were counted. A variation of the writing of a familiar sentence is to write the alphabet. A one minute version of this test was used by Connelly, Dockerell and Barnett (2005, p 101) to investigate the writing speeds of university students. They also analysed both the speed and structure of two extended writing tasks from the same students (pp 103-7).

A three-minute copying exercise was used to assess the handwriting speed of university students (Summers and Catarro 2003) while other research has used a range of tasks. Koziatek and Powell (2003) in their assessment of US fourth grade students included writing the alphabet and numbers from memory, both far and near copying, dictation and sentence composition, these comprising the Evaluation Tool of Children's Handwriting–Cursive (ETCH-C) test. This series of tests cover a range of skills necessary to assess handwriting although as Koziatek and Powell commentated they did not necessarily allowing direct comparison with published handwriting speeds (p 285). Dennis and Swinth (2001) used a range of writing tasks in their matched pairs research comparing fourth grade pupils with dynamic tripod and atypical grips. As these were all part of the different classes' regular assignments they included free writing with titles such as `What I do at Recess' or `The Things that Bother Me', copying various passages about St Patrick's Day and the Original Colonies of the US, or two passages of different lengths about Washington State government. Although the matched pairs received the same instructions since they were part of the same classes, the researchers allowed the class teacher to vary the instructions to the different classes, for example, concerning the style of writing to be employed. They considered that although matching those in their study removed some of the error variability in their results, allowing the tasks to be varied increased legibility error variability (p 181).

When testing older children or university students the decision is made to simulate an examination situation. Dutton (1992) in his research into secondary school pupils writing speeds used a thirty-minute free writing task with the title `My Life History' the conditions replicating examination conditions as closely as possible. The choice of thirty minutes was rather opportunistic as it conveniently fitted into pupils' forty-minute English lessons. Given the potentially sensitive nature of the topic, although pupils' names were included to motivate them, the names were removed before the essays produced were passed to Dutton and his colleagues. Connolly et al also set university students a 30 minute essay on a single topic which did not require too much specialist knowledge but was as demanding as the essay writing by which students are assessed. The task set on this occasion was to produce an essay to the prompt `It is often necessary, even desirable, for political leaders to withhold information from the public' (2006 p 182). Working with different colleagues in the previous year (2005) Connelly had used both a one minute alphabet writing task to assess letter writing speed and then analysed pressured and unpressured writing tasks produced by students as a part of their university course. Although interesting results were produced, indicating that students wrote more in a pressured examination, unfortunately some students admitted after the examination that they had not adhered to the one hour recommended for that examination question.

Handwriting remains an integral part of the education system and is important not only for its own intrinsic merit but because it is used as the primary tool for final assessments. Children need to be able to increase their handwriting speed while maintaining legibility as they progress through school, and handwriting speed has thus been tested in a variety of ways. Writing is not simply a mechanical process but one employing a wide range of other skills, with a deficit in any may cause impair handwriting performance. Tests of handwriting speed varying in length between one minute (Connelly et al 2005) and thirty minutes (Dutton 1992, Taylor 2001). However, the precise timing of a free writing exercise may be varied for Roaf (1998) used a ten-minute test while other researchers have used 20 minutes (Allcock 2001a) or 30 minutes (Taylor 2001, p 43). In addition to the length of the test the exact nature of the task also varies as each assessment seeks to precisely reflect the set of skills required by the participants. A summary of the handwriting speed results for free writing tasks are shown in Table 2:1 on p 54.

Analysis

When the writing task employs sophisticated computer equipment then timing and letter speed can be calculated automatically (Sovik 1993 et al, p 137). However, if this is not used then either a letter or a word count has to be made manually. The precise decision as to which is more appropriate frequently depends on the length of writing sample, which in turn depends on the time allocated to it. Graham et al (1998) counted the number of letters in their one and a half minute writing task while Ziviani and Elkins (1986) and Ziviani and Watson-Will (1998) counted the number of letters over two minutes. Mason (1991 and 1992) reported word counts on his three minute neat copying; two minute fast copying and five minute free writing exercises. He, however, asked the pupils involved to count the numbers of words that they had written in each task, assuming that `all children can count' something that random checks indicated to be untrue. However, the word counts were not repeated (Mason 1991, p 44). Koziatek and Powell (2003) had one researcher score the handwriting speed of their timed tasks and calculate the handwriting speed of the US fourth graders in the study in letters/minute (p 285).

Dutton's results of thirty-minute essays written by secondary school pupils were expressed in words per minute (1992, p 86). In addition to the overall number of words written, the numbers of words written in each three-minute period was also calculated. He also calculated average sentence length and percentage of non-monosyllabic words as indicators of pupils' abilities. Not all researchers have calculated handwriting speed by actually counting the number of words. A large scale survey (Lyth 2004) investigating correlation between writing speed in Year 8 and subsequent examination performance used the number of completed (ten) word sentences to calculate the number of letters written per minute.

Thus although there are in general two ways in which results can be presented, either letters per minute or words per minute, not all published results have been calculated in an identical way. Added to the dichotomy in tasks being analysed it becomes increasing confusing to draw conclusions about writing speed. The extent to which published results have accurately measured writing speeds must also be considered.

Reliability and Validity

Just as the reliability of grip assessments were made so too can the reliability of the letter or word calculations involved in producing handwriting speeds although Dutton considers this to be unnecessary for assessments of numbers of words written. Furthermore in his research, time constraints also prevented double marking of the scripts but since the majority of the information collected was numerical Dutton did not consider this invalidated the results obtained (1992). However, other researchers including Ziviani and Watson-Will produced correlation coefficients to assess the reliability of a range of their results with the reliability coefficient for handwriting speed being 0.99 (1998, p 62). While this calculation could be based on a full recount Ziviani and Watson-Will based this calculation on a sample around 13% of their participants. Graham et al (1998) also assessed inter-observer reliability of their word count to be 0.99 when a second researcher recalculated writing speed in 40% of their sample.

Summers and Catarro (2003) assessed the validity of using a word count rather than a letter count on both the short handwriting test and the longer examination paper reporting validity levels of 0.99 and 0.95 respectively.

The reliability of handwriting speed calculations are very high and far higher than those reported for grip analysis. When a piece of text is being copied then the calculations are relatively simple and many researchers have not considered it necessary to perform a reliability calculation. When calculations of the two different tests (copying and free writing) have been done on the same sample of handwriting (Summers and Catarro 2003, p 152), that for word count is slightly less reliable presumably as crossings out may be counted differently. It is thus important to have very clear rules as to what constitutes a word to ensure absolute consistency in word counts. However, although every effort must be made to ensure replicability it is generally acknowledged that no measure dependant on human interpretation can ever be fully valid and that such measures are a matter of degree rather than an absolute (Cohen et al 2007, pp 133-4).

Choice of Handwriting Speed Test

As stated previously each handwriting speed test also tests other linked attributes such as short term memory and spelling decisions. The choice as to which handwriting speed test to use depends primarily on the purpose to which the result is to be put. Another factor which must considered are the circumstances surrounding the test, particularly the age of the children involved and the time available. Moreover there is evidence that the instructions given can affect the pupils writing speed (Sovik et al 1993, p 145; Mason 1991, p 46).

Relationships between Grip and Handwriting Speed

Sovik et al (1993) found that subjects in their sample with poorer writing wrote significantly faster than their peers with good handwriting. Moreover those considered to have good writing were more likely to be using `a rather awkward grip' and `appeared to have poorer coordination of movement'. However, the precise nature of these awkward grips was nowhere clarified although the conclusion was made that `the grip of the pen seems to play an important role for the efficient (good) coordination of movements' and this in turn affects writing speed (pp 140, 147). Koziatek and Powell (2003) working with 101 fourth grade students on four (short) timed writing tasks found that only the one individual using an interdigital grip had a lowered speed while although Ziviani and Elkins did determine that those with `undesirable' grips wrote more slowly than those whose grip was `desirable', the difference was not significant. However, only one of their four grip groupings did not have pad to pad opposition with the other two atypical groups being based on degree of forearm supination and the degree of index finger flexion. However, the two children that had both fast (58 letters/ minute) and legible (5+) writing had 'what most educators define as a desirable grip (i.e. thumb and index finger opposed on the shaft of the pencil, the pencil resting on the distal phalanx of the middle finger, index finger in relaxed flexion, and the forearm held in more than 45 degrees of supination)' (p 252). Conversely the three children at the other extreme, with slow writing of less than 23 letters per minute and legibility scores of 1 or 2 displayed a variety of grips including the dynamic tripod. However, handwriting speed and legibility were not assessed on the same writing samples nor were the effects of fatigue considered (1986, pp 257-8). However, the majority of research in this area has only considered the four variants combinations of dynamic or lateral tripod or quadrapod (Summers and Carraro 2003, p 151); or been concerned with the grip of young children for whom speed not relevant (Schneck and Henderson 1990; Carlson and Cunningham 1990; Tseng 1998; Burton and Dancisak 2000) or did not include an assessment of writing speed (Dennis and Swinth 2001).

It is against this background of a relative paucity of information that the current research is planned. Far more research has been conducted into the relationship between speed and other facets of handwriting.

Comparison of Handwriting Speeds

As noted previously handwriting speed is very sensitive to the instructions given. Other aspects of handwriting also affect the overall speed, and these have been extensively studied.

Graham et al (1998) found that mixed cursive and manuscript writing was faster than either used exclusively. This was the result that had been expected as once children have completed their handwriting instruction and become confident writers they develop their own personal style. In fact of the four styles the fastest writing speed observed was that that was mostly manuscript (104 letters per minute) followed by mostly cursive (98 letters per minute) then manuscript only (88 letters per minute) with the slowest being cursive (85 letters per minute). Girls were observed to write faster than boys and older children faster than younger (pp 292-3). Mason also observed that girls wrote significantly faster than boys (1991, p 46).

Dutton collected writing samples from each pupil across the age range of a Scottish school. His analysis of thirty minutes of free writing showed that until S5 (Year 5 of secondary education) girls significantly outperformed boys. In S4 boys wrote an average of 15.4 words per minute while girls wrote 18.8. This difference reduced in S5 (18.9 and 17.9 respectively) but what is not considered in this article is that S4 is the year that pupils take their Standard Grade examinations and reach the age of 16 and may leave full-time education after 11 years of full time education (7 primary and 4 secondary) (Education website 2007; see also Mason 1992, p 108). Thus the mean writing speeds for pupils in S5 does not represent an entire cohort of pupils for although the staying on rate is higher in Scotland [72% aged 16 in 1999 (Scotland gov 2007) than in England (DfES 2004 p 27)] boys represent a disproportionate proportion of those who leave at the earliest opportunity as noted by Dutton (p 93). Dutton's calculation of average sentence length showed an increase between Years S3 and S4 and Years S4 and S5 although the reservations expressed above must also be applied to the latter increase (1992, p 87). The percentages of non-monosyllabic words increased in all year groups except between Years S3 and S4 and a similar reservation applies. However, Dutton indicates that preliminary analysis of the essays suggests that it is the three and four syllable words that are more accurate differentiators of ability (p 88). The analysis of the pupils writing persistence is interesting, for all year groups except the youngest show an almost constant writing rate with Dutton drawing the conclusion that `pupils seem capable of writing at a fairly uniform rate for at least half an hour' (p 88).

Although the majority of authors have found that girls write faster than boys there has been research than found little differences between the sexes. Ziviani and Watson-Will (1998) found that following the introduction of a new cursive script into Queensland primary schools overall the there was no statistical difference between boys' (69.9 letters per minute) and girls' (68.9 letters per minute) writing speeds. Girls, however, tended to be faster until the age of 11 while boys were faster after this age (pp 62-3).

The following table summarise the writing speeds found in the literature. Given the focus of the current research on secondary school pupils, only relevant ages are included. The table is from free writing tests as there is insufficient research data to produce a table of copied handwriting speed and the two results are incompatible. Mason (1992), for example, found at age 11 a neat copying speed of 10 words per minute, fast copying speed of 16 words per minute and a free writing speed of 17 words per minute, albeit over only a five minutes test. The results indicate that a writing speed of one words per minute more than the pupils' age is average:

Table 2:1 Table of other researchers' handwriting speed results (free writing). Results words/minute

	Mason (1992)	Dutton (1992)	Taylor (2001)	Allcock (2001b)	Summers and Catarro (2003)
Test length	5 minutes	30 minutes	30 minutes	20 minutes	2 hour exam
11	17	na	na	na	na
12	na	12.7	na	13.9	na
13	na	14.4	12.5	14.6	na
14	na	15.9	14	15.7	na
15	na	17.1	16	16.3	na
16	na	18.4	17	16.9	na
17	na	na	18.5	na	na
university	na	na	na	na	17.75

NB Dutton S1 has been equated with age 12 as the timing of the test during the academic year is unclear.

The exact choice of handwriting speed test is influenced by a large number of factors as whichever test is selected also tests a variety of other skills. In addition, the instructions given before any test of handwriting must be considered since speed and legibility are inextricably interlinked and even tone of voice used in the instructions can affect the speed/ legibility trade-off (Barnett and Henderson 2005, pp 175-7, 180). As this research will be conducted on pupils of secondary school age, a test that most closely replicates the pupils' educational experience is to be preferred. A handwriting speed test that duplicates everyday writing tasks is most likely to detect the problems resulting from the adoption of an unorthodox grip. Consequently, a short free writing task was chosen rather than a copying exercise or repeated writing from memory of a poem, short phrase or the alphabet. Most writing tasks reported in the literature have been undertaken in groups, thereby permitting the setting of longer tasks. However, the focus of this research is the grip and as it is an essential part of the research that discomfort demonstrated while writing be observed. Thus the writing task must be kept short enough to fit into the single, usually one hour, lesson allocated to the detailed interviewing and testing of each pupil.

HANDWRITING NEATNESS AND LEGIBILITY

It has been demonstrated both that pupils can write more neatly, if requested to do so, and that this affects their overall handwriting speed (Mason 1991) meaning that any analysis of handwriting neatness or legibility must take into account the speed at which it was written. While the analysis of speed is based on an accurate word count is a relatively objective measure of handwriting performance. Assessment of legibility is much more subjective and `it is very hard to find a reliable, objective measure of handwriting skill' (Barnett and Henderson 2005, p 173). A variety of approaches to assessing legibility have been employed and some of these are considered here.

Task

An important aspect to be borne in mind when considering the analysis of handwriting is nature of the task set. Not all research into handwriting speed considered above investigated the quality of the written material produced.

Graham et al analysed three samples of handwriting from each pupil. As described previously, a copying task alone was utilised for writing speed but a total of three samples from each pupil were analysed for style and legibility. Prompts of `One day (choose person) had the (choose best or worst ) day at school' and `I like (choose person place or thing) because _____' were used for each of the two extra five minute writing tasks. Unusually the children were allowed to finish their sentence after the allotted time although after five minutes they marked their work and only this material was analysed (1998, p 291).

Schneck (1991) used the tasks of printing the alphabet and copying the sentence `The quick brown fox jumped over the lazy dog' with her six year-old subjects (p 704); Ziviani and Elkins having used this sentence in their earlier research (1986) on six to fourteen year-olds and was also subsequently used by O'Mahoney, Dempsey & Killeen (2008) in to test handwriting speed. Alston, however, had tackled the problem of assessing legibility in a different way. The task she set the Cheshire seven year-olds in her study was to write about their favourite person for 20 minutes (1983).

Thus both copied and free writing tasks have been used to assess legibility with Graham et al (1998) using samples collected both ways.

Legibility Analysis

Generally analysis of handwriting legibility has been conducted by matching the handwriting specimens to a predetermined scale of examples. The main variation is the number of examples in the scale and how many individual assessors independently undertake this task. Thus the criterion is purely legibility not the uniformity of letter size, slant, appropriate use of ascenders and descenders or word spacing that other researchers have used (Stott, Henderson and Moyes 1987, p 141).

The largest number of writing samples was employed by Graham et al (1998) who matched their writing samples to nine graded specimens with two scorers carrying out this analysis independently (p 292). In Ziviani and Elkins' 1986 research, a single experienced teacher graded legibility into seven grades in such a way that there were equal numbers in each category. A similar strategy was used in Ziviani and Watson-Will when two experienced teachers in scored handwriting legibility using the seven-point scale (1998, p 62).

Burton and Dancisak, however, measured drawing accuracy on the line drawing activity with three to five year-olds using a six-point scale (2000, p 13), while Summers and Carraro (2003) assessed a single predetermined page of the students' written examination papers. Although a broad categorisation into three groupings was initially intended (p 151) this had to be refined (p 153) with legibility 1 being defined as `can be read smoothly, there may be hesitation on 1-4 words'; legibility 2 as `hesitation with 5 or more words and/or the flow stops on 1-4 occasions because the word is difficult to read or illegible' and legibility 3 as `flow of reading stops on 5 plus occasions because the word is difficult to read or illegible'.

Schneck (1991) used three assessors to independently rate samples of the children's writing as either good or poor. An individual was only included in the research if at least two of the ratings were the same as their teacher's earlier holistic assessment which required them to make an assessment on the basis of legibility; accuracy of letter formation; uniformity of letter size; uniformity of letter slant; spacing and alignment (p 703).

A radically different approach was taken by Koziatek and Powell (2003) who had one researcher score the numbers of legible letters and words and express these as percentages of the total thereby allowing analysis of any differences between the different grips used by the fourth grade students involved in the study (pp 285-6). This technique is similar to that previously used by Dennis and Swinth who used a range of writing tasks in their matched pairs research comparing fourth grade pupils with dynamic tripod and atypical grips. The legibility of the written samples was assessed using the specific criteria the Evaluation Tool of Children's Handwriting ETCH, although scorers were required to `use their own clinical judgement in determining whether a given letter met the criteria for legibility'. The short writing samples each had fifteen words assessed letter by letter and word by word for legibility producing both letter legibility and word legibility scores. The words selected for analysis were the first, middle and final five words, while for the longer written samples only a word legibility score was produced (2001, p 178).

While most scoring of legibility has been, or appears to have been carried out by the researchers themselves, Alston enlisted the assistance of five teachers to analyse the handwriting sample, with the selection process being extremely rigorous. The teachers were all previously unknown to her, with at least five years experience, and although then unemployed they had worked in the last year (1983, p 239). They assessed legibility of the handwriting samples by applying Alston's comprehensive list of 23 aspects of legibility.

Connolly et al (2006), who had set university students a 30-minute essay on a single topic, analysed the essays produced for ideas and development; organisation; unity and coherence; vocabulary, sentence structure and variety; grammar and usage; capitalisation and punctuation; overall length; spelling errors; average sentence length and lexical diversity (pp 182, 184).

Reliability and Validity of the Legibility Results

Dennis and Swinth (2001) used the ETCH criteria to score their matched pairs handwriting samples. The ETCH manual includes two practice tests and these were completed by the researchers with a reliability of 0.90 before scoring the research samples. Dennis scored every sample with Swinth scoring every fifth sample (p 178), producing an inter-rater reliability for letter legibility of 89.0% to 98.7% while for word legibility was slightly more variable ranging from 86.7% to 100% (p 180). Dennis and Swinth in their research, comparing 23 pairs of pupils with atypical and dynamic tripod grasps, found no difference in the levels of legibility of the two groups writing although they cautioned about the small sample size involved.

Graham et al (1998) trained their two assessors of handwriting legibility and over the almost 2,000 samples graded had an inter-rater reliability of 0.87 (p 292). In Ziviani and Elkins' research (1986) the intra-rater reliability was 0.89 (p 250), although with a sample of only 20 reassessed it is not obvious how this result could be obtained. A more assiduous approach was taken by Ziviani working with Watson-Will (1998). Two experienced teachers scored both handwriting speed and legibility with a seven-point scale. The raters working independently and the scores of a random sample of fifty of the pupils' work were compared to calculate a reliability coefficient (intraclass correlation coefficient). The reliability coefficient for legibility was 0.79, although that for handwriting speed had been higher at 0.99. However, they reported that values higher than 0.75 represent good reliability (p 62).

Burton and Dancisak, who had measured drawing accuracy on a line drawing activity with three to five year-olds with a six-point scale, had two raters independently assess all the trials, with an inter-rater reliability of 0.80 (Kappa 0.73). One rater subsequently reassessed a sample of all the trials of two randomly selected children from each of the six gender/age groupings with an intra-rater reliability score of 0.90 (Kappa 0.87) (2000, p 13). Other research with preschool children by Carlson and Cunningham (1990) initially involved Carlson working alone to identify grip, although subsequently a second evaluator revaluated the written evidence of 12 children with inter-rater reliabilities ranging from 0.87 for line quality to 0.97 for tracing dotted lines. They also sought to have the validity of the line drawing, dot joining and name writing tasks they employed in their research into four and five year-olds by having them `assessed by a panel of professionals in early childhood development' (pp 283-5).

While the desirability of having scripts assessed by two independent appraisers is evident, this is not always carried out with writing quality. Dutton alone assessed writing quality in his 1992 research (p 85). As noted previously he was also obliged to use only a sample of the secondary school essays rather than scoring all those collected.

When the students follow instructions and write quickly, the letters they wrote were significantly more likely to be deformed; furthermore, this was more likely to happen in those deemed at the outset of the research to be poor writers (Sovik et al 1993, p 146). This choice between legibility and speed can be related to gender, for although Ziviani and Watson-Will (1998) found no difference between boys' and girls' writing speeds, the writing of the girls was more legible than that of the boys, which could have been the result of the girls preferring legibility to speed (p 63).

A large proportion of all marks awarded in examinations both at school and university are given for handwritten work. Soloff's carefully controlled 1973 research indicated that a `sloppily' written copy of model essay was awarded lower marks for content than a `neatly' written copy of the same essay. Indeed of the 32 teachers marking two essays on American history on only one occasion was the sloppily written copy given a higher mark. This result was significant at the 0.01 level indicating that teachers are influenced by the legibility of the handwriting and an essay's overall appearance (p 51). Thus it is very important in this research to attempt to establish whether any unorthodox grip can be linked to poorer legibility as this may impact on the pupils' educational success.

Very little research has been done into the effect the grip used may have the legibility of the handwriting produced. Writing with Elkins in 1986, Ziviani drew attention to the importance of pad to pad opposition and the numbers of fingers on the pen but considered that it had yet to be determined whether such variation affected speed or legibility (p 248). Subsequently Dennis and Swinth (2001, p 181) found that pupils with atypical grip had more legible writing than those who wrote with a dynamic tripod grip, although the difference was not statistically significant (p=0.054). They suggested a number of reasons why their sampling methods may have produced this result. They did not include any children receiving intervention to improve their handwriting, effectively removing those with atypical grip and poor handwriting from the study.

WRITING STYLE

In addition to handwriting speed and legibility, several research publications have included information on writing style. Mason, as an adjunct to his work on handwriting speed discussed above, preformed an analysis of handwriting style amongst 11 year-olds in two UK schools (1992, pp 109-110). It is not clear from his report which samples of handwriting he used - copying or free writing, nor is there any evidence of any secondary substantiation of the three categories he used: print, mixed and cursive. His results showed that print was used by 34% of pupils, a mixed style by 8% and cursive by 58% of pupils. Interestingly, he noted (1991, p 47) that significant numbers (in excess of 21%) of the 11 year-olds in his research made spelling errors even when copying from a printed text. A slightly later US study by Graham et al (1998) classified the same three samples of handwriting collected for style into four groups: manuscript, mostly manuscript, mostly cursive and cursive. Manuscript, mostly manuscript and cursive were almost equally represented (30-31%) with mostly cursive levels being about 9%. The inter-rater reliability in this four way classification of handwriting style were between 0.98 and 0.99 (p 292).

Three groupings were also used by Summers and Catarro (2003) in their Australian research. They analysed 20 consecutive words from the middle of their sustained writing tasks: those that had less than 20% joined letters were labelled printed, those with more than 80% joined were described as cursive while the remainder were considered mixed. The relative proportions were 21% printed, 44% mixed and 35% cursive (pp 151-2). In this study the style of writing employed was not related to the quantity written.

ABILITY

Handwriting speed has been shown to be linked to academic ability (Summers and Cattaro 2003, p 150; Lyth 2004, p 32) except at the extremes of the ability range. As a consequence many researchers have sought to screen their participants to ensure that they are of average ability by asking their teachers whether they were `within the normal range of intellectual abilities' (Ziviani and Elkins 1986, p 249) or by explicit testing (Tseng 1998). When the issue of ability is more important to research design this may again involve explicit testing (Hatcher et al 2002), although alternatives may involve including an appropriate range of ability in the research's design (Graham et al 1998, p 291) or matching the children for ability, again either explicitly or implicitly by selecting children from the same classes (Dennis and Swinth 2001, p 177). When explicit testing of ability is involved then a range of tests are available. Tseng used the Chinese version of the Binet-Simon intelligence Test (1998, p 233) while Hatcher et al used the Wechsler Adult Intelligence Scale to match university students' verbal abilities and Ravens Advanced progressive Matrices for their non-verbal abilities (2002, p 121).

Raven's matrices is a test designed to be short and attractive to the participants (Raven, Court and Raven 1996, p 1) and to assess educative ability (Raven, Raven and Court 1993, p 3). Educative ability embraces making meaning out of confusion, developing new insights, formulating non-verbal constructions (Raven, Raven and Court 1993, p 3) and `measure the ability of educe relationships' (Raven, Raven and Court 1993, p 5).

Raven's progressive matrices is one of the best single measures of g available (Raven, Raven and Court 1993, p 5) where tests of g have predictive validates of approximately 0.7 to academic areas. Similar results were found in recent Icelandic research by Pind, Gunnarsdottir and Johannesson (2003). They established that in the seventh grade (equivalent to England and Wales Year 8) there was a correlation of 0.75 with mathematics while in tenth grade (Year 11) the correlation was 0.64 and concluded that Raven's matrices are a sound measure of ability (pp 383-4).

PAIN/FATIGUE

Pain while writing may be caused not only by the way in which the pen is held but also by an excessively tight grip (Taylor 2001, p 50), although there are difficulties in measuring this (Herrick and Otto 1961; Sassoon et al 1986, p 69). One of the simplest methods of assessing the absence of sophisticated equipment, is to detect indentations on the back of the paper, as pressure on the pen point is correlated with grip pressure (Herrick and Otto 1961, p 228), but to obtain reliable results the same ballpoint pen and paper would have to be used which may have an effect on pupils' handwriting speed. The utilisation of more sophisticated equipment can enable pressure as well as directionality to be recorded (Mojet 1991) through the use of an electronic writing tablet.

In the absence of equipment capable of measuring pressure, two ways of assessing discomfort may be applied. The first is simple observation for Dennis and Swinth (2001) who observed that one participant who used an atypical quadropod grasp shook out her hand while writing, although her writing was subsequently discovered to be at least averagely legible (p 180). The alternative is to ask the participants about their experience of writing pain. Sovik et al (1993), for example, included a short questionnaire about their subjects' experience of pain (p 138) and found that those with awkward grips were more likely to experience `pain in their fingers, hand, wrist and/or arm' (p 147). Summers and Catarro (2003), however, asked their university subjects to self-report the level of pain using a ten-point scale as well as indicating where in their hand or arm pain was experienced (p 151).

The level of discomfort experienced while writing is important because if a grip is uncomfortable it is unlikely that it will be possible to maintain it over a prolonged period. The aim of this research is to provide as objective a measure of discomfort as possible in order that comparisons between the matched pairs may be made. Handwriting produced using a tripod grip is produced by the coordinated stretching or flexion of the distal parts of the index finger, and thumb: the ultimate in fine motor control. However, if a grip that restricts the variety of movement is adopted then there is a reduction in manipulative ability. Some grips, such as the lateral variants of the tripod and quadrupod require that movement involve the wrist or even elbow.

To assess the effectiveness of grip it would be desirable for the degree of movement at these joints be measured. This, together with the detection of release of pressure, would provide excellent objective measures of the efficiency of each grip. Such sophisticated equipment was, however, unavailable and furthermore, its use would be most appropriate to laboratory tests, rather than assessment within a school environment.

In the absence of sophisticated laboratory equipment, there remain two possible methods of assessing a writer's discomfort: asking questions during an interview and observing whether grip is released, or perhaps if it is extremely uncomfortable that the hand is shaken.

RESEARCH ANALYSIS

As described in the previous chapter, a number of different atypical non-tripod grips have been identified by the literature. A major part of the research aims to establish which, if any grips, including any not previously by the literature, can be considered not to disadvantage pupils during their secondary schooling. An integral aspect of the process will be to seek to establish if there is any relationship between the grip adopted and the speed of the pupil's handwriting. The various ways in which this task has been approached by previous researchers has already been considered in this chapter. The research will use an opportunity sample with a cross-sectional technique thus preventing control effects (Cohen et al 2007). Pupils with a wide range of non-tripod grips will be identified and matched with peers using a tripod grip. As in Dennis' and Swinth's research (2001) all those participating must not have any diagnosed learning difficulties, and give explicit consent. It is anticipated that all those who meet these criteria will be included in the sample. The grips will be classified based on contemporary nomenclature which was initially based on that used by Schneck and Henderson (1990). Photographs of the pupils' grips will allow for analysis and grouping after the research has been competed. Individualised testing and interviews permits pupils to be observed during the writing task. This requirement impacts on the type of handwriting speed test that can be undertaken. Many of the writing tasks described in the literature have been undertaken in groups, thereby permitting the setting of longer tasks. Since the aim of this research is to link grip and handwriting speed it is essential that the writing be observed. Thus the writing task had to be kept short enough to fit into time allocated to interview and test each pupil as well as reflecting the writing needs of secondary school pupils. Thus handwriting speed will be assessed by six minutes of free writing. This speed test is based on the Alston 20 minute test that can be reduced to only five minutes (Taylor 2001, p 43). The selection of a free writing task means that other features of writing such as short term memory and spelling decisions will impact on the results. Moreover this writing task reflects the type of real life writing exercise that closely approximates to the skills needed in the middle years of secondary schooling.

The handwriting and other variables collected will be analysed statistically using the Mann-Whitney U-Test to identify any differences. The Mann-Whitney U test is a non-parametric test that is used to compare two groups that come from the same population. It is suited to matched pairs tests as it requires equal sample sizes. As a non-parametric test it is particularly suited to this research as it does require any prior assumptions in relation to the distribution, for example that the sample be drawn from a population showing normal distribution. Furthermore the research sample accords with the requirements as of the Mann-Whitney U test as both groups in the sample were randomly selected and mutually independent (Statistical solutions 2010).

SUMMARY AND CONCLUSIONS

The strategies and techniques used by researchers into grip and other aspects of handwriting were considered in this chapter. A random sample permits inference of results to the wider population, although most research conducted into handwriting has involved geographical clustering because a sample drawn from a national sampling frame would be too costly. This is the strategy that will be employed in this research.

The way children's manipulative skills develop is well understood, but very little research has been conducted into the range of grips used by older people while writing. Much of this research has focused on young children, leaving the long-term consequences of an unorthodox grip unreported. It is a widespread belief that if older children or adults use a grip then it is an acceptable alternative to the dynamic tripod.

New grips are still being reported for the first time with Dennis and Swinth describing two previously unreported grips as recently as 2001; an indication that the range of non-tripod grips has not been well-researched. Dennis and Swinth (2001, p 182) in commenting on the high incidence of atypical grips observed in their study concluded that this `indicates that the prevalence of atypical grasps may have increased since those previous studies were conducted'.

Research into the appropriateness of unorthodox grip patterns is incomplete since much of it has only involved a few alternatives such as the dynamic quadrupod, the lateral tripod and the lateral quadrupod, following its identification by Dennis and Swinth in 2001. Indeed, the argument put forward by Bergmann (1990, p 739) in her discussion that modern alternatives to writing exist, seemingly questions the importance of handwriting. However, this position overlooks the fact that handwritten examinations are the method by which secondary school children are currently assessed, both for placement within the school as well as at the conclusion of their education. If a child is handicapped by poor writing, whether in terms of speed or because they are suffering an abnormal amount of discomfort while writing, then a child might journey through a whole school career without ever achieving what he or she is capable of and without his or her underachievement being appreciated. Although grip may be only one reason for poor writing skills, Ziviani writing with Wallen recently (2006) considered that there was still the need for more research into the relationship between typical and atypical grips (p 220).

CHAPTER THREE

PHASE ONE - METHODOLOGY FOR OBTAINING A DEMOGRAPHIC DISTRIBUTION OF PENGRIP

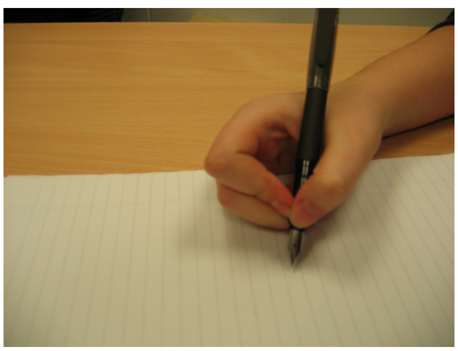
INTRODUCTION

When conducting research into unusual grip a problem encountered is the high proportion of pupils with an unusual grip, inspections of secondary school classes indicating that at least one pupil in ten uses a non-tripod grip. It thus seemed important to obtain empirical evidence of the actual incidence of unusual grip in the age range that is the subject of this research: Years 8 to 11. Conversely, it is unusual to observe an adult writing with anything other than an orthodox tripod grip, although this may be a result of certain social environments or that adults with unusual grips avoid writing. It thus seemed important as part of this larger scale study to test this observation, and extend the demographic section of the study upwards from secondary school age to consider the incidence levels of unusual grip in adults. Given that the grip is generally fixed by the age of eight (Taylor 2001, p 50) or nine (Jarman 1993a, p 43) it also seemed relevant to consider the incidence in younger children especially as the more recent publications instructing teachers (Taylor 2001, p 49) emphasise the efficiency of a tripod penhold and advise that it be encouraged.

METHODOLOGY

The aim in this section of the research was to determine whether the observation that it is only school pupils or younger people who use a non-tripod grip is accurate. Since it was intended to observe fifty male and fifty female subjects write in each of the age categories a limited number of penholds were coded for. The first variable was handedness, with each person observed being coded as either `R' or right-handed or `L' left-handed. The purpose of collecting information about the incidence of left-handedness is to act as a control, for if the research sampling technique is accurate then it is expected that the number of left-handed people in the group should be approximately the same in each age grouping.

The second variable to be recorded was the actual grip. The first variant is the `T' or tripod grip in which the pen is held between the ball of the thumb and the first finger and resting on the second finger. The second grip is a two fingered or `quadrupod grip' (Tseng 1998, p 214; see also Chapter 1 p 113; Chapter 6 pp 130-4 and Chapter 7 pp 217-9) in which the first two fingers are above the pen while the ball of the thumb acts in opposition. This was coded as `Z'. The third grip is `Th', thumb or as Sassoon et al (1986, p 96) described it `thumb half over' (see also Thomas 1997, pp 129-130). In this grip either one or two fingers are placed above the pen but the thumb's distal interphalangeal joint (knuckle) provides the opposition, thus the thumb is generally held parallel to the writing surface rather than pointing towards it as in the tripod and quadrupod grips. The fourth category was coded by `U' for unusual and included any grip that did fit into the other categories. Photographic examples of the four grips are shown below, although the unusual represents only one variation within that category.



Photograph 3:1 Tripod grip – pupil 38

Photograph 3:2 Quadrupod grip – pupil 23

Photograph 3:3 Thumb grip (Bladon 2004 p 51)

Photograph 3:4 Unusual grip – pupil 29

The precise methodologies employed to obtain the data presented in Chapter 5 are described in the three sections that follow.

SUBJECTS: SECONDARY SCHOOL PUPILS (YEARS 7 TO 13)

This research was conducted in rural West Wales, an area in which almost all children in a given comprehensive secondary school catchment area generally attend that school. Since secondary schools are located at approximately 15 mile distances, commuting to an alternative school as a day pupil is both tiring and expensive. This results in the schools being very representative of their local populations. As these children form the main focus of the research it is desirable to obtain as accurate an indication of the incidence of the different types of pen grip in these pupils. For this reason it was decided to determine the different types of grip in a single secondary school. A seven hundred and fifty pupil comprehensive school was chosen with the intention of assessing every pupil in the school and recording the grip of the first fifty boys and fifty girls observed in each year group.

This assessment was undertaken on two separate days in March 2005. The school concerned was very cooperative and provided the registers and a timetable and every pupil in school on either of these days was observed writing. Although the initial intention was merely to observe whole classes of pupils writing and comparing the class attendance list with the school register, so few of the teachers had taken attendance during the lessons observed that another method had to be developed. In each class a single sheet of paper was passed around and pupils wrote their name on it. As they wrote their grip was assessed as being tripod, quadrupod, a thumb grip or unusual which included any grip that did not fall into any other category. This final group included the more extreme versions of the `thumb' grip named the `lateral tripod' by Bergmann (1990, p 736). This was judged unusual because in this position the thumb is not involved in controlling movement. These unusual grips are described, and categorised with photographs in Chapter 6 of this work. The hand with which each child wrote was also recorded. Pupils with the unusual grips were thus easily identified in this first school, in the demographic part of this research, and their names recorded separately.

The names of all the children who had been observed writing were then checked off against the register and any pupils absent on the first day were seen on the second. For most year groups there were sufficient boys and girls seen in the same school, but in the few cases between Years 7 and 11 when there were too few boys or girls, then pupils in a second secondary school with a contiguous catchment area were used (with these pupils being chosen entirely randomly).

A problem arose with pupils in Years 12 and 13, for in each year group there were approximately 25 boys and 25 girls. For pupils to continue in this school after GCSEs, five good grades (A* to C) are required. With the rate of pupils obtaining these grades being around 60% (with girls doing better than boys) approximately 25 boys and 25 girls left school at the end of Year 11. Obviously a small percentage goes into employment but many pupils, especially girls, go to the local further education college.

A visit to the local college was made in May 2005 and the pen grips of seven classes observed. These classes include several adults (nineteen years of age and over) as well as ten young men and twenty-five young women who would otherwise have been in Years 12 or 13 of school. It was a matter of concern that perhaps these young people were displaying a different grip than their peers who had remained in school. If this were the case it would be wrong to include this high proportion of girls into the main demographic data. The inclusion of this group was tested by comparing the type of grips in the twenty-five girls observed in the college with twenty-five girls from each of the two school years. This is displayed in the table below.

Table 3:1 Showing numbers and percentages of different pengrips in college and school (female)

	College	School		College	School
Left tripod	2 **(8%)**	3 **(6%)**	Right tripod	14 **(56%)**	23 **(46%)**
Left quadrupod	0 **(0%)**	0 **(0%)**	Right quadrupod	2 **(8%)**	12 **(24%)**
Left thumb	0 **(0%)**	0 **(0%)**	Right thumb	2 **(8%)**	2 **(4%)**
Left Unusual	2 **(8%)**	0 **(0%)**	Right unusual	3 **(12%)**	10 **(20%)**
Left total	4 **(16%)**	3 **(6%)**	Right total	21 **(84%)**	47 **(94%)**

There are two main differences. There is a relatively high proportion of left-handed college students. This, while interesting, is not the focus of this research but could be the subject of further research (see Chapter 7 p 241).

Returning to the question of whether the data collected in the local further education college should be included in the demographic study, it was decided that in order to obtain as accurate as possible representation of local pengrip the college data should be included. In a 1987 survey of 5,147 Canadians, Coren found (1992, pp 50, 206) that the left-handed rate was 15% for 10 year-olds so the incidence of left-handed girls in college does not appear to be disproportionate.

The second difference is that the non-tripod right-handed grips, especially the unusual grip, are much more common in the school pupils. This is another unexpected result that could be the subject of further research. However, it was decided to include the college data in the demographic study. The converse result with a relatively high proportion of people with unusual grips being found in college (having come from different schools) would have meant that the college data could have skewed the proportion of unusual grips in these age groups in the demographic study and should not have been included. However, it seems justified to include all the college data.

The remaining data for Year 12 and 13 pupils was collected with the adults, in the way described on pages 72-3 below.

SUBJECTS: PRIMARY SCHOOL PUPILS (YEARS 0 TO 6)

The pencil grip of primary age children was collected in twelve primary schools between March and June 2005. The schools were all located in West Wales, with the majority being in the feeder schools for the secondary school for which the demographic data for older pupils had already been collected. In each school every class was visited and the year group of each pupil ascertained from the teacher, as many local schools have only two or three teachers resulting in mixed year group classes. The pupils were then observed while writing. With the youngest children it was necessary to adopt a slightly different strategy, variations in approach frequently being necessary in the conduct of wide cross-sectional studies (Cohen et al 2007, p 217). The very youngest children wrote the intial letter of their name on a single sheet of paper. The children were aware that their writing was being observed but not the specific area of interest. The teachers were aware of the research topic and very many of them expressed concern about the grips being used by many of their pupils and in some cases explained at great length the strategies they and their colleagues had used to attempt to remedy a particular pupil's unusual grip. The consensus of this significant number of teachers was that there was little they could do to affect a child's grip because as soon as the child was writing other than with the teacher's supervision, the pupil would revert to their previous non-tripod grip.

Numerous teachers sought advice and the literature indicates that once grip is fixed by the early junior years there was little that can be done to remedy it, and that trying to remediate unusual grip in junior school is probably be counter productive. On one occasion, having observed a boy in a reception class write with three fingers over the pencil, the teacher was advised to try and modify this grip to a quadrupod grip, which appeared to be more functionally acceptable given the large number of pupils adopting it. After the research in the classroom was completed, some class teachers told their pupils that the research concerned non-tripod grips, with a very gratifying shift of the majority of pupils to a tripod grip as they wrote.

SUBJECTS: ADULTS

The demographic data for adults obviously had to be collected in a different way as adults rarely assemble in tidy cohorts. As it was intended to collect the data in five year age groups, with the intention of there being of fifty men and fifty women in each age group, it was necessary to determine the adults' age.

To ask this question could be embarrassing to both parties but more importantly it could produce a high participation refusal rate as well as the possibility of subjects incorrectly reporting their age, both of which could affect the validity of the results obtained.

Since it was the articulation of the question and answer that caused difficulties, as well as the need only to know into which five-year age category each individual fell, a data collection sheet was devised. This is shown on the next page and was used to collect the majority of the adult demographic data between June and August 2005.

Please write the word “Sunday” in the appropriate column below.

Age 19	Age 20-24	Age 25-29	Age 30-34	Age 35-39	Age 40-44	Age 45-49	Age 50-54	Age 55-59	Age 60-64

Participants were approached in wide variety of locations and asked to write the word Sunday on the sheet as part of a handwriting survey comparing children and adults writing. The word Sunday was chosen because it is a familiar word, very easy to spell but yet long enough to allow the hand, nature of grip as well as the age and gender of the writer to be recorded. Each individual was observed writing and his or her age, gender, handedness and grip recorded in a separate notebook. Although the occasional person would sign (either intentionally or accidentally) this did not affect the result. The refusal rate was low which gives confidence that it does reflect contemporary handedness and grip patterns.

When a participant asked the nature of the survey, it was explained only after the individual or group of people had each been observed writing. Most people displayed interest and a few provided interesting insight into the way their unusual grip had affected their lives. A woman (50-54) whose 25-29 year-old son had an unusual left-handed grip, explained that her right tripod grip was artificial as she had been forced to write with her right hand when at school and that left-handedness occurred in three generations, as her grandson was also left-handed. This `forced change of writing hand' often occurred `in the first half of the present (20^{th}) century but is now less frequent in Western societies, although still common elsewhere' (Annett 1998, p 65). A successful professional woman (45-49) who used a right-handed lateral tripod (unusual) grip told me that in secondary school her whole class had been made to stop writing to observe her unusual way of holding her pen. A few people told me they were dyslexic and with encouragement did show me their writing. One dyslexic (male 35-39) with an unusual right-handed grip movingly explained that he had totally failed at school and although he was an extremely competent mechanic, had been severely handicapped in life due to his poor literacy skills and the resultant low self-esteem.

Although it was the intention to collect observations of fifty men and fifty women in each five-year age grouping, this was not completed in two groups of people. Firstly, in the oldest three groups namely 50-54, 55-59 and 60-64, out of the 220 subjects sampled only one person - the right-handed women described above was observed to have an unusual grip and even the minor irregularity of grip of writing with quadrupod grip was very unusual. It thus seemed unnecessary to continue sampling these older groups of people.

The second research grouping that caused some difficulty was male Year 13 pupils and both male and female nineteen year-olds. As observed above, there were only 24 boys in Year 13 in the secondary school sampled. By the time this problem became apparent other schools in the local area were on examination study leave and it was thus difficult to find representative groups of eighteen year-olds. Small numbers of eighteen year-olds were observed writing on three university campuses in October 2005 but as with the nineteen year-olds these were not representative samples in that they were all academically successful. The inclusion of a separate category for nineteen year-olds was always going to be problematic and was done for two clear reasons. Firstly, so that so that the later groups would fall neatly into five year groupings of, for example, early and late twenties, and secondly in an effort to more closely identify the timing in any shift in handwriting orthodoxy. The nineteen year-old grouping was initially collected with an option remaining to amalgamate them into the 20-24 year grouping on a proportional basis at the data handling stage.

As noted above, there were difficulties in obtaining representative samples of eighteen year-old (Year 13) males and nineteen year-olds. By definition Year 12 and 13 pupils were academically successful and had obtained five A* to C grades in GCSE examinations. The problem of obtaining a more representative population sample was overcome for the girls by visiting a local college but most of the missing boys had gone into employment and were difficult to access as a group. As noted previously, there were no left-handed Year 13 boys although three were later identified in the other fourteen boys of this age observed.

Twenty-one female and eleven male nineteen year-olds were identified in the adult data collection process, some of whom may of course have been students, while 20 female and 20 male students observed on three different campuses. Although the left handed rates were similar, there were far more unusual right handed grips (see Table 3:2) amongst the students and it was thus decided to not collect any more data for the nineteen year-olds or Year 13 (eighteen year-olds) but to use all the information already collected.

Table 3:2 Showing numbers and percentages of left handed and unusual right-handed grips in nineteen year-olds separating adult and student data

	number	No. left	% all left	no. right unusual	% right unusual
male adult	11	1	9.0	0	0
female adult	21	1	4.8	4	25.0
total adult	**32**	**2**	**6.3**	**4**	**16.7**
male student	20	0	0	3	15.0
female student	20	2	10	7	35.0
total student	**40**	**2**	**5.0**	**10**	**25.0**

Subsequent to the decision to suspend data collection for this group, a test whether these two sample percentages could have come from different populations (that is whether the student group were different to the adult grouping in respect to the incidence of unusual right handed grip) was carried out using MINITAB statistical software. The test of the null hypothesis that the two groups were different gave a Z value of -1.37, which has an equivalent probability of 0.170. For the test to show that the two groups were different, with only a one in twenty chance of an error, this probability would have had to be less that 0.05. The null hypothesis was disproved and the alternative hypothesis accepted that the two groups could have come from the same population. It therefore seemed justified to include all the data collected for nineteen year-olds. It will, however, be important that the various methods used in data collection be considered when the significance of the data is being analysed.

ETHICAL AND OTHER ISSUES IN DEMOGRAPHIC DATA COLLECTION

As described above, slightly different techniques were employed in collecting information from the three groups: secondary school pupils, primary school pupils and adults. The issues therefore varied slightly and will thus be discussed separately.

All pupils in the one secondary school, unless they were absent both days, were observed writing. Thus it is probable that the incidences of the different grips recorded accurately represent the incidences within this age group in this geographical area. The only names recorded were those with unusual grips who were to comprise the part of the second part of the research. Before inclusion in the second part of the research, individual, parental permission will be sought. Given that permission from both the LEA and the head teacher had been sought, no further ethical issues arose.

Twelve primary schools had to be visited in order to complete the one hundred subjects in each year group. Once again, both the LEA and head teacher permission had been sought. Given the proximity of these schools to each other and the secondary school it is believed that these results accurately reflect the pattern of penhold in local primary schools.

Data collection for adults was more problematic. Ethical considerations were less important since no names were recorded and all adults had the choice not to participate. In selecting situations in which to collect the data, every effort was made to collect information in as many locations as possible and to sample as many social groups as possible. For example, car owners were approached in car parks and non-car owners in bus stations. Since not everybody in a given location could be approached, nor did everyone agree to participate, less confidence should be placed in these results than those in either of the two school groupings.

With the decision to conclude data collection, the first part of the research was completed and the data was ready for tabulation and analysis. The raw data obtained using the techniques described above is displayed in Tables B:1 to B:24 in Appendix B. In the majority of age bands handwriting grip observations were carried out on fifty males and fifty females, the exception having been noted above. Given the relatively small number of age groups where the full data was not collected, it seemed desirable to adjust the smaller sample sized data statistically to give male and female figures for a sample size of fifty. These are shown in parentheses below the raw data in Tables B:14 and B:15 and B:22 to B:24. These calculations were performed separately for males and females when necessary. The male and female figures were added to produce the final row of each table, with only the statistically altered figures being added in the tables when the sample size was less than one hundred.

SUMMARY AND CONCLUSIONS

In this section of the research the incidence of right and left-handedness and of four types of penhold were investigated. Data was collected for fifty males and fifty females in each age group. For children these groups were school year groups while older people were investigated in five-year age bands. Data was collected for the full one hundred in each group with only a few exceptions which were explained in detail. Given the way the data was collected, a high degree of confidence can be placed that the results, for at least the geographical area of West Wales, represent the demographic pattern of writing grip.

The data collection described above was undertaken to test the research hypothesis that unusual penholds are more common in younger age groups. This will be tested statistically using to investigate whether the different age grip patterns could have come from the same population.

This detailed analysis of the results of the data collected on the population distribution of pengrip is contained in Chapter 4.

CHAPTER FOUR
PHASE ONE - RESULTS OF THE INVESTIGATION INTO THE DEMOGRAPHIC DISTRIBUTION OF PENGRIP

INTRODUCTION

Although the major part of this research focuses on secondary school pupils, it was decided to attempt to discover the prevalence of unusual grips in the wider population. The precise methodology of the techniques used is included in Chapter 3 with all the raw data being displayed in tables in Appendix B.

The figures for secondary school children up to Year 11, which forms the main focus of the research, were obtained in a single secondary school in March 2005 (see pp 69-71).

The grip of primary age children was collected in twelve primary schools between March and June 2005. The majority of these schools were feeder schools for the secondary school mentioned above (see pp 71-2).

The demographic data for adults was collected in five year age groups with the intention of there being of fifty men and fifty women in each age category. This data was collected between June and August 2005 by approaching a wide cross section of people and asking for a sample of their handwriting as part of a handwriting survey comparing children and adult writing (see pp 72-7).

The survey of eighteen and nineteen year-olds was completed in September and October 2005 with the complete survey containing information about the grip used by 2,290 people. This encompasses data for fifty boys and fifty girls in each year group up to Year 12. Slightly fewer people were observed in the Year 13 and age nineteen groupings for reasons explained in Chapter 3 (pp 76-7). Information about adult grip was collected for fifty men and fifty women in each five-year age grouping from the age of twenty to forty nine. Data was also collected for people up to the age of sixty-four, although the sample sizes were slightly smaller. The reasons for the smaller sample size in these age groupings have been explained in Chapter 3 (pp 75-7).

RELIABILITY OF THE SAMPLE

In order to assess the reliability a different rater may view the same writing activity producing a measure of inter-rater reliability or the same rater may subsequently reassess either a still photograph or video, creating an intra-rater reliability score. In order to assess reliability of the identification of unusual grip in the demographic research, still photographs were shown to three raters in order that inter-rater reliability could be established. The selection of the alternative raters required that they have some experience of assessing handwriting but not be familiar with the current research project. The three raters were professionals with experience of assessing children's writing and were a primary school teacher, a secondary school teacher of English with substantial experience of teaching children with Special Needs and a retired psychiatrist. These will be identified as rater A, rater B and rater C respectively.

In this research the raters were given 100 still photographs and asked to identify them in accordance with the following protocol. The photographs were of the grips used by school pupils who participated in the research. The photographs were of approximately the first 100 pupils interviewed and were numbered and presented to each rater in the same numerical order.

Handwriting identification protocol

1. Is the pen held with the ball of the thumb and the index finger on opposite sides of the pen barrel, with the pen resting on the middle finger?
   Yes - tripod grip
   No - go to 2.
2. Is the pen held with the ball of the thumb on one side of the pen and the index and middle fingers close together on the other side of the pen jointly providing opposition?
   Yes - quadrupod grip
   No - unusual grip

After each rater had identified the grip used in the photographs, the researcher checked the results noting both the number of inconstancies as well as any particular photographs that were consistently mis-assigned. The raw results are shown below together with Cohen's kappa, the preferred method of calculating inter-rater reliability especially when there are more than two categories (Dewey 1983, p 489). (See also Appendix B)

Table 4:1 Inter-rater reliability

	Rater A	Rater B	Rater C
Overall consistency	0.94	0.96	0.85
Inter-rater reliability (Cohen's kappa)	0.896	0.931	0.747

The inter-rater reliability scores for the three choices of grip, especially for raters A and B, compare with those obtained by other researchers into pen grip. These are not dissimilar to those found by other researchers. Ziviani and Elkins (1986), using only two choices obtained kappa scores of 0.97 for the number of fingers used and 0.90 for finger opposition. Thus there was greater agreement for the number of fingers than for finger opposition as a Cohen's kappa of 1 indicates perfect agreement while a score of 0 indicates total disagreement (Dewey 1983, p 487). Photographs were also used to identify the grip used by children in Koziatek and Powell's 2003 research. Their assessment initially used Tseng's 1998 fourteen grip classification, with the addition of a newly defined grip, the lateral quadrupod. All but two of the 101 children used the dynamic or lateral form of either the tripod or quadrupod grip with 76% agreement between the two raters. This was a low level of inter-rater reliability although the two researchers then reviewed their findings and worked collaboratively to finalise the grip used by each child (p 285). Slightly higher reliability inter-rater reliability results were reported by Yakimishyn and Magill-Evans (2002). The agreement using Schneck's (1991) condensed five point scale of maturity was 90.1%, although this scale relates to maturity and groups different grips together, such as the dynamic and lateral tripod grips.

The photographs that were mis-assigned by the raters in this research were analysed and of particular interest were those that were incorrectly assigned by more than one rater. The photographs that were mis-assigned are all detailed in the table below together with a classification of the type of error.

Table 4:2 Rater mis-assignments and error type

Rater A	Rater B	Rater C	Error type see below	Comments
		1 (Z) to U	d	
		14 (U) to T	g	
	15 (U) to T	15 (U) to T	g	2/3
22 (U) to Z			f	
		32 (T) to U	b	
36 (U) to T		36 (U) to Z	e	2/3 second finger position unclear
	41 (U) to T		b	
		44 (T) to Z	a	
		45 (T) to Z	b	
49 (U) to Z	49 (U) to Z	49 (U) to Z	c	3/3
		51 (T) to T	b	
		55 (U) to Z	g	
60 (T) to U			d	
63 (U) to Z		63 (U) to Z	c	2/3 third finger position unclear
		73 (U) to Z	g	
	86 (U) to Z		c	
		88 (U) to Z	c	
89 (T) to U			d	
		93 (T) to Z	b	
		95 (U) to Z	g	

T – tripod, Z – quadrupod, U - unusual

Error types
(a) poor photography (angle)
(b) poor photography (focus or lighting)
(c) no opposition of thumb and forefinger(s) – insufficient consideration given to this aspect of the definition
(d) opposition present but forefinger and thumb close leading to mis-assignment
(e) thumb pad not used
(f) high forefinger with only second finger providing opposition
(g) no obvious reason for the mis-assignment

Only one photograph was incorrectly assigned by all three raters, number 49. This does not display a grip in which there was opposition of thumb and index finger or joint opposition of index and second fingers and it seems as if insufficient consideration was given to this aspect of the definition. Other grips were incorrectly identified as tripod grips (for example numbers 14 and 15) rather than unusual. Further clarification of the definitions may prevent this mis-assignment as when the thumb's metaphalangeal joint is bent over the forefinger(s), identified by the whitening of the knuckle, opposition cannot be present as the contracted joint cannot exert oppositional pressure on the pen.

This detailed analysis is not crucial to the demographic aspect of this study but it will have an increased importance in the school research as it will incorporate a detailed analysis of the types of unorthodox grips employed by these pupils. The way that mis-assignments may occur should aid the definitions used in the protocols in Chapter 6 identifying the various types of atypical grip.

Not every individual in a study need be reassessed in order to establish inter-rater reliability. Yakimishyn and Magill-Evans (2002) had a second occupational therapist double code the trials of every fourth child from videotapes. As a second check of reliability the writing of every second child was double coded 2 months later, again from video. This produced an intra-rater reliability of 95.1% (p 566). Such reassessment can obviously be made from either still photographs or video recordings but if reassessment is made of a second writing activity then a potential source of error to the intra-rater reliability result may arise if the writer uses a different grip.

Before beginning an analysis of the data it is essential to consider how representative this sample is of the population.

VALIDITY OF THE SAMPLE

Since the information about pupils in Years 7 to 11 was collected in a single secondary school this data is a very accurate indication of handwriting grips in the local area. Only a very few pupils were absent on both days the research was conducted, and unless it is assumed that the pupils missed on these two days are frequently absent and possibly as a result of less schooling they have a higher incidence of unusual grip, then the data collected should be considered reliable. If these absent pupils had either the same incidence of less usual grips or even had uniformly right-handed tripod grips, the total percentages of irregular grips would be little affected.

Of course it may be that other parts of the United Kingdom have a different pattern of grips than that prevalent in rural mid-Wales. It is obviously outside the scope of this survey to investigate the pengrip in every school in the country although it would be possible to investigate grips in single year groups in schools in a few scattered geographical locations. A problem with this approach, apart from the time and practical difficulties involved, is that few urban schools truly reflect the demography of their local populations. Thus, for example, if it were discovered that Year 8 or Year 9 in an inner city school had an unusual right handed grip of 5% compared with the 15% in this research study it could be because many of the more able pupils that earlier research found had a higher incidence of unusual grip (Bladon 2004, pp 38-9) had gone to either a private or selective school. Alternatively, the lower incidence could be the result of many of the children having begun their education abroad in countries that insisted upon a tripod grip being adopted. Conversely a higher unusual grip rate of, for example, 30 % may be the result of a very high incidence of pupils with Special Needs or perhaps because the high numbers of new migrants reflect education practices in other countries.

The data for pupils from Reception (Year 0) to Year 6 were collected in twelve primary schools. These schools were chosen because they were feeder schools of the sample secondary school. This means that once again a high degree of credence can be put on the results. The only caveat is that the youngest pupils may be displaying immature rather than unusual grip.

Although the school age study was conducted in only one geographical area many children who were observed writing had begun their education outside the immediate area. However, the proportions with unusual grips seem to be the same in both the English and the Welsh linguistic streams. Of the four registration groups in the secondary school in which the data was collected, two receive their education in English and two in Welsh. Of the fifteen pupils identified for inclusion in phase two of this research, seven were from English classes and eight from Welsh. This reinforces the impression that unusual grip is common in groups of children of all backgrounds and in all parts of the country. This impression is reinforced as the researcher has observed unusual grips in both children and adults in widely scattered situations and locations.

As described in Chapter 3, during the adult data collection phase attempts were made to gather data in as many different locations as possible. The degree of confidence that can be placed on this data needs to be considered carefully. Given the strenuous efforts to approach as representative a sample of the population it is believed that the overall results of the age groups over twenty are as typical as is possible given the sample sizes involved.

The situation is slightly more complicated for people between the ages of seventeen and nineteen. Some of the problems with obtaining representative sample of Year 12, Year 13 and nineteen year-olds were discussed in Chapter 3 (pp 70-1, 76-7). The main difficulty is that many pupils leave school at the age of 16, especially those that have fewer than 5 A* to C at GCSE. Attempts were made to track down some of the former pupils from that school and others with similar academic achievements and this was successful, especially for girls, although the women in college had a far higher left-handed rate and much lower right-handed unusual grip rate than those who had stayed in school. However, since the both the male and female data eventually collected for Year 12 are similar to those for Year 11, they appear to be reasonably accurate. A table of raw data for these two groups is reproduced below:

Table 4:3 Raw data for Year 11 and Year 12 pupils

Year 11	left tripod	left quad	left thumb	left unusual	**left total**	right tripod	right quad	right thumb	right unusual	**right total**	**total**
male	3	1	0	1	**5**	31	2	4	8	**45**	**50**
female	3	1	0	2	**6**	25	9	2	8	**44**	**50**
total	**6**	**2**	**0**	**3**	**11**	**56**	**11**	**6**	**16**	**89**	**100**
Year 12/ age 17											
male	2	3	0	1	**6**	20	10	6	8	**44**	**50**
female	5	0	1	0	**6**	25	7	3	9	**44**	**50**
total	**7**	**3**	**1**	**1**	**12**	**45**	**17**	**9**	**17**	**88**	**100**

Although similar strategies were employed to obtain Year 13 data the results were far less satisfactory. As described in Chapter 3, there were no left handed boys remaining in school and very few boys had progressed to the local further education college. Efforts were made to collect data from accessible groups of these boys in universities but these were abandoned in view of the researcher's concerns about the unexpectedly high proportions of unusual right-handed grips in the nineteen year-old sample.

Table 4:4 Raw data for pupils in Year 13 or aged 18 (including extrapolation for a sample size of 50)

Year 13/ age 18	left tripod	left quad	left thumb	left unusual	**left total**	right tripod	right quad	right thumb	right unusual	**right total**	**total**
male	1 (1)	1 (1)	0 (0)	1 (1)	**3 (3)**	25 (32)	6 (8)	2 (3)	2 (3)	**35 (46)**	**38 (50)**
female	2	0	0	3	**5**	18	13	4	11	**46**	**50**
total	**3**	**1**	**0**	**4**	**8**	**50**	**21**	**7**	**14**	**92**	**100**

The data collected for pupils in Year 13 and other eighteen year-olds is shown in Table 4:4 above. The low number of left-handed people, especially males (6%), is apparent, as is the very high number of girls with unusual right-handed grips (22%). These two inconsistencies are even more pronounced in the data collected for nineteen year-olds with percentages of 2% and 26% respectively (see Table 4:5 below). The total figures for both these sets of data are not too dissimilar from those for the slightly younger pupils because the higher numbers of left-handed girls and lower numbers of boys with unusual grips offset each other. The differences between the two sexes in both handedness and grip will be considered in greater detail later in this chapter.

Table 4:5 Raw data for adults age 19 (including extrapolation for a sample size of 50)

Age 19	left tripod	left quad	left thumb	left unusual	**left total**	right tripod	right quad	right thumb	right unusual	right total	**total**
male	1 (2)	0	0	0	**1 (2)**	20 (32)	5 (8)	2 (3)	3 (5)	30 (48)	**31 (50)**
female	3 (4)	0	0	0	**3 (4)**	20 (24)	7 (9)	0	11 (13)	38 (46)	**41 (50)**
total	**6**	**0**	**0**	**0**	**6**	**56**	**17**	**3**	**18**	**94**	**100**

In conclusion, there are inconsistencies with the data collected for Year 13 and nineteen year-olds, especially with respect to the proportions of left handed men and women with unusual right-handed grips. Thus the data for these two groups, unlike all the other data collected, should be treated with a degree of caution. However, although showing inconsistencies, the data is not so unexpected as to justify its non-inclusion in the full data analysis, which is shown below.

DATA ANALYSIS OF LEFT-HANDED INCIDENCE

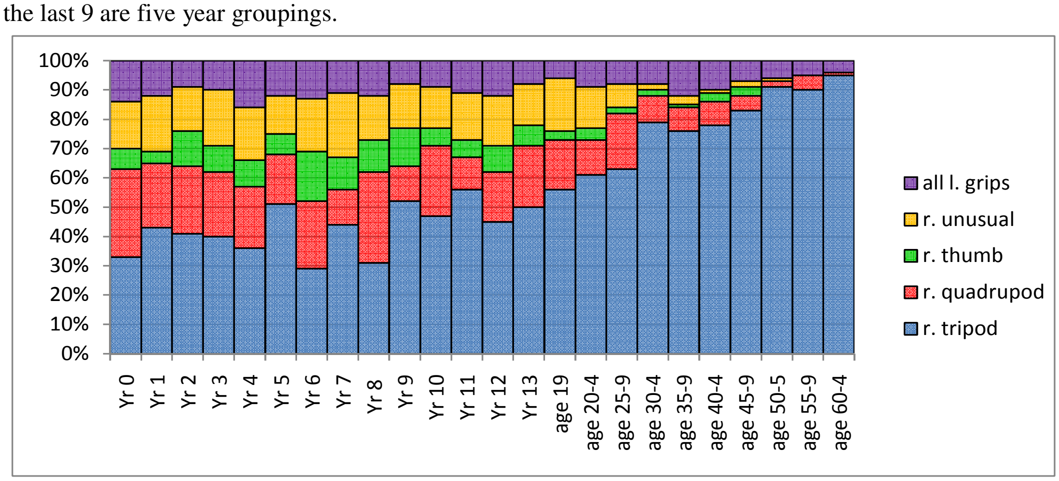
Since there are only very small numbers of left handed people in each of the types of left handed grip, in the analysis of pengrip according to age that follows, the four groups, tripod, quadrupod, thumb and unusual are grouped together. The analysis of how pengrip varies between left-handers is dealt with later in this chapter on pp 102-4.

A summary table including all the results obtained is shown below followed by a graph of the data showing how left-handedness and right-handed pengrip varies with age.

Table 4:6 Results of the demographic survey (in percentage form, including sample size adjustment)

	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11
r. tripod	33	43	41	40	36	51	29	44	31	52	47	56
r. quad.	30	22	23	22	21	17	23	12	31	12	24	11
r. thumb	7	4	12	9	9	7	17	11	11	13	6	6
r. unusual	16	19	15	19	18	13	18	22	15	15	14	16
all l. grips	14	12	9	10	16	12	13	11	12	8	9	11
	Yr 12	Yr 13	age 19	age 20-4	age 25-9	age 30-4	age 35-9	age 40-4	age 45-9	age 50-4	age 55-9	age 60-4
r. tripod	45	50	56	61	63	79	76	78	83	91	90	95
r. quad.	17	21	17	12	19	9	8	8	5	2	5	1
r. thumb	9	7	3	4	2	2	1	3	3	0	0	0
r. unusual	17	14	18	14	8	2	3	1	2	1	0	0
all l. grips	12	8	6	9	8	8	12	10	7	6	5	4

Graph 4:1 Demographic data illustrating how handedness and right-handed grip varies with age. The horizontal axis (X axis) has an inconsistent scale. The first 15 groups are single year groups while the last 9 are five year groupings.



The purpose of collecting information about the incidence of left-handedness was to act as a control. If the research sampling technique was accurate then it is expected that the number of left-handed people in the group should be approximately the same in each age grouping. This would be shown as a narrow purple band along the top of the graph at the 90% line, as approximately 10% of the population are left handed (Springer and Deutsch, 1999, p 119). This pattern does emerge although there is some variation as would be expected from research results. Table 4:6 and Graph 4:1 indicates two areas where this pattern might not be true. The first is the nineteen year-old group and to a certain extent the Year 13 sample next to it. Here, there seem to be too few left-handed people. This problem had been highlighted earlier in the chapter when the validity of the sample was being considered and could relate to the low number of left-handed males staying on in school into Year 13 and then progressing to university. This lower proportion of left-handed males is an unexpected result and one that deserves further research.

The second unexpected pattern and one which cannot be as easily dismissed, is the falling off of numbers of left-handed people after the age of 44. In the age band, 40-44, 10% of people were left-handed while for 45-49 year-olds the rate was only 7% falling one percentage point in each five-year age band to reach only 4% in the 60-64 age group. Fortunately, the explanation for this statistical anomaly has a simple solution that lies in the research itself. As described in Chapter 3, a woman in the sample, aged between 50 and 54, was approached with her son. He had a left tripod grip while she had an unusual right-handed grip and indeed was the oldest person to be identified with this grip. She explained that she had been forced to write with her right hand when at school but that she was naturally left-handed, as were her son and a grandson. It is well known that at one time children had been forced to write with their right hand whatever their natural tendencies, with Annett reporting that it often occurred in the first half of the twentieth century (1998, p 65). In addition to this woman who was included in the research sample, two male teaching colleagues both aged about fifty, revealed that they were naturally left-handed although they actually write with their right hands, incidentally with a regular tripod grip. Neither of the men referred to were included in the sample but their information does reinforce the notion that educational, or in one case parental pressure to write with the right hand, could affect the proportion of older adults who are left-handed.

Subsequent to this stage of the research several other incidences of naturally left-handed people who where encouraged to write with their right hands were reported. A left-handed man in his sixties stated that at school he had had his left hand hit with a ruler every time he picked up his pen with it. A woman born in 1965, was forced to sit on her left hand at school in order to use the 'correct hand', while her two left-handed sons who were educated in France were 'encouraged' to use their right hand, with one becoming right-handed. The evidence of these conversations seems to indicate that in West Wales where these adults had been educated, the practice of forcing children to write with their right hands was long-lasting.

Previous research has demonstrated that older people often have relatively low percentages of left-handedness. Annett (1998 p 67) reported that in those over 50 (in 1974) only 2.9% were left-handed. A slightly later (1987) survey of 5,147 Canadians, Coren found that the left-handed rate was 15% for 10 year-olds, 13% for 20 year-olds, 5% for 50 year-olds and 0% for 80 year-olds (1992, pp 50, 206).

Although a satisfactory explanation of variable proportions of left-handedness in older adults has been proffered and supported by primary research, research into the definitive incidence of left-handedness in the literature brought up another possibility. Coren and Halpern (1991, pp 93-96) and Bradley (1992, p178) suggested that the reason might be the premature death of left-handed people with Coren and Halpern reporting that there was a nine year difference in mean longevity, with right-handed people living to the age of 75 while left-handed die at 66 (p 95). While this is a novel idea it was disproved by subsequent research (Ellis, Marshall, Windridge, Jones and Ellis 1998, p 1634).

This survey of the literature as to the exact incidence of left-handedness was confusing, as all too often the interest was not only the dominant writing hand but also a host of other tasks that may be preformed with the right or left hand (Thomson 1984, p 84). It also seemed essential to have a study that considered the differences between males and females, given that there was a higher incidence of left-handed males in this survey. The most definitive UK study available was Bradley's 1992 survey with a sample size of 8435.

In comparing the two sets of results the decision was taken to use the full results up to the age of 64 from the current research, rather than excluding the last two groups so that both research studies ended with 54 year-olds. This was due to the thirteen-year difference in the research dates and the belief that any different rate amongst older people was caused by older educational and cultural influences. The two sets of results are shown below:

Table 4:7 Incidence of left-handedness in two research studies

	Bradley age 15-65+	Bladon age 5-64
Overall	10 %	10.0 % (9.96%)
Male	11 %	12.0 % (11.99%)
Female	9 %	8.0 % (7.99%)

The overall left-handed rates are very similar although there is a greater disparity between the genders in the current survey. Interestingly, Bradley's incidence for all ages in England was slightly higher at 11 to 12% for those aged under 44 while, that in the Celtic fringes including Wales, with a sample size of 320 was lower at only 8%. Bradley (1992, p 178) dismissed several theories for this lower rate and proffered a convincing argument that the reason for the difference was probably genetic. Although Bradley's study investigated adults from the age of 15 across the UK and the current study was primarily Welsh and included children but ended at the age of 64, the two overall percentages correspond very well. It seems as though Bradley's primarily English study raised the left-handed incidence only to lower it by including older people. However, the harmony between the two studies research is remarkable and does suggest that the results in this study do reflect contemporary writing handedness.

Having obtained two very similar incidences of overall left-handedness does permit a more detailed consideration of the validity of the individual one year or five year samples by calculating the 95% confidence levels for individual results with a sample size of 100 and comparing them with the overall left-handed rate. In addition, by making allowance for the reduced sample sizes in some of the data sets, the validity of these results may also be assessed, especially those for which doubts had earlier been raised.

Table 4:8 Maximum and minimum confidence limits for left-handed %, male and female c.v. mean 10.0%

		Left-handed %	95% confidence
Maximum	Year 4	16%	9.4 – 24.7 %
Minimum	Age 60-4	3.6%	0.7 – 10.1 %

The complete results are shown in Table B:25 in Appendix B. They show that for male and female samples added together, without adjustment for the sometimes variable numbers of men and women in the samples, the highest 95% confidence level was for Year 4 pupils, while the lowest was for the oldest group, the 60 to 64 year-olds. With 24 samples and 95% confidence intervals it would be expected that the left-handed rate of the whole study of 10.0% would lie outside the confidence intervals on one or perhaps two occasions without throwing doubt on 10.0% as the true rate for the whole sample. As it does not, this indicates that none of the individual age samples is inconsistent with the calculated mean of 10.0% and the concerns raised earlier are not substantiated statistically. This does not mean that, for example, older people are not less likely to be left-handed but that with these sample sizes there is no statistical evidence in support of this.

This variation in the percentage of left-handed from 8 to 16% in individual year groups was very similar to the 9-18% found by O`Mahony et al (2008) in their study of the handwriting speeds of Irish school pupils aged eight to eighteen. As described above, in this research this variability has been shown to be purely random. Thus no significance, such as O'Mahony et al attempted to draw from their results that in some year groups 'naturally left-handed children are using the non-preferred right hand' (p 174) possibly due to 'variability in teachers' policies with regard to handedness' (p 176), can be drawn.

As shown in Table 4:7, the rates of left-handedness in males and females differ, with men being more likely write with their left hand. Although the sample sizes were smaller, given the earlier concerns about the low numbers of left-handed men in the Year 13 and nineteen year-old samples, possibly due to a sample biased in favour of the more academically successful, a similar statistical analysis for male and female samples was conducted with the complete results once again shown in Appendix B (Table B:26). These calculations show the 95% confidence limits of the separate male and female samples.

Table 4:9 Maximum and minimum (in bold) confidence limits for male and female left-handed %, c.v. means of 12.0% (male) and 8.0% (female)

	Male left-handed %	Male 95% conf. limits	Female left-handed %	Female 95% conf. limits
Year 0	16%	7.1 – 29.2 %	**12%**	**4.5 – 24.3 %**
Year 4	**22%**	**11.5 – 36.0 %**	10%	3.3 – 21.9 %
Year 5	12%	4.5 – 24.3 %	**12%**	**4.5 – 24.3 %**
Year 6	**22%**	**11.5 – 36.0 %**	**4%**	**0.5 – 13.8 %**
Year11	10%	3.3 – 21.9 %	**12%**	**4.5 – 24.3 %**
Year12	12%	4.5 – 24.3 %	**12%**	**4.5 – 24.3 %**
Age 40-4	16%	7.1 – 29.2 %	**4%**	**0.5 – 13.8 %**
Age 60-4	**2.4%**	**0.1 – 12.9 %**	4.6%	5.7 – 15.9 %

The highest 95% confidence levels for the males were for Year 4 and Year 6 pupils while the lowest was for the oldest age group. All of these confidence intervals contain the total male sample mean of 12.0%. The highest 95% confidence levels for the females were for Years 0, 5, 11 and 12 pupils while the lowest were for Year 6 and 40 to 44 year-olds. All of these confidence intervals contain the total female sample mean of 8.0%. With 48 samples and 95% confidence intervals it would be expected that the left-handed rates of 12.0% and 8.0% for males and females respectively would lie outside the confidence intervals on two or even three occasions without throwing doubt on these rates as the true rates for the gender samples. As this does not happen in any of the 48 data sets, this indicates that none of gender and age samples appear inconsistent with the calculated means of 12.0% for males and 8.0% for females.

The very different incidences of left-handedness in the males and females in the sample were statistically tested. The full statistical test results (Statistical Test 1) are shown in Appendix B. The conclusion can be made from the results of this test that there is only a one in a thousand chance that the incidence of left-handedness in males and females is the same. It therefore seems safe to conclude that there is actually a difference between the rates of left-handedness between men and women with men being more likely to be left-handed in a ratio of approximately 3:2.

The aim of this section on data analysis of the rates of left-handedness in the sample is thus achieved namely that the data collected shows a consistent level of left-handedness albeit with different rates between the sexes. The next stage of data analyses investigates whether there is a relationship between age and the way a pen or other writing implement is held.

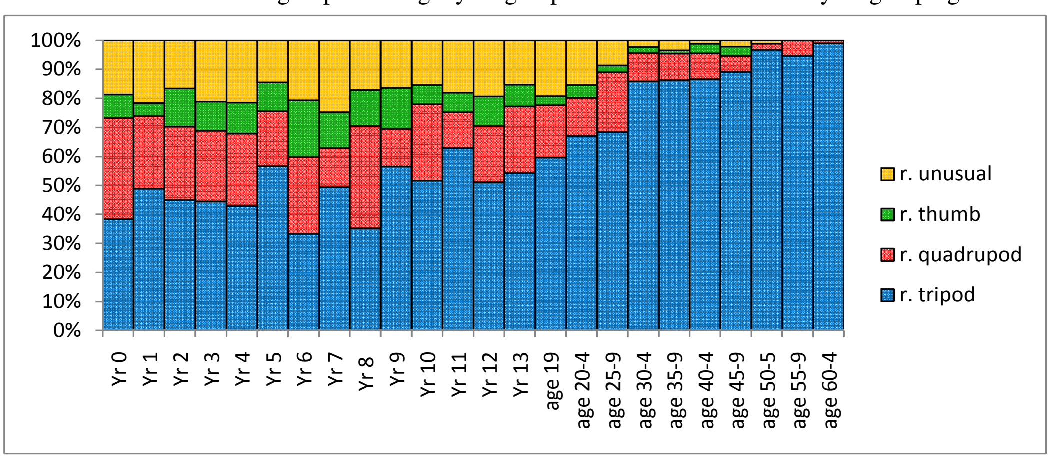
AGE AND RIGHT-HANDED NON-TRIPOD GRIPS

As shown in Table 4:6 above, the percentage of left-handed people in the age groupings varied between 16% in Year 4 and only 4% for 60 to 64 year-olds. In order that the proportions of the different right-handed grips might more easily explored, the right-handed figures from Table 4:6 have been converted into percentages and then displayed on a graph. These are both shown below:

Table 4:10 Percentages of right-handed grips (Table B:27 in Appendix B shows the results to one decimal place)

	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11
r. tripod	38	49	45	44	43	58	33	49	35	57	52	63
r. quadrupod	35	25	25	24	25	19	26	14	35	13	26	12
r. thumb	8	4	13	10	11	8	20	12	13	14	7	7
r. unusual	19	22	17	21	21	15	21	25	17	16	15	18
	Yr 12	Yr 13	age 19	age 20-4	age 25-9	age 30-4	age 35-9	age 40-4	age 45-9	age 50-5	age 55-9	age 60-4
r. tripod	51	54	60	67	68	86	86	87	89	97	95	99
r. quadrupod	19	23	18	13	21	10	9	9	5	2	5	1
r. thumb	10	8	3	4	2	2	1	3	3	0	0	0
r. unusual	19	15	19	15	9	2	3	1	2	1	0	0

Graph 4:2 Right-handed grips according to age. The horizontal axis (X axis) has an inconsistent scale. The first 15 groups are single year groups while the last 9 are five year groupings.



Apart from some sharp fluctuations in the proportions of pupils showing tripod and quadrupod grips in Years 5 to 12, a strong pattern emerges. This is most clearly appreciated by focusing on the most extreme form of grip, the unusual, shown in yellow on the graph on the previous page. There are two distinct age-related sections to the graph with a brief transitional stage between the two. The first is from Yr 0 and includes the 20 to 24 age group while the second extends from the 30 to 34 year-olds to the upper limit of the survey. The next most extreme form of grip, the thumb grip in which the pen is held by the thumb knuckle rather than the ball of the thumb, is relatively uncommon above the age of 35 but is much more common especially in nineteen year-olds and younger, although it perhaps less frequent in the very early writers of Years 0 and 1. The quadrupod grip is found in all age groups but is very much less common in the older samples. The mean percentages of the four forms of grip are shown in the table below for each of the two major age groups described above.

Table 4:11 Mean percentages for the four right-handed grips for two age groupings (calculated using the exact percentages shown in the appendix, Table B:27)

	Yr 0 to age 24	Age 30 to 64
Unusual	18.4	1.4
Thumb	9.5	1.4
Quadrupod	22.1	5.9
Tripod	49.9	91.2

Although it seems obvious that the two groups are different, this needed to be tested statistically with a summary of results shown below.

Table 4:12 Percentages of three different right-handed penhold groupings for younger and older ages with a probability calculation indicating the probability that the two groups were drawn from the same population. See statistical tests 2, 4 & 5 in Appendix B.

	% under 25	% over 30	P-value	Probability
Unusual grip	18.42	1.39	0.000	$p<0.001$
Unusual & thumb	26.19	2.78	0.000	$p<0.001$
All non-tripod	69.26	8.64	0.000	$p<0.001$

The results for three separate tests are shown. The first simply compared the number of unusual right-handed grips in the two age groups. The second grouped the unusual and thumb grips together before making the comparison and finally, all the non-tripod grips in the two groups were assessed. These tests were performed in this way because although the incidence of a thumb grip may be similar, for example Year 1 at 4.5% and 40-4 year-olds at 3.3% (Appendix B Table B:27), and a statistical analysis of these two figures might show that they have were likely to have come from the same population, the unusual grips in these two age groups were 22.6% and 1.1% respectively and thus it is grips that are thumb or more unusual that must be compared. In each case the null hypothesis being tested was that the two results could have come from the same population, with the alternative hypothesis that they did not, but instead represented samples drawn from different populations.

As shown in the Table 4:12 each of the three tests performed indicated that the probability is less than one in one thousand that the pattern of grips shown by those under 25 and those 30 and over are the same. Thus it may be concluded that there is very strong evidence (Arsham 1988, p 132; $p<0.01$ indicates very strong evidence) there was a significant change in the way that people held their pens and this occurred in an approximate five-year period. This sharp change was an unexpected result, and certainly one not anticipated at the outset of the research. Such a dramatic change in grip observed cannot be due to a genetic alteration or a change in teaching staff but rather a change in teaching methods and this is an idea that will be discussed in Chapter 7 (pp 237-9). It could of course be argued that the shift was gradual and it was the grouping of such large numbers that artificially created a significant difference over this five-year period. This was tested statistically by comparing the numbers with unusual grips, the main focus of this research, as well as the other non-tripod groupings described above with the age bands on either side of the transition group, namely the 20-24 and 30-34 year-olds.

Table 4:13 Percentages of right-handed unusual penholds in the transitional and adjacent age groups with a probability calculation indicating the probability that the three penhold groups were drawn from the same population. See statistical tests 3 & 6-13 in Appendix B.

	Group 1 %20-4	Group 2 % 25-9	Group 3 % 30-4	cf 1&2 P-value	cf 2&3 P-value	cf 1&3 P-value
Unusual grip	9.78	8.70	2.17	0.162	0.065	0.001
Unusual and thumb grips	19.78	10.87	4.35	0.090	0.093	0.001
All non-tripod grips	32.97	31.52	14.13	0.834	0.004	0.002

The null hypothesis was that the results could have occurred by chance with the two samples either side of the transition age group coming from the same population. The statistical results shown indicate that the probability of this happening was one in a thousand (p=0.001) for both unusual and unusual and thumb grips with only a very small increase in the probability of this happening to 1 in 500 (p=0.002) for all non-tripod grips. Thus the null hypothesis can be discarded in favour of the alternative – that these two groups of young adults are different in respect of their choice of handwriting grip.

The handwriting grips of the transition group are shown in Table 4:10 and in more detail in Table B:27 (Appendix B) with a summary of statistical analysis in Table 4:13, although some of the results should be treated with caution due to the relatively small sample sizes. However, the left-handed rate is similar to the groups immediately above and below it, while the right tripod rate is similar to that below it and the thumb rate is like that above. Most significantly, the observed unusual rate is an arithmetic mean of the groups on either side. Perhaps the most remarkable feature is the very high quadrupod rate. However, this is perhaps the most variable of all the non-tripod grips identified and higher rates were observed in five of the six primary and three out of the seven secondary school year groups. It does thus seem that this is merely the sort of anomaly that occurs in any data set. Interestingly, if the quadrupod and the tripod rates accepted as minor variations of grip (Sassoon et al 1986, p 101) and considered together then the overall functionally acceptable rate for 25-9 year-olds (89.1%) falls almost exactly between that in the two neighbouring groups (80.2% and 95.7%). This provides further evidence that the 25-9 year-old group is transitional.

In addition to this non-empirical approach, the grips of the transitional group of 25-9 year-olds were subjected to statistical comparison with both the older and younger groups on either side, namely the 20-24 and the 30-34 year-olds. The transitional group is more similar to the younger group with respect to the unusual (probability that they come from the same population is about one in six (p=0.162)) while the unusual and thumb rates are equally similar to the older and younger (probabilities that they come from the same population is about one in eleven (p=0.090) and 0.093)). However when all non-tripod grips are considered then the transitional group is very similar to the younger group (p=0.834) but very dissimilar to the older group (p=0.004) although given the small number of unusual grips these results must be treated with a degree of caution and merely regarded as indicative of a sudden change in handwriting grip rather than proof of it.

GENDER AND RIGHT-HANDED NON-TRIPOD GRIPS

Having ascertained in the previous section that there is a significant difference in the way that people over thirty and under twenty five hold their pens, it now becomes important to consider the effect of gender. The issue of gender has already been demonstrated to play a part in whether an individual writes with their right or left hand, with men being more likely on the basis of the results in this research to be left-handed, but are men more or perhaps less likely to adopt a non-tripod grip?

In order to determine whether gender is related to unusual grip of a pen or other writing implement, the percentages of right-handed males and females holding their pens with an unusual grip was calculated. This transformation from numbers into percentages was necessary due to the variable rate of left-handedness observed. The results obtained are shown in Table 4:14 below, and in Graph 4:3 which follows.

Table 4:14 Percentages of right-handed males and females with unusual grip

age	Yr0	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	Yr11
male	14.3	9.3	15.5	18.1	17.9	11.4	10.3	20.5	18.6	9.1	16.7	17.8
female	22.7	33.3	17.4	23.9	24.4	18.1	29.2	28.9	15.5	22.9	14.3	18.1
age	Yr12	Yr13	19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64
male	18.1	5.7	10.0	17.8	11.4	0	7.1	2.4	2.1	0	0	0
female	20.5	23.9	28.9	13.0	6.3	4.4	0	0	2.2	2.4	0	0

Graph 4:3 Percentages of right-handed males and females with unusual grip. The horizontal axis (X axis) has an inconsistent scale. The first 15 groups are single year groups while the last 9 are five year groupings.

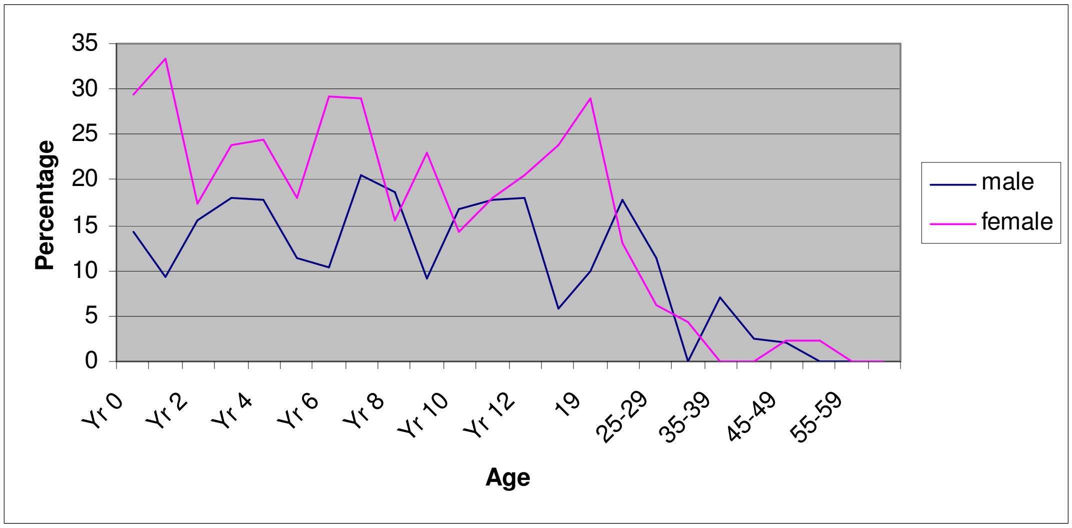


Table 4:14 and Graph 4:3 show that there are several differences in grip between the genders. There is a very great difference between the unusual grip rates in the youngest children, namely those in Reception (Year 0) and Year 1. This could be due to immaturity, but within weeks of completing this part of the research two young girls aged about 5 were observed writing with grips far more extreme than any observed in the whole of this large sample. Thus, although this is an anecdotal observation, it does seem that very young girls are particularly prone to very unusual grips, although it remains a possibility that with practice the grip may become less radical.

As already observed, unusual grip is relatively uncommon in those over the age of thirty and this is again obvious from Graph 4:3. It also appears that in those over thirty the numbers of men and women with this grip are very similar, although with such small numbers this it is impossible to be certain that this is more than a chance observation. At younger ages, and especially under the age of twenty, right-handed females are much more likely than right-handed males to use an unusual grip. The overall unusual incidence for males under 25 is 14.7% while that for females is 22.1%. The difference in rates is particularly marked in the eighteen (Year 13) and nineteen year-old age groups as had been observed before. If these groups and that which follows them (age 20-24) are not included the means are nearer, at 15.2% and

22.3% respectively. Thus it can be seen that unusual grip is more common in girls and young women. This observation was tested statistically with the null hypothesis that the male and female samples come from the same population. This was disproved, thus supporting the alternative hypothesis that the genders are different with respect to the likelihood of adopting an unusual pengrip.

Table 4:15 Percentages of right-handed unusual and non-tripod penholds in younger males and females with probabilities that the gender groups were drawn from the same population. See statistical tests 14-17 in Appendix B.

	Male	Female		Male	Female	
	Yr 0-12	Yr 0-12	P-value	% <25	% <25	P-value
Unusual grip	15.23	22.26	0.002	14.67	22.13	0.000
All non-tripod grips	49.82	56.49	0.023	45.36	54.50	0.001

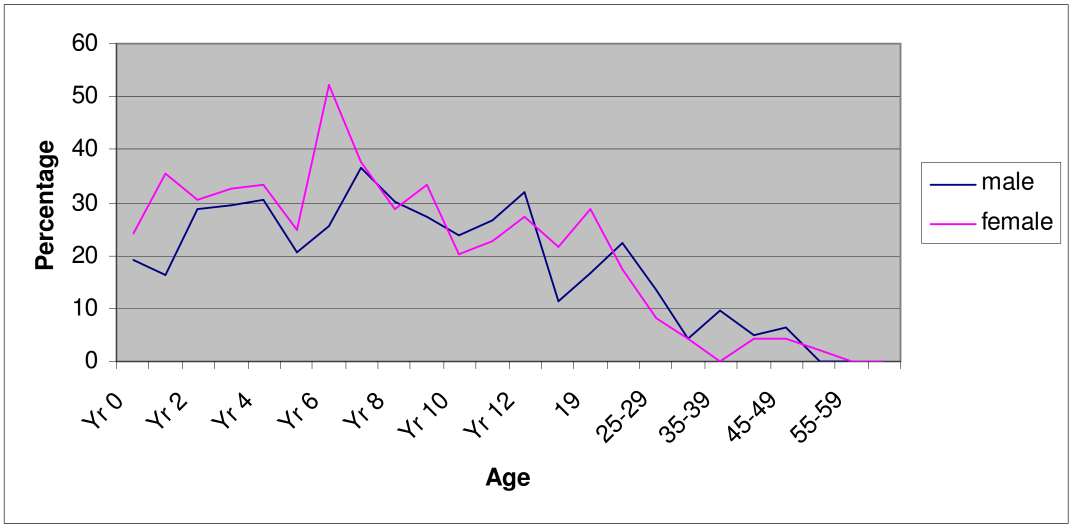
The results show that for school pupils, excluding Year 13 there is a probability of only 0.002 that the unusual grip rates for males and females came from the same population. If the next three age groupings are included (Yr 13, nineteen year- olds and 20-24 year-olds) the probability falls to less than one in a thousand. As previously explained, there are reservations whether the sampling of these older ages was sufficiently random because those selected were more academically able. It is for this reason that greater confidence should be placed on the results for the smaller, younger sample. Given that there is only a one in five hundred chance that the results for the genders were the same, it can be concluded that girls are more likely than boys to be using an unusual grip.

Similar tabulation was conducted for unusual and thumb grips in order that the incidence of these two grips might be considered together. The relevant table and graph are shown below:

Table 4:16 Percentages of right-handed males and females with unusual or thumb grip

age	Yr0	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	Yr11
male	19.0	16.3	28.9	29.5	30.7	20.5	25.6	36.4	30.3	27.3	23.8	26.7
female	24.1	35.5	30.4	32.6	33.3	25.0	52.1	37.7	28.9	33.3	20.4	22.7
age	Yr12	Yr13	19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64
male	31.8	11.4	16.7	22.2	13.6	4.3	9.5	4.8	6.4	0	0	0
female	27.3	21.7	28.9	17.4	8.3	3.4	0	4.2	4.3	2.2	0	0

Graph 4:4 Percentages of right-handed males and females with unusual or thumb grip. The horizontal axis (X axis) has an inconsistent scale. The first 15 groups are single year groups while the last 9 are five year groupings.



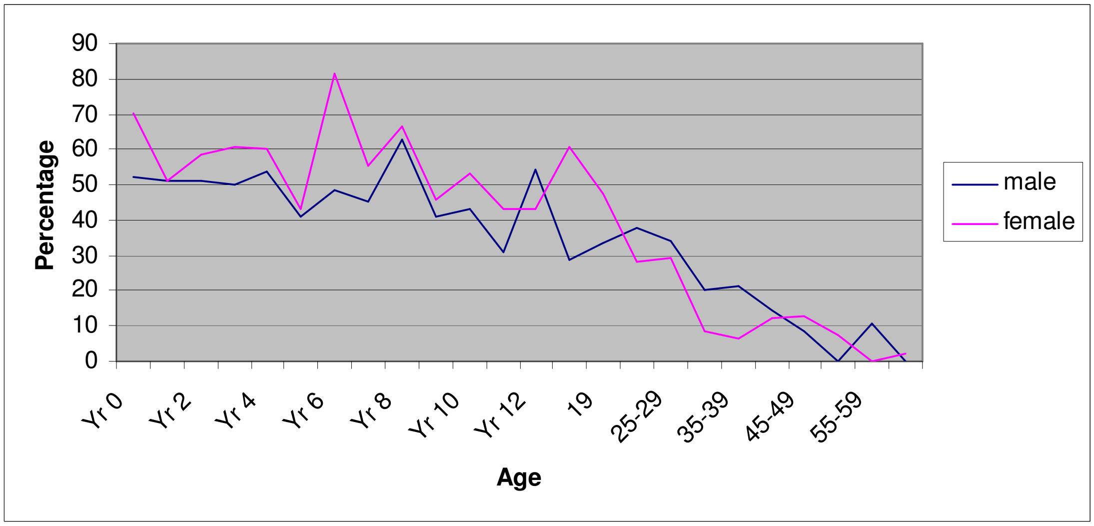
Graph 4:4 shows that although there are slightly higher unusual and thumb grips in primary school girls, with Year 6 girls having a rate of over 50%, the rates are very similar in secondary school pupils while the pattern for adults mixed. The very high unusual grip rate in eighteen and nineteen year-olds is still obvious while in older adults it is men that have the slightly higher rate. The possibility that the separate thumb rate was higher in males in Years 0 to 12 was tested. Although there was a higher rate for boys, 11.5% as opposed to 9.3% for the girls this difference is slight and no statistical significance could be drawn.

The final variable to be considered is the incidence of all non-tripod grips for both males and females. This includes not only the unusual grips but also the thumb and quadrupod grip. The rates for both sexes are displayed in the table below, and the graph that follows.

Table 4:17 Percentages of right-handed male and females with any non-tripod grip. The horizontal axis (X axis) has an inconsistent scale. The first 15 groups are single year groups while the last 9 are five year groupings.

age	Yr0	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	Yr11
male	52.4	51.2	51.1	50.0	53.8	40.9	48.7	45.5	62.8	40.9	42.9	31.1
female	70.5	51.1	58.7	60.9	60.0	43.2	81.3	55.6	66.7	45.8	53.1	43.2
age	Yr12	Yr13	19	20-4	25-9	30-4	35-9	40-4	45-9	50-4	55-9	60-4
male	54.5	28.6	33.3	37.8	34.1	20.0	21.4	14.3	8.5	0	10.4	0
female	43.2	60.9	47.4	28.3	29.2	8.5	6.5	12.5	13.0	7.3	0	2.1

Graph 4:5 Percentages of right-handed male and females with any non-tripod grip



Non-tripod grip is more common in females than in males until the age of 20-24 after which it is more common in men. The higher female rates commented upon before are still visible, namely in the very youngest reception children (Year 0), the probably anomalous Year 6 and the possibly poorly sampled Year 13. As shown in Table 4:12 the higher incidence of non-tripod grips in those under twenty-five is statistically significant ($p<0.001$).

Given the reservations about the way the eighteen and nineteen year-old samples were obtained the same statistical test was repeated excluding these groups and the 20-24 year-olds. Once again this was statistically significant ($p=0.023$) with moderate evidence (Arsham 1988, p 132) of only a one in forty probability that the samples come from the same population. Thus, although it may be concluded that girls are less likely to use a tripod grip than boys, the major reason for this appears to lie in the much higher rates of unusual grip rather than the slightly higher rates of quadrupod grip which for males under 25 was 20.2% compared with the female 23.7%; a difference which is not statistically significant.

LEFT-HANDEDNESS AND UNUSUAL GRIP

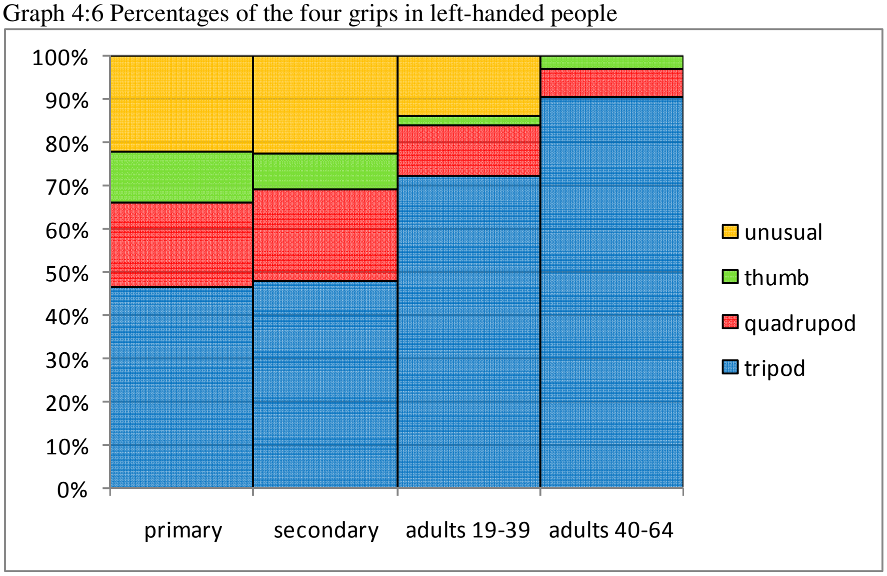
The difficulties that left-handed writers experienced were discussed in Chapter 1, although when writing speed and quality of the written trace are considered left-handers perform no less well than right-handers (Askov et al 1970, p 103;

O'Mahoney et al 2008, pp 172-174). Although the main focus of interest of this research is right-handed writers, left-handed writers also frequently have an unusual grip. Owing to the limited sample size and the lower incidence (Springer and Deutsch 1999, p 119) of left-handedness in the population the only way to reach any conclusions was to group the data. The data naturally fell into three groups, primary age children, secondary age children and adults. Following the identification of the 25-9 year-olds as a transitional group for right-handed people, the older adults were kept as a group but given the small numbers involved the transitional group were included with the younger adults. The data used to produce the graph that follows is shown in the table below.

Table 4:18 Percentages of left-handed people using the four categories of grip.

	primary	secondary	adults 19-29	adults 30-64
tripod	46.5	47.9	65.2	86.5
quadrupod	19.8	21.1	8.7	9.6
thumb	11.6	8.5	4.3	1.9
unusual	22.1	22.5	21.7	1.9
number	86	71	23	52

Graph 4:6 Percentages of the four grips in left-handed people



The unusual grip rate is fairly constant at about 22% under the age of 30 after which it falls to almost zero. The other non-tripod grips follow a similar pattern although the quadrupod is much less common in younger adults. Given the relatively small numbers other patterns, such as those related to gender, could not be investigated. The one comparison that is possible is the incidence of unusual grip in left and right-handed people. Given that the incidence of unusual grip is fairly consistent in right-handed people under the age of twenty-five, it is the total number of people with unusual grips in all age categories up to the age 24 that will be used to make this comparison.

Of the 172 left-handed people, aged under 25, observed writing, 37 or 21.5% used an unusual grip while the comparable figure for right-handers were 263 of 1430 or 18.4%. Thus slightly more left-handed people used an unusual grip than did those who wrote right-handedly. However, when the significance of these two proportions was tested (Test 18 Appendix B) there was a high probability of about one in three (p=0.344) that these results could have come from a population with the same rate of unusual grip. Thus, although more left-handed people used an unusual grip, this observation could have arisen by chance.

Although in the rest of this study only right-handed unusual grip will be considered because of the low rate of left-handers, there is no reason to believe that those write with their left hand are any less subject to the difficulties that unusual pengrip causes.

CHANGE IN GRIP

As described above, the incidence of unusual grip, the main focus of this research, changed quite dramatically over a five-year period. As described earlier in this chapter, the results of the demographic survey indicate that there are two distinct age-related groupings with a brief transitional stage between the two. The first age-related grouping extends from Year 0 and includes the 20 to 24 age group, while the second extends from the 30 to 34 year-olds to the upper limit of the survey. There is a less than one in one thousand probability that the pattern of grips shown by those under 25 and those 30 and over are the same and it was concluded that there was a significant change in the way that people held their pens occurred over approximately a five-year period.

The transitional stage was observed to include people aged twenty-five to twenty-nine in the summer of 2005. Assuming they entered primary school in Year 1 in the

September after they were five, they would have begun their education between the years 1980 and 1984. The changes in early years education at this time will be considered in more detail in the final chapter**.**

This study has identified a relatively dramatic shift and it was over this period (1975-90) that the handwriting manuals this researcher has reviewed (Bentley 1990; Jarman 1993a; Sassoon 1990a; Sassoon 1990b and Sassoon 1999) seemed to recommend a laissez faire attitude to many aspects of handwriting instruction, not least penhold. Sassoon et al in their 1986 research, close to the period under consideration, noticed this shift but considered that the difference was due the children developing a mature handwriting grip. They recorded that only 38% of 15 year-olds used a classic tripod grip although by including the two fingered modified (quadrupod) variation of the tripod concluded that 85% of fifteen year-olds in their survey had a functionally tripod grip. However, the younger children (seven and nine) who had learnt to write more recently, showed much lower levels of functionally tripod penhold (71% and 72% respectively). The fifteen year-olds would be aged about thirty-four in 2005 while the seven and nine year-olds would be aged twenty-six and twenty-eight. The research does not give precise dates as to when the research was conducted but the participants cannot have been younger and this allows direct comparison with the handwriting grips adopted by comparably aged people in this research, grouping quadrupod and tripod grips together.

Table 4:19 Comparison between percentages of functional tripod grip in two research surveys

	Sassoon et al 1986	Current research
Age 7/9 / age 25-9 Age 15 / age 30-34	71.5 % 85 %	87 % 96 %
Difference	13.5%	9 %

Although the actual rates vary between these two surveys, the differences between the two age groups are similar. The disparity between the results seems to be the result of the very strict definition of an unusual or thumb grip adopted in this research. While Sassoon et al's research included aspects such as flexion of thumb and fingers, relative positions of the fingers and thumb on the pen and the position of the hand, this research looked merely at the positioning of the digits. A tripod grip thus merely required the ball of the thumb and the first finger to be holding the pen between them; flexion and the angle at which the pen was held was irrelevant. So, for example if a right-handed person wrote with a hooked wrist (see below) or an unflexed thumb this was deemed tripod provided the pen was held between the ball of the thumb and the first finger (see Photograph 4:1).

Photograph 4:1 Pupil number 4 - an example of an unusually angled tripod grip

The sheer scale of the work involved and a desire for the two parts of the research to use the same definition of unusual pengrip, necessitated the very tight definition adopted by this survey. Thus while Sassoon et al’s research investigated only 294 pupils with two photographs taken of each pupil, allowing later more detailed analysis, the demographic element of this research involved 2,290 children and adults and had to be done rapidly and without photographic assistance, as a more complicated investigation procedure would have increased the refusal rate and the possibility of bias (Cohen et al 2007, p 110). In addition to those included in the demographic survey, pupils in a further eight secondary schools were observed writing in order to identify those suitable for the comparative research. Although precise records were not kept, a rough estimate suggests that the original observation size was doubled. Although desirable, a more complicated recording system would have become unwieldy and would have been difficult to implement with consistency. In the adult section of the demographic survey a 40 to 45 year-old man was observed to write right-handed with the hooked grip usually associated the left-handed writers. This angled the pen so it pointed towards the writer and had been previously observed by Ziviani albeit in a right to left writing system (1987, p 34). This hooked tripod grip caused some confusion as to how it was to be categorised. It was, however awkward, a tripod grip and was categorised as such.

The demographic part of this research has shown the number of people using an unusual grip changed very sharply over an approximate five-year period. A much more detailed investigation into the pengrips of the adults aged 25 to 29 in 2005 would be needed to discover whether this shift was gradual or sudden. For a shift from unusual rates of about 2% to that of about 15% to have occurred in just five year seems remarkable.

Another possible cause for the shift in the early 1980s may been (in addition to increasingly liberal education policies) children being introduced to writing much earlier than previously possibly due to increased usage of nursery or other 'day-care' scenarios without qualified teacher supervision. The increased use of day-care without one to one supervision of early writing experience may allow grip to be so fixed by five that change is it impossible. (Thomas 1997, p 130) This hypothesis will be considered in greater detail in the final chapter.

Whatever the cause, far more children are using an unusual grip and it seems likely that this unusual grip may affect their progress during their secondary education. It is the potential consequences that this adoption of an unusual grip that the remainder of this research will be considering.

SUMMARY AND CONCLUSIONS

Over two thousand people, aged between five and sixty-four, were observed writing and the hand with which they wrote and they precise way they held the pen noted. By using the left-handed rate, which accorded with that found by other researchers, it was concluded that these observations could be accepted as a representative sample of the population.

The sample was considered in single year groupings up to the age of nineteen and in five year groupings for older adults. The proportions of the different grips used by people of different ages were investigated with detailed statistical analysis allowing some firm conclusions to be made.

First and most importantly, those writing with their right hand fell into two age-groupings with only a brief transitional stage occurring between the ages of twenty-five and twenty-nine years of age. There is extremely strong evidence that the proportion of those using an unusual grip was far higher in those under twenty-five. The mean percentage for those exhibiting unusual grip under the age of 25 was 18.4% while those 30 and over it was 1.4%. There was very strong statistical evidence that the difference existed even between the two groups either side of the transitional grouping. In addition, there is strong evidence that the two age groupings are different in respect of all non-tripod grips, although the reason for the difference seems to stem from the much higher rates of unusual grip.

Unusual grip in those in the younger age groups was more common in females than in males with the overall unusual incidence for males under 25 being 14.7% while that for females is 22.1%. Statistical evidence very strongly indicates that this result could not have occurred by chance but is the result of a difference between the sexes in the way that pens are held. The reason for this difference is unclear, although it could be due to young girls be writing more independently or younger than their male peers.

Although far fewer left-handed people were observed writing, similar patterns of grip were observed with the unusual rate in those under 30 being over 22%. This is a slightly higher rate than that observed in right-handed people but given the small numbers of observations no firm statistical conclusions could be drawn.

The causes for such a dramatic change are unclear, but certainly worthy of further investigation. However, the main focus of this research is the possible educational consequences of unusual pengrip. Far more children are using an unusual grip and it seems likely that this unusual grip may affect their progress. It is this that the remainder of this research will consider in the next chapters.

CHAPTER FIVE

PHASE TWO - METHODOLOGY FOR OBTAINING INFORMATION ON GRIP PATTERN FROM SECONDARY SCHOOL PUPILS

INTRODUCTION

The research hypothesis is that pupils with unusual penholds have undiagnosed learning difficulties and consequently may be performing differently to their classmates, perhaps due to their poorer recording skills. To examine these issues further, the following research was designed to investigate the difference in performance of pupils with unusual and regular penholds. It is intended that one hundred pupils with unusual penholds will be identified and carefully matched with pupils with pupils from the same school showing similar levels of school performance. Each of the pupils' abilities will be tested and their writing speeds measured. Interviews concerning their early educational experiences and any current writing problems will also be conducted. In an earlier survey (Bladon 2004) several other issues were highlighted including the very low levels of a fully or partial cursive script; and the high levels of pain reported by pupils sometimes on even very short writing tasks. These issues will also be considered in the research protocol which is explained below.

RATIONALE

The research is envisaged as a classic, theory-testing project with an essentially quantitative approach. Given the practical problems associated with undertaking a longitudinal study (Barnett and Henderson 2005, p 187; Cohen et al 2007, pp 214-7), an approach of matching achievement will be adopted with a control group comprised of the unimpaired (Henderson 1993, p 287). The independent variable will be the grasp pattern used by the pupil while it is intended that the dependant variables will include ability, writing speed and writing legibility. As with Dennis' and Swinth's study using matched pairs, pupils will be controlled for gender, age (via year grouping) and handedness but in addition school performance via set groups for mathematics, science and the school's first language (English or Welsh).

The most efficient penhold is developed in the early years of schooling and can be described as `where the tool is held between the pads of the thumb and index finger' (Taylor 2001, p 49) and it is this finger pad and thumb pad allowing maximum fine motor control which will be used as the definition of normal penhold in this research. Owing to the increasingly observed trait of using two fingers on the barrel of the pen - the quadrupod grip, perhaps due to the increasing use of ballpoint as opposed to fountain pens, such a grip will be considered as a variant of normal since it still allows fine motor control. However, this idiosyncrasy will be considered as a separate subgroup during later analysis. Since the aim of this research is to investigate the effect of unusual penhold on performance, this leniency in the matching of pupils should allow for better pupil matches to be made.

In order to improve the detection of educational consequences associated with unusual grips it is intended to identify and classify the most extreme idiosyncrasies of penhold. As described above, these pupils will be matched with a pupil with a tripod or quadrupod grip. The research is centred on the null hypothesis that achievement matched pairs of pupils, differing only in the way they hold their pens, will have similar abilities. Disproving this hypothesis would result in support for the initial hypotheses that pupils in the research group have either a higher or lower ability level and are thus are under performing or over performing.

ETHICAL CONSIDERATIONS

A variety of ethical considerations have had to be addressed while planning this research. Although the research design involves pupils between Year 8 and Year 11, it was decided at the outset to not include pupils in Year 11 after the Christmas holidays, as they would be involved in preparing for important external examinations.

Informed Consent

An important ethical consideration was obtaining permission from the appropriate LEA, head teachers, parents and pupils to carry out the research. Having obtained permission from the two LEAs involved to approach the schools, the details of the whole research project were explained during a meeting with each head teacher.

The head teachers also approved the parental permission letters, on one occasion requesting it be produced on school stationary. Following the identification of pupils to be included in the research, these letters were distributed seeking parental and pupil permission. The bilingual parental permission letter (see appendix A) described the research as investigating handwriting and performance and included a guarantee of confidentiality.

Staff in each school were informed of the nature of the research by the head teachers although it was made clear that pupils should only be told that the research concerned handwriting. The teacher's permission was sought before any class was surveyed. On some occasions the researcher returned later in the lesson and on two occasions a class was omitted from the survey as they were having a whole lesson subject test.

Confidentiality

Confidentiality will be maintained with only grouped data being presented if there is any possibility of individual pupils being identified from non-grouped data, for example, the month of a pupil's birth will not be reported However, if any part of the research indicates a pupil is experiencing difficulties sufficiently severe to possibly warrant additional support or extra time in external examinations, then the researcher's concerns will be raised with an appropriate member of staff in the school concerned.

Privacy

In timed free writing it is important that if pupils are not going waste a disproportionate amount of time thinking about the subject that they are writing about, the subject of their writing should be well known to them. While `All About Me' (Mason 1991) and `My Life History' (Dutton 1992) fulfil this criteria Dutton did feel that the subject matter should not be presented to the researcher with the pupils' names attached. The subjects suggested as possible writing topics in this research have been selected so that similar concerns should not arise.

Meetings with pupils were held in private with no one other than the pupil and the researcher present. The room varied from school to school. If an empty classroom was available this was used, alternatively the first aid room or a senior teacher's office.

Disruption

The impact on the pupil's education was minimised. Each pupil missed one lesson. The pupils selected to be assessed on each day assembled before the first lesson and after discussion arranged the order between them. The guidance was given that they should choose the lesson that it would be least disruptive, for example, that would involve minimal `copying up', with priority being given to the older pupil if there was any disagreement. It was important that there should be very little disruption to each pupil's education because the children involved would not personally benefit from this research, an important ethical aspect of planning any research (Cohen et al 2007, p 52). The participating pupils whose parents had given permission were eager to take part in the research and seemed to benefit from an adult from outside the school taking an interest in them and their school experiences.

PARTICIPATING SCHOOLS

The research was conducted in state secondary schools in West Wales local to the researcher's home. At the outset of the research it was intended to include ten schools in the research, each providing approximately ten pupils with unusual grips. Since the intended numbers of pupils were identified from only nine schools, this was the eventual number of schools involved. The schools surveyed included six of the seven secondary schools in Ceredigion, the seventh having been the setting for the pilot research (Bladon 2004), together with three secondary schools in the neighbouring county of Carmarthenshire.

Of the schools, three were Welsh medium and three English medium with overlapping catchment areas while the remaining three schools were traditional bilingual schools providing a choice of three education streams: Welsh medium (English, mathematics and science taught in English), English medium (Welsh and

PE taught in Welsh) and a bilingual stream. The schools varied in size reflecting population densities but all educated pupils from 11 to 18.

Prior to the research the two LEAs were contacted and outline permission for this research to be conducted in their schools obtained. The head teacher of each school was approached and an interview arranged. During these interviews the research project was explained, together with its possible educational implications. All tools to be used during the research were explained, especially Raven's matrices as well as measures to be taken to ensure the anonymity of the participants. A copy of a bilingual parental permission letter was given to each head teacher and the access to pupils discussed. In every case permission was given for the research to be carried out. Permission was facilitated by the researcher's personal circumstances, as she was a Carmarthenshire resident employed as a teacher by Ceredigion County Council with appropriate CRB clearance.

THE SUBJECTS

The research required the identification of one hundred pupils from Years 8 to 11 each using an unorthodox right-handed pencil grip. As explained above it is suggested that these pupils may have undiagnosed learning difficulties. Left-handed pupils were explicitly excluded, as left-handedness would introduce a multitude of other variables. In addition, the proportion with unusual grips may vary (Springer and Deutsch 1999, p 132) and matching left-handed pupils would be difficult given the lower incidence of left-handed writers.

The identification of the pupils was carried out in slightly different ways in the first school than in the others. Pupils in this school formed part of the demographic study and two days were spent in the school where every pupil, except the very small number absent on both days, was observed writing. If the class being surveyed were writing as a part of their normal activity then the grip employed during this activity was recorded. This obviously did not happen in all classes and when pupils were not writing they wrote their names on a sheet of paper as it was passed round the class with the grip used being noted. Thus, in the first school, only the names of those with unusual grips were recorded for later matching. It became apparent that because of the higher than anticipated rate of unusual grips this method of identification would increase the number pairs of pupils that could not be included in the final analysis. Thus, in subsequent schools the name of every pupil was recorded as using an unusual grip, a right-handed tripod grip (preferred match), a right-handed quadrupod grip (acceptable match) or not to be matched. This final grouping included pupils that were left-handed, those that held the pen between the thumb knuckle and forefinger, characterised as a thumb grip in the demographic survey, and the single pupil who did not want to participate as well as any pupils previously known to the researcher. To this group of inappropriate matches were added all pupils identified as having unusual grips that were receiving additional educational support within the school. These pupils were identified by consulting the Special Needs Register in each school prior to the matching of pupils.

Initially the request was made to the school to see all pupils in Years 8 to either 10 or 11. Timetables were drawn up to achieve this but in the third school surveyed when the same year group was seen in different lessons there was an overlap with some pupils being surveyed twice and others potentially not surveyed thereby reducing the potential sample. In the fourth and subsequent schools more stringent conditions were implemented. This required that a whole year group be surveyed in a single lesson, a task most easily accomplished when they were in a core subject set across the entire year group (or in the larger schools half year group) as the classes usually occupied adjacent classrooms.

The research design required each pupil identified as writing with an unusual grip to be as closely matched as possible with a pupil with a tripod pengrip. In identifying controls, as many variables as possible were matched. The first being the school, as each pupil was matched with another from the same school. The second was gender. The set lists for mathematics, science and English (or Welsh in the Welsh medium schools) were obtained. The pupils were matched with a pupil in the same set for, first mathematics, then science and thirdly language. Whenever there was a choice of the pupil to be the control then a pupil in the same or closest possible linguistic group was selected.

Parental and pupil permission was then sought. A bilingual letter was produced that explained that the researcher, was conducting research into handwriting and performance and requesting permission for the pupil to assist in this research. These letters were distributed in the registers together with a stamped, addressed envelope for the permission slip's return. Those pupils who did not wish to participate could choose not to pass the permission letter to their parents and without a returned slip giving permission the pupil was not included in the final research sample.

Appointments were made to see all the pupils included in the final sample. The pupils were seen individually, with a lesson allocated for each assessment. The school would be notified in advance which pupils were to be seen on a particular date and they would be assembled together to arrange the order in which they would be seen. On each occasion it was suggested that they pick a lesson that would involve least copying up or disruption to their education.

THE ASSESSMENT PROCEDURE

As described above individual pupils were interviewed in a private room. The room varied from school to school. If a spare classroom was available this was used, alternatively the first aid room or a senior teacher's office.

After a brief conversation to settle the pupil the first aspect of the assessment administered was Raven's Standard Matrices (1956). As the pupils were of secondary school age all the pupils were allowed to turn over the pages of the test, and state their answer while the researcher recorded the results on a prepared form. This departs from standard procedure (Raven 1956, p 8) but since pupil scores will be compared with each other rather than with the standardised data, this departure from the norm does not invalidate the test as the main requirement is that the test be administered consistently in exactly the same way to all those tested (Raven et al 1996, p 39). Since the pairs of pupils are age matched it is unnecessary to adjust the results for age.

It is possible to use the test in a variety of ways including as an individual, untimed test of capacity or as a 20 minute speed test (Raven et al 1996, p 2) although as the speed test discriminates against slow and careful workers (Raven et al 1996, p 5) it was decided not to use the test in this way. However, prior untimed application of Raven’s Matrices indicated pupils adopted different approaches in tackling the task, some carefully considering their answer while others replied more holistically. This variation in attitude may affect the outcome of the test and thus it seemed important to record the time taken by each pupil to complete the task. While it would be possible to covertly record the time, to do so raises ethical problems. It was thus decided to be open in the timing of the exercise. Each pupil was told that they should look for the correct answer as carefully as possible and that the time taken would not affect their mark but the time was needed during subsequent analysis to remove from the research sample anyone who had guessed the answers rather than trying to work them out. It was decided in advance that all participants would be allowed to change their answer, even if they had turned over to the next question, but not if they had given an answer to that question. This approach was taken to maximise cooperation as perceiving that they had been unfairly penalised may jeopardise their enthusiasm for the subsequent timed writing task or limit their willingness to answer the interview questions. The creation of trust with the children participating in research is an essential aspect of the research process (Cohen et al 2007, p 374). In fact pupils changed answers on several occasions but never asked to do so in circumstances that were unacceptable.

The next aspect of the research was to measure pupils’ writing speed. This was assessed by six minutes of free writing. This speed test is based on the Alston 20 minute test that can be reduced to only five minutes (Taylor 2001, p 43). Although this short period of writing does not accord with the protocols adopted by other researchers (Dutton 1992, Allcock 2001a, Dennis and Swinth 2001, Connelly et al 2006), this short writing test is designed for internal comparison between the pairs of pupils. This short test was not chosen for comparison with published results that was often the explicit reason for other writing choices being made (Ziviani and Elkins 1986, p 249). Another reason for this short speed test is that the pupils will already have undertaken the Raven’s matrices test, and will also be interviewed so that the writing test, conducted individually, is only one small part of the overall investigation. It is also important that a test of handwriting speed exercise should not be unduly onerous as longer tests may measure disaffection, `boredom and inattention' (O`Mahony et al 2008, p 175) rather than an inability to sustain writing over a longer period. Graham et al (1998) observed that pupils seemed to enjoy a five-minute handwriting tasks and did not need prompting to write continuously (pp 291-2). To ask the pupils to write for twenty minutes would have the advantage of allowing for comparison with published speed tests but would have the disadvantages of increasing variability and decreasing reliability for it seems likely that pupils who dislike writing may be less enthusiastic and thus write more slowly, and the result might be testing their cooperation rather than their ability to write quickly. If pupils in the research group do have slight learning difficulties, other researchers have shown that these pupils have handwriting presentation problems and often use avoidance strategies when set writing tasks (Montgomery 2003, p 73). Thus to improve the reliability of the data, this shortened test seems most appropriate.

The instructions given to pupils had to be carefully considered as there is evidence that varying the instructions, such as to write as fast as they can or to write normally can affect the resultant handwriting speed (Ziviani and Watson-Will 1998, p 60; Barnett and Henderson 2005 pp 177-8) or fluency (Tucha, Tucha, Walitza, Kaunzinger and Lange 2007, p 47). For example, Lyth's (2004) handwriting speed test produced a writing speed of 112 characters per minute on a 39 character phrase or around 28.7 words/ min for Year 8 pupils. The instructions for this test were to write the phrase as many times as they could and that their handwriting must be `readable and clear' although this was not checked. This writing speed was much faster than Dutton's thirty minute (1992) or Allcock's twenty minutes test that produced (2001b) 12.7 and 13.9 words/ min respectively. Since the instructions given will affect the way in which the writing is produced it is important that these instructions are carefully worded and delivered in exactly the same way as even the tone of voice can affect the way the task is approached (Barnett and Henderson 2005, p 178).

Each pupil was asked to write as they would in an examination or as if they had to finish this writing before going for lunch, and that the researcher, on this occasion, was concerned with how quickly they could write rather than perfect spelling.

Given the bilingual nature of the population being studied the pupils were told they could write in English or Welsh, selecting whichever language they felt they could write most fluently. This instruction was not given to the first pupil in the first English medium school, although during her interview it became obvious that her first language was Welsh. She was given the opportunity to repeat the writing task in Welsh, which she opted to do. Thereafter all pupils, including those in English medium schools were told they could write in either English or Welsh although few pupils, in these schools, availed themselves of this opportunity. Although pupils' linguistic backgrounds were a factor in matching pupils this was not a major consideration and any pairings in which different language choices were made will be included in the analysis, although the mean numbers of letters for English and Welsh words must be calculated before word counts alone can be considered.

Pupils were asked to write on a topic of their own choosing with suggestions being a hobby, a description of a holiday or alternatively to describe the inside of a house (their own or another they knew well). They were asked not to include personal details such as the names of family or friends as a small sample of their writing might be included in the finished project and their work should be unidentifiable. Pupils seemed to have no difficulty identifying a writing topic and all but one wrote anonymously. The task was similar to those set by other researchers (Montgomery 2008, p 6; see also Chapter 2 p 54). Although a topic choice was allowed the task was more standardised than that used in Dennis and Swinth (2001) in which copying and creative writing on a set topic were used (same task for each pair) with results amalgamated and not reported individually (p 178), a limitation to the research they noted (p 181).

It was intended that each pupil should use their own pen, although ballpoint, fountain and gel pens will be available should a pupil not have brought their own with them. Once they had chosen a topic the stopwatch was started. Once they had written for six minutes it is indicated that they can stop, with almost all pupils completing their sentence. This time was noted as well as any significant pauses. While they were writing the researcher carefully recorded the penhold employed, the type of pen used and noted any other significant features of their positioning. Regardless of the location of the meeting the researcher was seated to the pupil's left and at right angles, thus ensuring an unobstructed view of the pupil's right hand. Close observation of the pupil writing is necessary in order to observe not only grip but also posture, and head position (Stott et al 1987, p 140) but how often they readjusted their grip or stretched or shook their writing hand. This was an important aspect of the research and one often overlooked in other research when writing including timed writing is undertaken as a group exercise. Sassoon observed (1993, p 101) `schools all over the world consider the written trace but seldom the writers' or indeed how the written trace is obtained as even teachers rarely have the luxury of undisturbed observation of their pupils as they write.

It was only as pupils began to write that their grip became obvious. Thus during the initial Raven's Matrices exercise and while giving the instructions for the handwriting speed test, the researcher did not know whether the pupil used an unusual grip or not, thereby reducing the possibility of researcher bias, an important aspect of research design (Cohen et al 2007, p 158). Although the researcher had, herself drawn up the sample and matched the pupils, this had often been done weeks in advance and the reason any pupil was included in the sample was deliberately not checked prior to meeting the pupils.

After the handwriting speed has been assessed the interview was conducted. A copy of the interview schedule used is found on the following page. The biographical information of gender and year group was double-checked. Pupils were then asked the month of their birth, as check that the average age of the pupils in the two groups does not significantly differ. This information was recorded on the interview sheet although individual results will not be reported in this research as this information could result in the pupil identification.

Handwriting interview schedule

Pupil number_____ Gender______ Raven's______________

Year Group______ Month of Birth________ Raven's time__________

What are your earliest memories of writing?

____

____

How much could you write when you first started school? (the initial for your name, your name)

____

Did you have any problems in infant school ? (reading and writing)

____

____

Did you have any problems in junior school ? (keeping up with written work, awkward grip)

____

____

Did you have any problems with writing in secondary school? Keeping up with written work, pain when writing, anything else).

____

____

If yes to either pain or speed then what do you do when you're in pain/ can't keep up?

____

____

How do you feel when in pain or writing too slowly?

____

____

Have you changed your handwriting in any way?

____

Have you changed your pengrip in any way?

____

____

pen___________ adjustments___________description____________

right thumb length_____ mm shake/stretch__________ h/w speed____________

It will be noted that some addition information such as Raven's Score as well as the handwriting speed calculation were subsequently added to the interview record sheets. This eased data analysis as all the information was on a single sheet of paper for each pupil allowing it to be stored with the sample of his or her handwriting.

The first two questions concern the pupils' earliest writing memories. This, together with the question about their infant school memories, is not intended to gain reliable information but should give an accurate impression of how they felt about their learning to write. If the question concerning their infant schooling elicits the reply that they had no problems, then a specific question will be asked about any reading and then any writing problems. It is the intention to try to find out whether the research pupils were more, or less likely to have had difficulties learning to read or write, that is did they show signs of any learning difficulty early in their school careers. Certainly any extra help involving withdrawal from the classroom is likely to be sufficiently memorable to be recalled. With all of the follow up questions (given in brackets on the interview schedule) it is intended to probe for as much detail as the pupil can remember. Any information collected so long after the even must be treated with caution for it is one of the dangers inherent in any retrospective study that memories are erratic and that recall is dependant on both the time elapsed (substantial) and the significance of the event (Cohen et al 2007, pp 214-5).

The next question concerns their junior schooling, with follow up questions on whether their unusual grip (if present) was a cause of concern and whether the pupil perceived that they had slower writing at this stage of their education. The final section concerns their experiences in secondary schooling, with the follow up questions again asking about handwriting speed and also pain in their hand or arm when they write. If pupils report pain they will be asked where this pain was most severe and then about how much writing it takes before the writing process becomes painful. In order to facilitate analysis it was decided that if pupils report pain then they would be asked how long they have to write before it starts to hurt. This was asked as closed question with three possible answers - either it hurt after the six minutes they have just written, that it would hurt after a whole (one hour) lesson of writing or halfway between these two answers that is after half an hour's writing.

By making the response time rather than length dependant it reduces the inconsistencies that could arise if the response were given in terms of number of pages written, which is in part dependant on writing size. Moreover while an hour's continuous writing may be unusual in contemporary secondary schools save in examination conditions, pain after only a few minutes writing must affect these pupils' education.

The questions concerning pain should indicate whether there is a greater incidence of pain in pupils with unusual penholds. As explained in Chapter 2 it was decided not to try to ascertain the reason for pain, for example, an excessively tight grip, but this will be noted if it is observed while pupils are writing. The next two questions concern what individual pupils do and feel about pain or their perceived slower handwriting. It is anticipated that children might have difficulty explaining their emotional responses and when necessary the interviewer will suggest a list of possible emotions - sadness, anger, frustration. In the event of negative responses such as anger, a range of repositories of emotions will be suggested – the work set, the teacher setting it, their hand that won't function or themselves. This is an important aspect of the research as Rosenblum considered that a child's physical and emotional well-being as important as legibility and speed in identifying non-proficient handwriting (2008b, p 299).

The final part of the interview is to measure the pupil's right thumb, since a very long thumb may be a reason for the lateral grip in which the thumb does not hold the pen. Sassoon, obtained a number of hand tracings but had yet to analyse finger and thumb lengths (1993, p 32). In the current research pupils' right thumb lengths were measured with a ruler, as they placed their index finger along a pencil line with their thumb forming a right angle.

Finally, express permission was sought to take two digital photographs of the research pupils' penhold. One was taken from the side showing the finger and thumb positions and the angle of elevation of the pen and the second from above. In the event of difficulty in pupils positioning their hands in the writing position they wrote a few words before pausing for the photograph to be taken.

THE SCORING SYSTEMS

The Raven's Standard Matrices instructions for scoring were followed exactly. Raven's matrices produces a numerical value which can be quantitatively analysed. Each pupil obtained a score out of sixty. The pairs of pupils are age matched so that it was not necessary to adjust the results for age and the raw data will be used for the analysis which is to be found in Chapter 6.

Counting the words written, including as words any scribbled out, and dividing by the exact time taken for the task gave the handwriting speed.

The Raven's matrices score sheet and the handwriting exercise and the completed interview schedule, all noting the pupil's number were then kept together for the analysis which was only undertaken once all the assessments were complete.

PUPIL BEHAVIOUR

In addition to academic underachievement, other consequences may result from a failure to diagnose able, learning-disabled school pupils. There is some research evidence that children with internal conflicts of ability and a learning disability may show disaffection and a defensive attitude with adults (Sanz 2002, pp 30-1). Another author on the same topic describes them as displaying aggressive behaviour or alternatively excessive timidity (Butler-Por 1987, p 7).

A measure of pupil behaviour was obtained in each school after all the pupil investigations in a particular school were completed. In each school member of the senior management team or the Head of Year 8, who also knew the older pupils, was asked to subjectively rate each pupil's behaviour on a scale of one to ten. The names were presented in a random order with the instructions to give a pupil a score of one if they had never caused any discipline problems in school and ten if they had previously been permanently excluded (from another school). In order to protect this confidential information the results from each school were recorded on a separate sheet of paper with no indication as to what the numbers referred to.

SUMMARY AND CONCLUSIONS

Approximately one hundred pupils with unusual penholds were identified and carefully matched with pupils with similar levels of school performance. Each of the two hundred pupils' abilities was tested and their writing speeds measured. Interviews concerning their early educational experiences and any current writing problems were also conducted.

With the collection of the raw data complete, Chapter 6 will contain the results and statistical analysis that tests the validity of the research hypothesis that secondary school pupils with unusual penholds are underachieving as well as an investigation into the other ways the matched pairs of pupils differ.

CHAPTER SIX

PHASE TWO - RESULTS OF THE INVESTIGATION INTO THE EFFECTS OF GRIP PATTERN IN SECONDARY SCHOOL PUPILS

INTRODUCTION

As described in the previous chapters the research hypothesis is that pupils with unusual penholds have undiagnosed learning difficulties and consequently may be performing differently to their classmates. This is a classic, theory-testing research project with a quantitative approach. The two null hypotheses that are central to this research are that the matched pairs of pupils will have the same ability and writing speed. Disproving these hypotheses would result in support for the initial hypothesis that pupils in the control group have higher (or lower) skills and are thus under performing (or over performing).

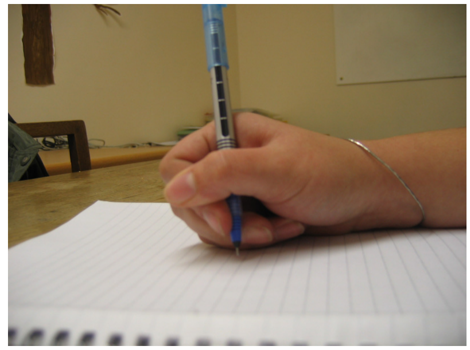
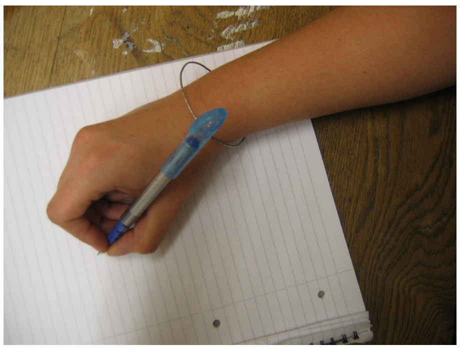
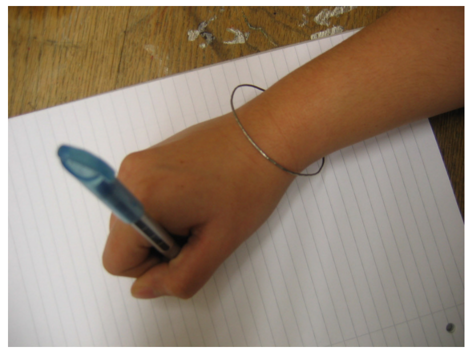
With the collection of the raw data complete, the following chapter contains the results and statistical analysis that tests the validity of the research hypotheses. The potential research group of pupils was identified as described in Chapter 5. Each member of the research group was matched for academic performance and linguistic background with a control pupil. Letters granting parental permission for the individual pupils to participate in the research were then distributed before the pupils to participate in the research were finally selected. Statistical analyses were carried out using the Statistical Package for Social Sciences 15.0 (SPSS).

RESEARCH PAIRINGS

Pupils forming the research and control groups were identified as previously described. Data was collected from a total of 196 pupils, although a number had to be removed from the total sample prior to data analysis. The reason for the removal of each of the pupils' investigated from the study is described below.

Two pupils, 31 and 72, were left-handed and were removed from the investigation as the research required the inclusion of only righted participants. This is because any mixed handed pairings could adversely affect research conclusions. As no alternative match could be found for Pupil 30, he was also removed from the research sample. As explained in Chapter 5, as the research progressed, greater care was taken to avoid the inclusion of any left-handed pupils in the sample.

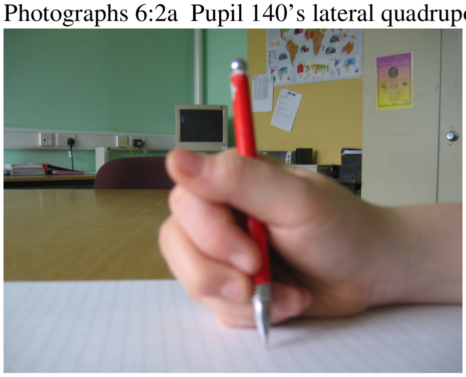
Some pupils were also eliminated as they proved to use a grip that was inappropriate to either the research or control group to which they had been initially allocated. Pupil 24 was eliminated from the sample as she used an unusual grip rather than a tripod grip while numbers 52 and 159 were removed for the opposite reason as they both used a tripod rather than the unusual grip expected following initial assessment. However, in each of these cases the matched pupil had not yet been seen or it was possible to rematch them appropriately, thus the removal of other numbered pupils was unnecessary. There were also a number of pupils who were observed to employ more than one grip during the 6 minutes of writing. Pupils 98 and 107 used both dynamic tripod and its lateral variant during the writing task. Both these pupils were eliminated from the sample together with 107's match 108. The writing technique used by 107 is noteworthy. She had been initially identified as using an unusual grip, a lateral tripod. However, she would begin each line with a tripod grip but move her thumb over her fingers after the first four to seven words and complete the line with this lateral grip before returning to a tripod grip at the beginning of the next line. These two grips are illustrated below and graphically show the way the angle of the pen becomes more upright in the lateral variant of a grip. A similar pattern to that of 107 was observed in two others, pupil numbers 135 and 190. Pupil 135, who was initially identified as having a lateral quadrupod grasp used the dynamic variant at the beginning of three of the twenty lines of her writing. Given this relatively low rate of dynamic quadrupod usage she was retained in the research sample. Pupil 190 also employed the same technique, although his grips were dynamic and lateral tripod. He explained that he would put his thumb over his fingers at the end of rows `to saving moving my hand over'. The lateral variant of the quadrupod raises the angle of the pen (Sassoon 1990a, pp 34, 36) and did seem to effectively reduce the need for gross left to right hand movement.

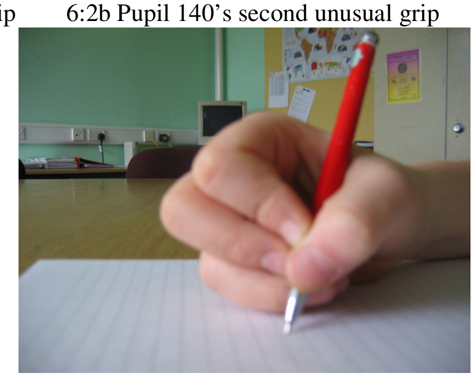





Photographs 6:1a & c Pupil 107's tripod grip   6:1b & d   Pupil 107's lateral tripod grip

Two other pupils also used two different grips during the observed writing task. Pupil 140 used two different unusual grips. Her main grip was a lateral quadrupod but she also used another unusual grip, two fingered with minimal thumb opposition, for two short periods totally about 26 seconds in the middle of the writing task. When asked about such changes, pupils explained that they do this to rest their hands while continuing writing. Pupil 140 explained that the change in position `eases pain' but the alternative grip is not comfortable and consequently she changes back. This pupil was retained in the sample and the primary grip used for analysis purposes. With Pupil 145, the use of a second writing grip only became apparent during the interview. He had initially used a variant of the lateral quadrupod grip with the thumb held high and clasped onto the index finger's distal interphalangeal joint. This grip exerted great pressure on the paper, indenting two sheets below that written on. However, when asked if he had ever held his pen differently he explained that when he printed he would hold his pen differently demonstrating a variant of the dynamic quadrupod with poor thumb opposition. He then wrote with this grip. His printed writing speed was slightly slower than his cursive, 15.0 rather than 15.2 words/ minute. Pupil 145 was retained in the sample and his cursive grip used for analysis.

Photographs 6:2a Pupil 140's lateral quadrupod grip 6:2b Pupil 140's second unusual grip





Photographs 6:3a Pupil 145's variant of the lateral quadrupod grip 6:3b Pupil 145's second unusual grip

The interview also revealed three pupils who now wrote with a quadrupod or tripod grip that recalled having used less orthodox grips in the past (Pupils 7, 143 (see Photograph 6:17b below and 168). Each demonstrated the grips which are illustrated below. Pupil 168 found that her early grip meant that she could not write a lot and she had changed it to a quadrupod grip by Year 1. Pupil 7 however, changed her grip much later in Year 5 when she started to wear rings which got in the way of her previous grip in which the pen lay between her second and third fingers. She reported that she did not find it difficult to change her grip, although this is rather later than grip changes reported in the literature (Jarman 1993a, p 43; Taylor 2001, p 50).

Photographs 6:4a Pupil 168's quadrupod grip 6:4b Pupil 168's early grip


Photographs 6:5a Pupil 7's tripod grip 6:56b Pupil 7's early grip

One final pupil was eliminated from the sample, number 101, leaving 102 to be matched with 123. Pupil 101 did not appear to take the Raven's matrices part of the assessment seriously. Despite being in Year 10 she scored a low 27 taking 6:41 minutes. However, it was not the low score or the time taken but the dismissive way she approached the task, apparently answering at random that initiated her removal from the research sample.

Following the removal of these pupils the total sample size was 186, consisting of 93 matched pairs of students. The tables below show the gender, year groups and ability groups of the pupil pairings.

Table 6: 1 Demographic analysis of group pairings

Gender		**Year group**		**Ability set**	
male	40 pairs	Year 8	40 pairs	High	28 pairs
female	53 pairs	Year 9	29 pairs	Medium	33 pairs
		Year 10	18 pairs	Low	32 pairs
		Year 11	6 pairs		
total	**93 pairs**	**Total**	**93 pairs**	**total**	**93 pairs**

Scrutiny of the final pairings generally revealed patterns that were not unexpected. There are fewer Year 11 pairings as these classes were only surveyed in one of the three terms due to concern about disrupting examination preparations. There were slightly fewer high ability pupils (Set 1 for mathematics, science and first language). The exclusion of too many high ability pairings was deliberate as the upper limit for ability in these sets was open and thus there could have been greater variability in these classes that could have resulted in some very erratic ability scores. The only unexpected result was the inclusion of more female pairings than male.

The demographic study (see Chapter 4 pp 98-102) investigated the proportions of boys and girls with unusual grips. This indicated that girls are less likely to use a tripod grip than boys, with the reason being the much higher rates of unusual grip rather than the higher rates of quadrupod grip, which, although higher, was not statistically significant.

However, the selection of secondary school pupils for inclusion for the second phase of the research initially included similar numbers of boys and girls: 160 boys and 156 girls. Eight boys and seven girls were removed from the potential sample as they had already been identified as having additional learning needs. Thus it was the higher response rate from the girls that resulted in fewer boys than girls being included in the final sample. The response rate was actually higher than these figures indicate, as both the pupil with the unusual grip and one of the appropriate matches had to both respond, agreeing to participate, before they could be included.

The quantitative information from all pupils was entered into an SSPS file for data analysis. The majority of the raw data is included in Table A:1 in Appendix A. Two categories of information have not been included, namely the month of pupils' birth, which could assist in their identification and their score on Raven's matrices due to the sensitivity of this information.

The first analysis to be made was a comparison of the age of the pupils. The months were coded numerically 1 for September through to 12 for August. As seventeen research pupils were matched with a pupil with a quadrupod rather than a tripod grip three means were obtained using SPSS. There was no statistical significance in the pupils' ages between the groups. The mean age of pupils was almost identical for the two control groups: 6.16 for the tripod and 6.18 for the quadrupod while the research group with unusual grip were about 5 days older with a mean of 5.99.

QUADRUPOD GRIP

Although it would have been desirable to match every pupil with an unusual grip with a pupil using an orthodox dynamic tripod grip, this became difficult because of the high frequency of quadrupod grip. To have insisted on a tripod match would have resulted in poorer matches. Thus it is essential that at the outset of the data analysis to consider the suitability of the quadrupod grasp as an acceptable alternative to the tripod. As shown in Table 6:2 below the seventeen pupils who used a quadrupod grasp scored slightly less on the Raven's matrices test. Closer analysis shows that 6 of the 17 (35.3%) using a quadrupod grip were low achieving Year 8 pupils. This was a much higher rate than observed in the tripod pairings (12.6%), although no further inference or significance should be drawn from the existence of this higher incidence. The selection of pupils for inclusion in the research depended on being identified (fewer Year 9, 10 and 11 classes were surveyed); selected (high achievers were deliberately avoided as part of the research design) and the response rate of pupils (which was controlled by pupils and parents rather than the researcher).

A further check was then made. Each of the seventeen pupils who used a quadrupod grip was matched with a pupil from another pairing who used a tripod grip. Matches were as close as possible although it was the high, medium or low pairings rather than matching individual classes, the procedure with the initial research. One middle achieving Year 11 girl was matched with a high achieving girl as this was the closest match possible. Nine of the seventeen matches were within school and if within school matches were impossible then a pupil from the next school in the random sequence was selected. Slight differences were detected by comparing the means for some variables. These are shown in Table 6:2. Statistical tests of significant difference were performed on data using the Mann-Whitney U-Test on the Raven's matrices scores, the time taken to complete the test and handwriting speed. Again SPSS was used. No significant differences were detected in any of the tests conducted.

Table 6:2 Summary of results for quadrupod and tripod pairings

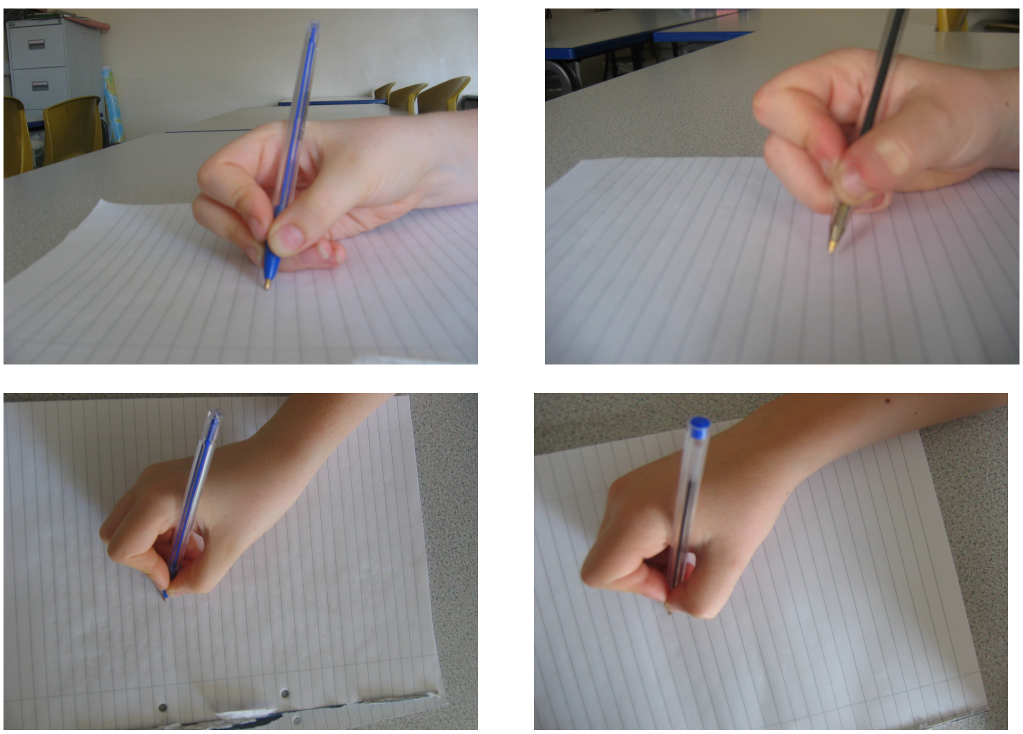
	Raven's matrices score	Time taken for Raven's (minutes)	Handwriting speed (words/minute)
quadrupod	37.8	11.96	23.59
tripod	39.3	12.10	22.75

One difference between the tripod and quadrupod grips was observed: a higher use of pens other than ballpoints in the pupils with a tripod grip. The pen chosen by each of the pupils in the control group was then investigated. The results are shown in Table 6:3.

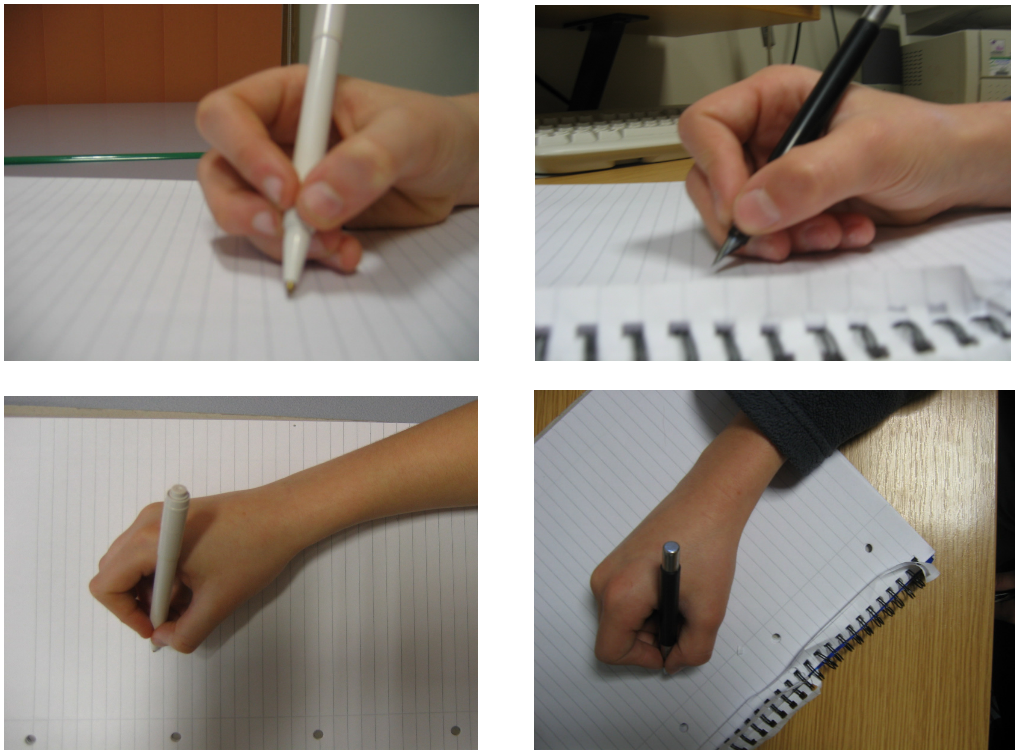
Table 6:3 Types of pens used by pupils using quadrupod and tripod grips

	Ballpoint Pen	Fountain Pen	Gel Pen	Total
quadrupod	14 (82.4%)	2 (11.8%)	1 (5.9%)	17
tripod	41 (53.9%)	25 (32.9%)	10 (13.2%)	76

This result is not unexpected as the quadrupod grip like the lateral grips causes the pen to be elevated and thus the ink in a ballpoint pen to flow more smoothly. This change in angle is illustrated by the two sets of photographs shown in Photographs 6:6 and 6:7. The lower pen elevation is particularly noticeable in 6:8b when pupil 118 writes with a fountain pen rather than the ballpoint preferred by the other three pupils.



Photographs 6:6a & c Pupil 77's quadrupod grip   6:6b & d Pupil 71's tripod grip (ballpoint pen)



Photographs 6:7a & c Pupil 128's quadrupod grip   6:7b & d Pupil 118's tripod grip (fountain pen)

The elevation of the pen above the line of the lower arm/wrist was measured for each of the photographs in the 17 pair sample. It was not always possible to do this as it had been difficult to maintain consistency of photography angle in so many different settings, and the early photographs, especially, were often unsuitable. Measurement of the angle of elevation on both photographs was possible for nine pairs. For the quadrupod the angles measured by the researcher ranged between 70° to 97° with a mean of 80.1° while the tripod ranged from 48° to 82° a mean of 58.6°. A check of the reliability of these measurements was made by a primary teaching colleague. On both occasions the angles were measured in pupil numerical order, not in pairs. These results to be found in Appendix C (Table C:3). The mean of these two measurements were then used for statistical analysis. There was a statistically significant difference between the averaged paired results, shown by testing with the Mann-Whitney U-Test, of 0.08. Namely, there is suggestive evidence (Arsham 1988, p 132) that for the pupils surveyed those who use a quadrupod grip hold their pens at a steeper angle.

However, a causal link cannot be established. It may be that the use of a ballpoint pen causes a child to adopt a quadrupod grip in order to encourage the ink to flow smoothly. Alternatively, those children who have already assumed a quadrupod grip may then find a ballpoint pen less difficult to use than their peers who have a tripod grip.

Although those using a quadrupod grip hold their pen at a steeper angle, this was the only statistically significant result observed. Those using a quadrupod grip did not perform differently on the key research issues - Raven's matrices scores, the time taken to accomplish that task, handwriting speed and levels of pain experienced. These pupils and their unusual matches do thus not need to be removed from the research and for the remainder of the data analysis a quadrupod grip will be considered as equivalent to a tripod grasp.

ANALYSIS OF THE RAVEN'S MATRICES SCORES

A central thesis of this research is that pupils with unusual penholds are underachieving, that is that they are being placed in subject sets groups lower than their ability warrants. As described previously, each of the research pupils with an unusual penhold was paired with another pupil on the basis of their set groupings in mathmatics, science and first language. During their individual interviews Raven's Matrices, a non-verbal IQ test, was administered individually with the time taken by each pupil also being recorded.

Table 6:4 Raven's matrices scores all participants (individual testing)

Score	Frequency	%	Cumulative %
21	1	.5	.5
25	3	1.6	2.2
26	2	1.1	3.2
27	3	1.6	4.8
28	5	2.7	7.5
29	3	1.6	9.1
30	2	1.1	10.2
31	4	2.2	12.4
32	8	4.3	16.7
33	6	3.2	19.9
34	10	5.4	25.3
35	12	6.5	31.7
36	6	3.2	34.9
37	11	6.0	40.9
38	15	8.1	49.0
39	8	4.3	53.3
40	8	4.3	57.6
41	9	4.8	62.4
42	10	5.4	67.7
43	10	5.4	73.1
44	10	5.4	78.5
45	6	3.2	81.7
46	10	5.4	87.1
47	3	1.6	88.7
48	6	3.2	91.9
49	6	3.2	95.2
50	2	1.1	96.2
51	3	1.6	97.8
52	2	1.1	98.9
53	1	.5	99.5
55	1	.5	100.0
Total	186	100.0	

The scores obtained by pupils ranged between 21 and 55. The lowest score was obtained by a Year 8 girl from the low set grouping who took only 6 minutes 25 seconds while the highest score was attained by a Year 9 boy from a middle set grouping who took 18 minutes 25 seconds. Both came from the control group using tripod grips. Overall the Raven's results were slightly lower than would be expected from standardised results, although the important aspect is that no pupil scored the maximum 60, allowing unproblematic comparisons between the matched pairs of pupils.

Table 6:5 Expected Raven's matrices scores for individuals aged 12 and 13½ (group testing)

Centile	Age 12	Age 13½
25	30	38
50	35	44
75	43	48
90	49	52
95	52	53

In summarising the results one pair was removed as the research pupil with the unusual grip took over 38 minutes to complete the task (scoring 51) far longer than her match (10 minutes 8 seconds, score 36).

Table 6:6 Summary results of the Raven's matrices scores
(outlier pupil number 114 and her match removed)

Grip	Mean	Number	Std. Deviation
Tripod	38.53	76	6.718
Quadrupod	37.76	17	5.652
All control	38.41	93	6.514
All unusual	39.59	93	6.747
Total	39.00	186	6.641
Control without 112	**38.46**	92	6.545
Unusual without 114	**39.47**	92	6.677
Total without 1 pair	38.97	184	6.641

As suspected there was a very wide range of times taken for this task, with all but one pupil taking between 4 minutes 38 seconds and 25 minutes 35 seconds (38 minutes 15 second outlier). A summary of the times taken by all participants is found in Appendix C.

Table 6:7 Summary results of the times taken to complete Raven's matrices
(outlier pupil number 114 and her match removed)

Grip	Mean	Number	Std. Deviation
Tripod	11.04	76	4.404
Quadrupod	11.96	17	2.512
All control	11.21	93	4.128
All unusual	12.18	93	4.588
Total	11.68	186	4.378
Control without 112	**11.24**	92	4.149
Unusual without 114	**11.88**	92	3.712
Total without 1 pair	11.55	184	3.939

Statistical tests of significant difference were performed on data using the Mann-Whitney U-Test on the Raven's matrices scores and the time taken to complete the test. Pupils using an unusual grip took longer to complete the task (12.18 minutes) compared with the control pupils' mean (11.21minutes). This difference was significant 0.083 (Arsham 1988, p 132) when tested with the Mann-Whitney U-Test. Pupils using an unusual grip also scored slightly higher on the test 39.59 rather than 38.39. This difference though was not significant (0.154). There is, however, a correlation between the time taken and the score obtained.

Table 6:8 Result of the correlation between Raven's score and the time taken for the task

		R.score	Time
R.score	Pearson Correlation	1	.559(**)
	Sig. (2-tailed)		.000
Time	Pearson Correlation	.559(**)	1
	Sig. (2-tailed)	.000	

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

Thus there seems to be a slight difference in approach between the two groups of pupils, although since the grouping together of pupils with unusual grips is arbitrary Raven's matrices will be considered as a variable in relation to each identified unusual grip later in this chapter (pp 153-182).

HANDWRITING SPEED

The second major aspect of the research was an investigation into handwriting speed. The research hypothesis is that pupils with unusual penholds are under performing and are placed in sets lower than would be expected in accordance with their ability. A potential reason for this could be pupils with unusual grips are less efficient at writing and fail to complete or write more briefly in examinations and are thus placed in lower sets.

Pupils' writing speed was assessed by six minutes of free writing. This short test was not chosen for comparison with published handwriting speeds but rather comparison between the pupil pairs. Since the instructions could have affected the way in which the writing is approached by pupils the instructions were carefully worded and delivered in exactly the same way, as even the tone of voice can affect the way the task is approached. Each pupil was asked to write as they would in an examination or as if they had to finish this writing before going for lunch, and that the researcher, on this occasion, was concerned with how quickly they could write rather than perfect spelling. Given the bilingual nature of the population being studied, the pupils were told they could write in English or Welsh, selecting whichever language they felt they could write most fluently. This instruction was not given to the first pupil in the first English medium school; although during her interview it became obvious that her first language was Welsh. She was given the opportunity to repeat the writing task in Welsh, which she opted to do. Interestingly, her writing speed in English was faster (24.3 words/min) than her Welsh (21.2 words/min) and thus she will be considered as having written in English. Thereafter all pupils, including those in English medium schools were told they could write in either English or Welsh although few pupils, in these schools, availed themselves of this opportunity. Although pupils' linguistic background was a factor in matching pupils, the language choice made by individual pupils could not be controlled. This meant that different language choices were sometimes made by the matched pairs with a total of seventeen pupils choosing to write in Welsh. These included just one pair, two boys, numbers 29 and 35. The other fifteen Welsh writers were paired with pupils who chose to write in English. In order for these to be included in the analysis although the mean numbers of letters for English and Welsh words must be calculated before word counts alone can be considered. This was done by selecting six English and six Welsh pieces of writing, and counting the number of letters in each of the first 100 words. The pupils' writing was chosen by selecting one English and then one Welsh sequentially, randomly starting with the second of the two files of data. Care was taken not to include both pupils of a pair. Although there is a range of characteristics in the two groups, and they do not exactly mirror each other (English writers slightly older and lower sets) other selection processes could have favoured the neater writers as this would have simplified the letter counting process.

When counting the words certain decisions were made to ensure consistency. These are summarised below:

- Illegible scored out words are included in the word count but excluded from the letter count, with the eventual letter total divided by the legible word count to calculate the mean

- Legible scored out words are included, with the scoring out counting as one letter
- Hyphenated words are counted as a single word but hyphens and apostrophes are not included in the letter count
- Misspelt words have their letters counted as they were written
- When two words are written as one then they are counted as one word eg `foodtable', `aswell'
- When one word is written as two then they are counted as two words eg `jelly fish', though when the same letters are written as one word (even in the same sentence) then it is counted as one
- When long words are written with a small gap between letters that could result in it being counted as either one or two words, then it is considered that the writer intended the correct spelling eg `snowboarding'
- Single or multi digit numbers are counted as one word with each digit counted as a letter
- Single or multi initials are counted as one word with each initial counted as a letter

Initial analysis of this original random selection revealed some problems. Five of the total of seventeen Welsh writers were boys and none of these were selected, although two boys were included in the English sample. The two boys had the highest and third highest mean number of letters per word (4.51 and 4.12) from the sample of twelve. Close analysis of the data from the twelve pieces of writing revealed that there was negative correlation between handwriting speed and the number of letters: those who wrote more quickly were using shorter words. In the whole sample boys wrote appreciably more slowly (21.45 words/ minute) compared with girls (24.04 words/ minute), although this will not create a difficulty for the wider research as pupils were gender matched. However, the inclusion of two boys who had lower writing speeds jeopardised the reliability of the sample. Another inconsistency was that the English writers also came from slightly higher sets. It was thus decided to add two more to each sample, deliberately selecting writers to equalise these two inequalities.

A primary trained teaching colleague counted the words using the above principles. Only very slight differences were noted, these are detailed in table C:6 in the appendix. In the word counts on the English writing, only two had differences of more than one and both of these were slightly unusual. One had several individual letters scored out which may have not been counted on the original count. The other interesting listed the whole of the Manchester United team with a great many initials again causing confusion on the initial count. Given the time consuming nature of the letter counts this was not requested of the teaching colleague.

A summary of all the results obtained is shown below, with further details in Tables C:6 and C:7 in Appendix C.

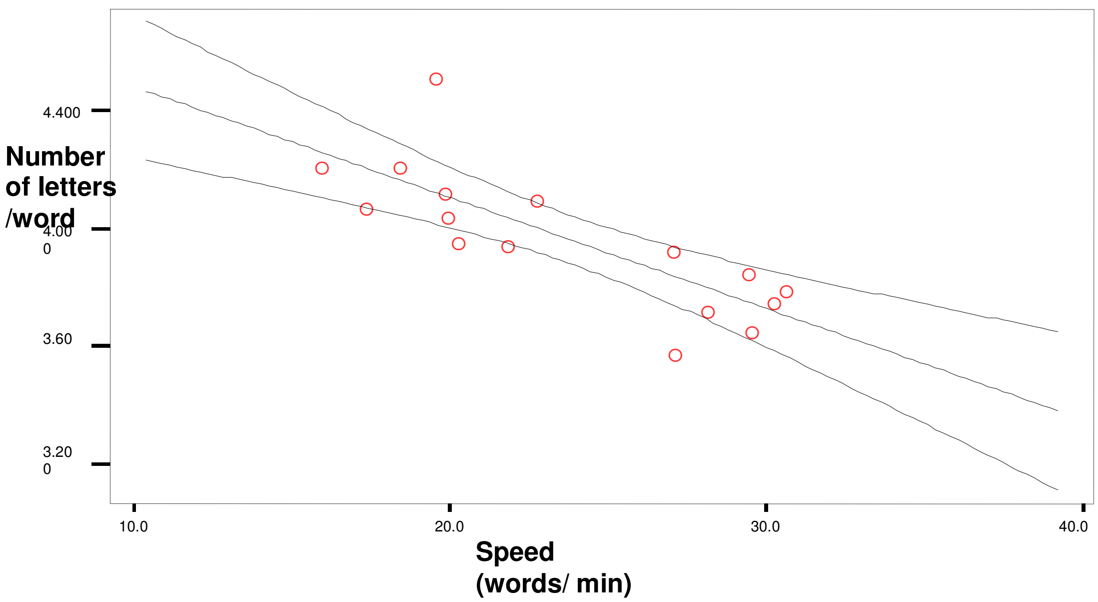
Table 6:9 Results of the comparison of the number of letters per word between Welsh and English writers

Pupil no.	Language	Mean (letters /wd)	Writing speed (wd/min)	Subject	Gender	Year group	Set	Grip
4	Welsh	3.65	29.7	House	female	9	mid	tripod
26	Welsh	4.04	20.1	House	female	10	high	unusual
94	Welsh	3.79	30.8	House	male	10	high	tripod
96	Welsh	4.21	18.6	Hobby	male	11	low	tripod
130	Welsh	3.72	28.3	House	female	8	high	unusual
140	Welsh	3.94	22.0	Hobby	female	8	mid	unusual
152	Welsh	4.07	17.5	House	female	8	mid	tripod
191	Welsh	4.10	22.9	Hobby	female	9	mid	unusual
	mean	**3.939**						
14	English	4.12	20.1	Football	male	8	low	unusual
21	English	3.92	20.4	House	female	8	mid	tripod
38	English	3.95	27.2	Hobby	female	9	mid	tripod
99	English	3.75	30.4	House	female	11	high	unusual
117	English	4.51	19.7	Hobby	male	10	high	unusual
131	English	4.21	16.1	House	female	8	low	tripod
141	English	3.57	27.3	House	female	9	mid	unusual
196	English	3.85	29.6	Hobby	female	10	low	unusual
	mean	**3.984**						

Once the selection of pupils was balanced for gender, age, ability and grip pattern the mean number of letters were very similar – 3.939 and 3.984 letters per word. This difference is not significant and thus the handwriting speed of pupils who wrote in English and Welsh can be compared. There was a slight tendency towards older and pupils from higher sets to write longer words but no other pattern emerged. It was important to consider the subject of the writing as the vocabulary could affect the mean word length. No significant pattern emerged.

One pattern which is concerning to the wider analysis is the tendency, previously mentioned, of a negative correlation between handwriting speed and the number of letters. This was tested using the sixteen samples of writing, for which the time consuming letter counts had been conducted, using SPSS. Using the program's interactive graph drawing facility this negative correlation is illustrated in Graph 6:1 below:

Graph 6:1 Linear regression with 95% mean prediction interval showing the negative correlation between the length of words and handwriting speed



The inter-rater reliability of word counts is usually very high and far higher than those reported for grip analysis. When a piece of text is being copied then the calculations are relatively simple and some researchers (Koziatek and Powell 2003) have not considered it necessary to perform a reliability calculation. It was, however, important to have very clear rules as to what constitutes a word, to ensure absolute consistency in word counts. The tightly defined method described on pp 138-9 was formulated and used by both the researcher and her colleague to count the words upon which the handwriting speed calculations were based. The inter-rater reliability coeffeicient obtained by the recounting of sixteen written samples was 0.993. This is similar to that obtained by other researchers (see pp 58-9 in Chapter 2) as would be expected with such an objective measurement.

Although there is negative correlation between the number of words written and the number of letters it is difficult and extremely time consuming to manually count individual letters in a free writing task. Indeed such counts are normally only conducted on short writing tasks (Graham et al 1998, Ziviani and Elkins 1986 Ziviani and Watson-Will 1998). Thus the norm is to use a word count for free writing by older children and this will be used although any conclusions must be made with caution.

The significance of these results was tested using Mann-Whitney U-Test as described above. The mean number of words written per minute varied slightly. Those using an unusual grip wrote 22.88 words/minute while those in the control group wrote slightly faster – 23.09 words/minute. There was no statistical significance to these results.

The girls wrote more quickly than the boys (24.20 and 21.37 words per minute respectively). This is similar to the results found by other researchers (Ziviani and Watson-Will 1998; Mason 1991 and 1992; Montgomery 2008). However, no statistical significance can be drawn from this result as the pupils were not matched for age and ability.

Pupils were questioned about any difficulties they had with their writing speeds as well as pain. Eleven pupils with unusual grip and nine pupils in the control group said that they felt that their slow handwriting had affected them either in junior school or currently in secondary school. One pupil who used a lateral tripod grip reported that she had been kept in to finish work `almost every day' whilst a boy using the same grip would copy up at home. Interestingly, one pupil in the control group explained that he dealt with incomplete work by copying from someone else or did not do it. Two pupils from the research group said that their slow writing made them rush or curtail endings although few pupils had any emotional response while one Year 8 boy said that he felt `embarrassed' by his slow writing.

A high achieving Year 8 pupil said that he had changed from using a ballpoint pen to a gel pen when told by teachers to write more quickly. He used a lateral tripod grip and this change is interesting as in this research those using ballpoint pens actually wrote more quickly than either a fountain or gel pen (ballpoint 23.7 words/min; fountain pen 22.2 words/min; gel 21.2 words/min). However, it cannot be concluded that the choice to use any particular pen affects handwriting speed these results are the product of pupils' gender, age and ability in addition to pen choice.

HANDWRITING PAIN

Pupils were asked during the interview about any problems with writing in secondary school, and if they replied none, or did not mention pain they were specifically asked about this. If they reported pain they were asked about how much writing it took before the writing process became painful. In order to facilitate the analysis their responses were recorded as pain after the six minutes of writing that they had just completed; pain usually after a full one hour lesson or examination or an intermediate of pain after about half an hour. Occasionally pupils felt pain after a shorter period and this was noted. They were also asked to describe where they felt pain and what they did when they found writing painful and how this made them feel.

Although the testing process was long (forty to fifty minutes for each pupil), the time spent with each pupil bore fruit. By the time the pupils were interviewed they were comfortable with the researcher and on many occasions able to discuss the pain they experienced while writing in considerable detail.

The time it took for writing to become painful was coded for analysis on SPSS. If no pain was reported it was recorded as 0, one hour as 1, half an hour as 2 and six minutes or less as 3. This information is contained in Table C:1 of Appendix C.

Table 6:10 Summary results of pain levels for research and control groups

	Unusual (%)	Tripod (%)	Quadrupod (%)	All Control (%)
3 - pain 6 mins	**20** (22%)	10 (13%)	5 (29%)	**15** (16%)
2 - pain 30 mins	**19** (20%)	15 (20%)	3 (18%)	**18** (19%)
1 - pain 1 hour	**31** (33%)	18 (24%)	4 (24%)	**22** (24%)
0 - no pain	**23** (25%)	33 (43%)	5 (29%)	**38** (41%)
Total	93	76	17	93

There were some insignificant differences between the level of pain experienced by pupils using a tripod and quadrupod grip. As previously stated, there is no statistical difference between these two groups allowing the research (unusual group) to be compared with the control group.

The significance of these results was tested using Mann-Whitney U-Test as described above revealing a statistically significant difference of 0.036 showing moderate evidence (Arsham 1988, p 132) that pupils using an unusual grip reported experiencing greater pain.

The location of the pain will be considered when the individual grip patterns are considered later in this chapter. However, it is appropriate to consider the ways that pupils react to pain while writing. The responses for the research and control groups will be considered separately.

Two pupils from the research group, numbers 116 and 133, indicated that writing became painful halfway through the six minutes of timed writing. For the purposes of quantitative analysis these were grouped with those who reported pain after the full six minutes. However, it is worth considering their responses concerning pain separately. Interestingly, these two girls, one from Year 11 and one from Year 8, used similar grip patterns – tripod and quadrupod without web space - in which the thumb and forefingers are on the same side of the pen. Pupil 116 said that she would `rub or shake' her hand to relieve the pain but that she would carry on writing for as long as she could. She let go of the pen twice during the timed writing. Pupil 133 however, made a total of 15 minor adjustments to her pen grip while writing, the third highest incidence observed. She reported that she relieved pain by rotating her wrist and shaking her hand. Turning to their feelings, Pupil 116 worried about the pain, especially in exams because she knows that the pain will come back and when the teacher rubs work off the board, she feels anxious. The other pupil felt frustrated and angry, mostly with herself `because I can't write tidy'.

The pattern of responses between the research and control group were generally very similar, although those that used unorthodox grips were more likely to experience pain after a shorter writing period, leading to their responses dominating. For the purposes of analysis, the responses of those reporting pain after the same period of time are grouped together. Both groups reported the same range of responses to pain after six minutes: stopping or slowing down and then continuing, shaking or stretching their hand or rotating the wrist, although some just carried on. Some pupils reported more than one response but of the 25 responses by those with unusual grips only two reported that they carried on writing, pupil number 177 explaining that she would `carry on even though my hand is hurting that's why my writing deteriorates'.

In contrast, those in the control group gave 17 responses with five pupils saying that they would ignore the pain or carry on, a far higher rate. No questions about the severity of the pain were asked as the experience of pain is a very individual and subjective sensation. It may be tentatively concluded that the pain experienced by the control group was less severe as they were able to keep writing despite the pain they were experiencing. Pupil 46 who used a tripod grip said that pain during examinations was not usually a problem as there was not too much to write. In contrast, a pupil from the research group said that he `attempts to keep writing' a comment that indicates a willingness which is perhaps not always achieved. Some pupils resorted to extreme measures to continue with their work. Pupil 140 used two different unusual grips. Her main grip was a lateral quadrupod but she also used another unusual grip, quadrupod with minimal thumb opposition, for two short periods totally about 26 seconds in the middle of the writing task. When asked about such changes, pupils would explain that they do this to rest their hands but continue writing. Pupil 140 explained that the change in position `eases pain' but the alternative grip is not comfortable and so she changes back. This change in grip was also observed in other pupils. Pupil 151, who reported pain after half an hour, used a quadrupod grip for the majority of his writing, although for 50 seconds, after writing for four minutes he adjusted his grip to a tripod grip explaining that by changing his grip he was able to carry on writing. Pupil 49, who reported pain after only six minutes writing, would even switch to writing with his left hand. He explained that he was right handed as both his parents were right handed a response which seemed to indicate that given other circumstances he could easily have been left-handed. His explanation that he had written with both hands during his Key Stage 2 SATs seemed believable, as he demonstrated his ambidexterity. This and the other responses demonstrate the perseverance of some young people to write, not only through minor discomfort but definite pain.

A similar pattern of responses was observed amongst those reporting pain after six minutes to the question about their feelings. A common response was that they had no feelings or were not bothered by the pain. This response was given nine times (out of the total 31) for the research group but twelve times (out of the total 22) by the control group: this again suggests that the control group were less affected by the pain they were experiencing. Additional information was given by some pupils in the control group. Pupil 4, for example, said that she was not bothered by the pain because when she stopped writing she would think about what to write next while another felt that it was not painful enough to be annoying (Pupil 60). Other comments included that it was a `bit annoying' (Pupils 114 and 129). Some in the control group reported more serious responses such as that it upset them as others in the class seem to be able to cope (Pupil 47) or Pupil 144 who, without prompting, said that he was annoyed by the pain because it means it he cannot do his work. Although his grip was tripod, the pen was held by the side of the thumb and he reported feeling annoyed with his thumb. The feeling of annoyance was reported by a total of five pupils in the control group (from 22) equally distributed between annoyance with themselves, their teacher and their hand.

A greater proportion of the research group reported annoyance (10 out of 31). Their annoyance was directed primarily at themselves or their hand, with only one feeling annoyed with the teacher. This annoyance was elaborated on by some pupils. Pupil 119 wrote that although he felt annoyed he wanted to keep up while Pupil 103 said that he would carry on as otherwise `if I stop I'll be in trouble, as usual'. In addition to feeling annoyed other emotions were expressed – `frustrated' (numbers 140 and 149 - with hand), (Pupil 138 - `because I can't get ideas down'), `irritated' (Pupil 141 - with hand), `stressed' (Pupil 174 - with self) or `pressured' (Pupil 37). Conversely those who felt that pain was normal explained that they held this belief because others also rotate their wrist (Pupil 17) - his preferred method of relief or that they accept it as friends have the same problem (Pupil 28).

Turning now to those pupils who reported pain after half an hour's writing, there were almost exactly the same numbers of pupils in the research and control groups, 19 and 18 respectively. These pupils gave responses in almost identical proportions. The range of responses to the pain that were reported by these pupils were the same as had been given by those who had experienced pain after less writing: namely stop for a period before carrying on; shaking or stretching the hand. One pupil with an unusual grip mentioned rubbing her hand before continuing while another in this group said that she would twist her wrist and one in the control group said that he would rotate his arm. One pupil in the research group (Pupil 130) who wrote with so much pressure that paper two sheets down were indented said that she would `write less hard' to relieve the pain.

A consideration of the pattern of responses to the question about their feelings about the pain revealed a slight variation between the two groups. Three of the research group revealed that they considered pain to be normal with comments such as `it's normal' (Pupil 185), `this is normal - usual' (Pupil 79) and `I think it's normal and carry on with the work' (Pupil 97). One reported feeling frustrated, mirrored in the control group by Pupil 168 who was a little frustrated. Only four of the research group reported feeling annoyed, primarily with their hand, with one spontaneously reporting feeling `a bit annoyed because I can't keep writing – especially in exams' (Pupil 189). Seven pupils in the control group expressed annoyance, again primarily with their hands. One boy said that he felt `disruptive' while a girl said she was fed up with the work. The most distressing response to this question came from a girl in the control group who said that she felt `agitated'. She had seemed very nervous throughout the whole interview completing the Raven's matrices test extremely quickly in only 4:38 minutes. Further enquiry elicited the response that aged about 5 or 6 she was told off by the teacher when she had written `d' instead of `b' – ball'. She reported that the words used had been `stupid child'. Since then she has always felt very nervous and when the teacher says do it in best writing `content goes out the window'. Her anxiety seems to have been exacerbated later in her primary school career after cursive writing was introduced when pupils were `put in the corner if it was not joined'. This insight into the experiences of this pupil are not relevant to the research but does show how early school experiences may impact on subsequent attitudes to schooling.

The final group only reported experiencing pain after an hour's writing. Twenty pupils in the research group reported pain after this length of writing compared with only fifteen in the control group. Six pupils from each group reported that they would stop for a time before carrying on - a slightly higher proportion in the control group. Other responses included stretch, rotating wrist, or shaking the hand. Seven pupils in each group reported one of these responses. One pupil in the research group said that they would click their fingers while another said that they would carry on writing only noticing the pain after stopping. Pupil 154 from the control group that he would `shake it to get the blood running again', while another said that in class he would stop writing, but in exams keep writing.

The responses to the question about their feelings concerning painful writing revealed similarities. Seven of the research group and four of the smaller control group said they had no feelings adding comments such as they `don't notice it'; `accept it'; `accept pain' and `it's not an issue'. These observations from the research group were similar to those from the control group: `friends complain as well so it's not a problem' (Pupil 1) and `it's fine' (Pupil 118). Four pupils from each group expressed annoyance. Other responses were also given, with Pupil 124 saying that she felt `frustrated with her hand' and Pupil 170, also from the research group saying that she felt `horrible' and that pain was upsetting because `in exams you have to keep writing'. Less vehemence was expressed by the control group with the only notable comments being two boys who said they were irritated with their hand (Pupil 68) and they were upset and annoyed by the pain (Pupil 113).

In summary, pupils who use an unorthodox grip are more likely to experience pain while writing. Since levels of pain are subjective this was not addressed in this research, though amongst those who have pain after the shortest writing period fewer were able to continue writing through the pain suggesting that their pain was more severe. The strategies the two groups use to deal with the pain do not seem to differ between the two groups. However, anger and frustration were more often expressed by the pupils using unusual grips.

WRITING ADJUSTMENTS

As observed in the previous sections, the number of times a pupil made two types of adjustments during the timed writing exercise was recorded. It was impractical in this research to have another researcher assess the reliability of the assessments as the writing was not video recorded. A permanent recording, while it would allow certain aspects of the research to be reassessed by both the researcher and others, would have been intimidating to the pupils involved and would have impinged on essential aspects of the research. It was important that the writing be observed as only then can the grip used be identified. It was quite difficult for the writers and considerable reassurance was offered before they began. It was also important that the researcher did not seem overtly interested in the writing process. Observation was discrete with the researcher seeming to be interested in filling in details on the interview schedule that was about to be used. However, given the proximity of the pupil and researcher and using peripheral vision it was not difficult to notice stretches or shakes of the writer's hand and more minor adjustments merely involving a release of pressure. These were recorded separately as a tally on the interview sheet which was to be used immediately after for the interview.

When coding for SPSS analysis the two types of adjustment were combined, with each shake or stretch being counted as equivalent to two releases of pen adjustment. This weighting was a subjective decision. The alternative considered was one to three ratio although this would have given greater weight to the larger movement and seemed less appropriate.

There were slight differences in the number of adjustments between pupils using tripod and quadrupod grips, with the latter group making more adjustments. However, these differences were not statistically significant and the control group were then compared with the research group (see Table C:9 in Appendix C). Pupils from the research group using unusual grips made more adjustments than their matched peers. The mean number of adjustments for the two groups were 4.18 and 1.56 respectively with a greater range observed in the pupils with unusual grips (range 0-24) than in the control group (range 0-10). The significance of these results was tested using Mann-Whitney U-Test as described above revealing that there was a very high statistical significance to these results with the probability of these two groups displaying the same level of adjustment being 0.000, significant at the 0.001 level.

As may be anticipated, there was also substantially more inconsistency in the research group given the variability in the grips they use. One pupil using a tripod and one using a quadrupod grip made 10 adjustments while eight using an unusual grip made 10 or more. These pupils and the way in which their grips were adjusted together with the pain levels experienced are shown below.

Table 6:11 Pupils showing 10 or more adjustments to grip during writing

Pupil number	Grip	Stretch or shake	Minor adjustments	Total weighted 2:1	Pain reported
164	tripod	5	0	10	30 minutes
1	quadrupod	1	8	10	1 hour
17	unusual	3	18	24	6 minutes
39	unusual	0	10	10	none
61	unusual	2	19	23	6 minutes
73	unusual	2	10	14	none
84	unusual	6	0	12	6 minutes
119	unusual	3	7	13	6 minutes
133	unusual	0	15	15	6 minutes
156	unusual	3	7	13	1 hour

As described in the previous section on pain, pupil interviews revealed that they would make adjustments to their grip and even in one case to the writing hand in order to relieve discomfort caused by writing. The pattern in the table above demonstrates not only that those pupils who made most adjustments to their grip were using unusual grips but that many also felt pain after only a short period of writing. Graphical plotting of pain levels against number of adjustments using SPSS demonstrated a slight positive correlation between the number of adjustments and pain reported after a short period of time. This correlation was tested for using Pearsons and Spearman's rho statistical tests of correlation which both demonstrated significance at the 0.05 level.

Tables 6:12a & b Correlations between pain and the number of adjustments while writing

			Pain	Adjust
Spearman's rho	Pain	Correlation Coefficient	1.000	.141(*)
		Sig. (1-tailed)		.028
	Adjust	Correlation Coefficient	.141(*)	1.000
		Sig. (1-tailed)	.028	

* Correlation is significant at the 0.05 level

			Pain	Adjust
Pearson	Pain	Correlation	1	.145(*)
		Sig. (2-tailed)		.048
	Adjust	Correlation	.145(*)	1
		Sig. (2-tailed)	.048	

* Correlation is significant at the 0.05 level

THUMB LENGTH

The most common unusual grips are not using the thumb in either a tripod or quadrupod grip, forming a lateral tripod or lateral quadrupod grip. This inability to use the thumb in the usual way aroused some curiosity. There could be two reasons for the way in which the thumb is held; either the thumb is particularly inflexible or the thumb is differently proportioned than the norm. Since this is relatively easy to measure, this was undertaken as the final part of the interview. Each pupil lined up his or her first finger against a line drawn on a sheet of paper. The thumb was then radially extended to form a right angle and the length measured with a ruler. Each pupil was asked to concur that the measurement was the maximum comfortable and that they agreed the measurement. The measurement was then recorded on the interview sheet. The results are included in Appendix C (Table C:1). There were only slight differences in the overall thumb length with a mean for the research group of 66.26 mm, while the control group mean was slightly less, 65.85 mm.

Three pupils found it difficult to extend the thumb to the required angle indicating thumb inflexibility. These were pupils numbers 26, 97 and 187. Pupil number 187 had particular difficulty with the angle being only approximately 45° between the first finger and thumb. None of the three pupils used their thumb in writing, two using a lateral grip while Pupil 97 had his thumb tucked under the index finger. The two boys, one Year 10 and one Year 8, both had shorter thumbs than the mean but the Year 10 girl's thumb was longer so no other discernable pattern could be detected.

BEHAVIOUR

After all other aspects of the research had been completed in each school, a member of the senior management team or the Head of Year 8, who also knew the older pupils, subjectively rated each pupil's behaviour. A score of one represented that the pupil had never caused any discipline problems in school while ten meant that they had previously been permanently excluded (from another school).

A summary of the results obtained is shown in Table 6:13. Those using an unusual grip were reported as having slightly less behaviour problems thus the hypothesis that those with unorthodox grip would have more behavioural problems in school is disproved. The relationship was tested using Mann-Whitney U-Test as described above, revealing that there was no significant difference in these results. The majority of pupils were reported as having no problems although the teachers undertaking the task were willing to give quite high ratings on the behavioural scale. Although no significant result was detected the system was not inappropriate, rather it indicated that a very high proportion of secondary school pupils do not cause staff behavioural concerns.

Table 6:13 Behaviour scores - research and control groups

Behaviour	Tripod	Quadrupod	All control	Unusual
1	48	11	59	62
2	10	1	11	13
3	6	1	7	5
4	3	3	6	5
5	3	0	3	4
6	2	1	3	1
7	1	0	1	2
8	3	0	3	1
9	0	0	0	0
10	0	0	0	0
Total	76	17	93	93
Mean	2.05	2.00	2.04	1.84

RANGE OF GRIP

All ninety three pupils in the research group were deemed to have an unorthodox grip, namely that they did not use a dynamic tripod grip with the pen held between the pads of the thumb and index finger or the variation in which two fingers are employed in opposition to the thumb. Initially described as a modified tripod (Ziviani 1983) this grip is generally referred to as quadrupod (Carlson and Cunningham 1990; Tseng 1998; Dennis and Swinth 2001; Amandson and Weil 2005 and Tuckett 2006).

The grip of each pupil was carefully noted as they wrote for six minutes. At least two photographs were then taken, one lateral and the other with the camera held vertically. The written information was particularly important because it was not always possible for the details of all finger positions to be shown on a photograph as the thumb often obscured the other digits. The method used to identify these grips was to rely primarily on the lateral photographs taken during the research. However, as the exact position of the fingers was often obscured in the photographs, the contemporaneous notes were decisive in determining the grip.

All the preceding analysis in this chapter has investigated whether these unorthodox grips collectively affect the writer. Clearly, these grips are unrelated to each other and thus vary in the effect on the writer and an essential part of this research is to seek to identify groups of writers using the same grip, determining the effects that each grip may have on those that have adopted it. As described in Chapter One, an increasing number of different grip patterns have been identified and wherever possible the literature's existing terminology will be used.

Lateral Tripod Grip

Although the lateral tripod has been reported since 1990 (Bergmann and also Schneck and Henderson), the definition appears to have changed over time. Myers' 1992 illustration shows the pencil held between the length of the forefinger and side of the ball of the thumb with Schneck's and Henderson's 1990 illustration similar with the thumb holding the pencil below the thumb nail, that is more distally than the thumb's distal interphalangeal joint. A more recent illustration in Dennis and Swinth (2001) exemplifies the lateral tripod grasp with a diagram in which pencil is apparently held by the thumb's distal interphalangeal joint. In these variations of the lateral tripod some control of the pen can be exerted by the thumb. However, Dennis and Swinth's illustration of the lateral quadrupod has the pen held more proximally in the web space similar to the photographs of other researcher's lateral tripod grasps (Tseng 1998; Koziatek and Powell 2003). In these the pen is held in the forefinger/thumb webbing and the thumb touches the forefinger. Interestingly, Bergmann illustrated this grip observing it in 0.9% of her adult sample and identified it as a separate group, naming it the cross-thumb.

When selecting pupils for the research sample, those with the less severe form were not included, with the criteria for inclusion requiring that the thumb was not involved in controlling the pen. Thus in pen was in contact with the thumb between the two joints of the thumb (distal and proximal interphalangeal joints).

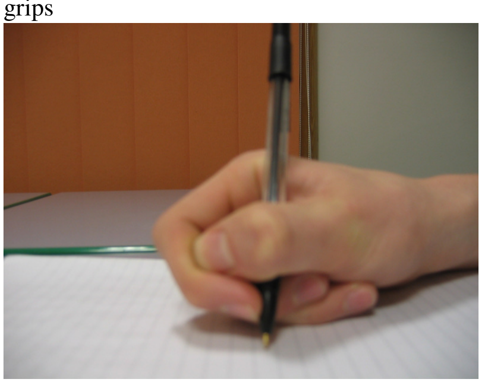
Summers (2001) described four variations of the lateral grip since her binary classification (for example position of thumb was either `opposed' value 0 (most desired) or `thumb contact other than pad' value 1) resulted in four different thumb positions: `against the radial border of the index: flexed over the index; flexed under the index;' and `held against the pencil shaft along the ulnar border' all being categorised as lateral grasps (pp 137-8).

There was considerable variation in the precise way the pen was held by the twenty-six pupils identified as using a lateral tripod in this research. The variation was primarily in the way the thumb was held, since according to the definition the index finger was contact with the pen, but not the thumb or middle finger, leaving very few other ways in which variation could be present. The thumb could be flexed around the pen but not clasping the index finger, alternatively it could be clasped onto the index finger in two different ways (lower or higher) while one pupil had her thumb tucked under the index finger. Another variation in the thumb's position was for the thumb to be held straight out and taking no part in holding the pen or forming the grip. The final variation was in the position of the index finger with in two pupils the index finger appearing to have only marginal contact. A table below shows the pupils using each of the variations identified with a photograph of each following.

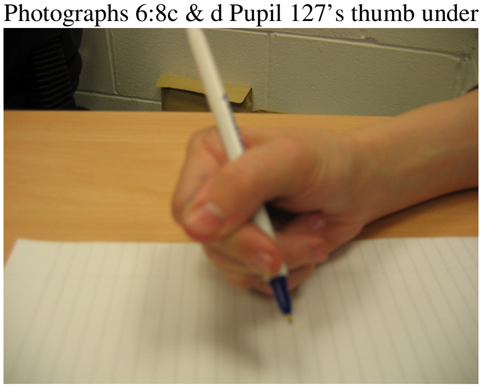
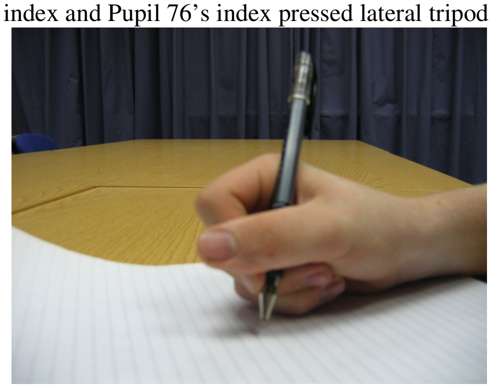
Table 6:14 Variations in lateral tripod grip - gender and ability groups

	Pupil numbers	% male / female	% high / middle / low sets
Thumb flexed	15, 25, 26, 41, 50, 64, 95, 100, 102	33 / 66	56 / 11 / 33
Thumb clasped over index	42, 73, 130, 141	0 / 100	80 / 20 / 0
Thumb clasped under index	127	100 / 0	0 / 0 / 100
Index pressing on thumb	76	0 / 100	0 / 100 / 0
Thumb high clasp over index	39, 126, 134	33 / 67	0 / 67 / 33
Thumb free	79, 88, 122, 162, 181, 190	67 / 33	33/ 33 / 33
Marginal index	28, 187	100 / 0	0 / 50 / 50

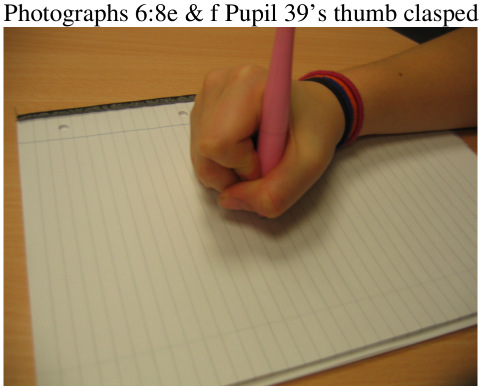

Photographs 6:8a & b Pupil 100's flexed thumb and Pupil 141's thumb clasped (low) lateral tripod grips




Photographs 6:8c & d Pupil 127's thumb under index and Pupil 76's index pressed lateral tripod grips

Photographs 6:8e & f Pupil 39's thumb clasped (high) and Pupil 181's thumb free lateral tripod grips



Photograph 6:8g Pupil 28's marginal index lateral tripod grip

The variation of lateral tripod that was most often observed was that in which the thumb was flexed. As can be observed from the sequence of pupil numbers these were deliberately excluded from inclusion after Pupil 102 since the research objective was to investigate the effects of a wide variety of unusual grips. The subjective impression that the typical lateral tripod with a flexed thumb is a female trait and one associated with higher ability is borne out by the table above, although it is not suggested that these figures prove association let alone causation due to the subjective selection of pupils for inclusion in the research. Some of the other variants of the lateral tripod appear not to be linked to female high achievement. Again these observations are qualified due to the selective and self-selective nature of the sample.

The quantitative data for all lateral tripod grips and each of the subgroups were tested using the Mann-Whitney U-Test on SPSS. Only one significant difference emerged and this was for the number of adjustments for all pupils using a lateral tripod grip. There was moderate evidence of a significant difference at a level of 0.027 (Arsham 1988, p 132). However, there was not a commensurate difference in the levels of pain observed with only three pupils (numbers 28, 122 and 141) reporting pain after six minutes of writing compared with five pupils in the control group. The grips of two of these pupils are pictured above and it will be observed that both use a great deal of tension to maintain their grip on the pen. However, generally a lateral tripod grip, while being a grip which appears to produce a significant number of adjustments while writing, is not a grip linked to more pain than the tripod grip used by control pupils.

An interesting observation about those using a lateral tripod grip is the number of them that believe they are using a tripod grip. Four (pupil numbers 15, 41, 100 and 130), of the twenty six pupils using a lateral tripod grip, picked up the pen to be photographed in a tripod grip. These pupils had to be convinced that this was not how they actually wrote and would have to write a few words before being photographed. One pupil with whom there was a longer discussion tried to write with a tripod grip but could not write even a single letter, much to her amazement.

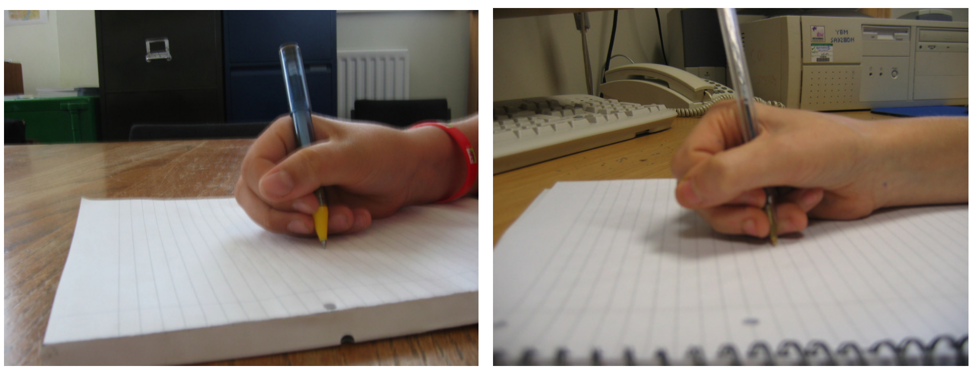
Six of these pupils recalled having had people observe or try to remediate their grips. A Year 3 teacher changed a pupil's grip from what was reported as a dynamic quadrupod grip to the pupil's current lateral version of a tripod grip. Another reported that his infant teacher tried very hard to change his grip but that the junior teachers never noticed it. Another pupil reported that a supply teacher and a lot of children have noticed her grip while another was told that it would be better if she would use a tripod grip. The final pupil was discussed earlier as her father used the same grip which she still uses despite her grandfather and all her teachers trying to persuade her to change it (see p 185 for discussion of legibility).

Lateral Quadrupod Grip

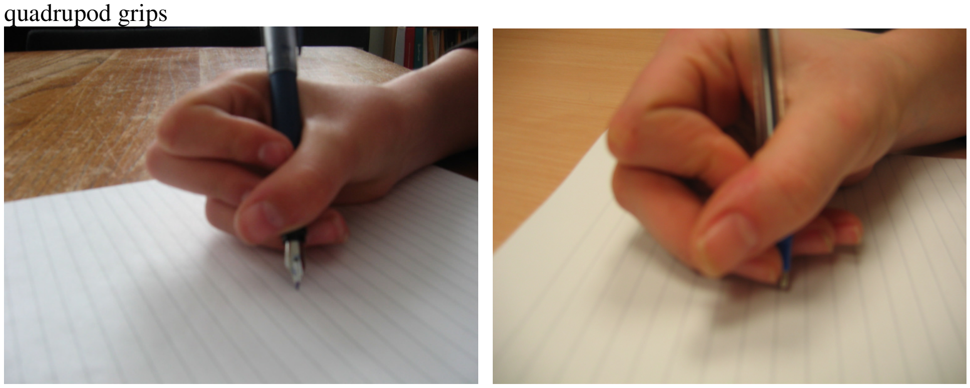
The lateral quadrupod grip is similar to the lateral tripod although with the index and second finger exerting equal pressure on the pen. As with the lateral tripod there was considerable variation in the precise way the pen was held by the twenty-eight pupils identified as using a lateral quadrupod in this research. Like the lateral tripod equivalents, the variation primarily lay in the way the thumb was held as the lateral quadrupod has the index and middle fingers in contact with the pen. The variations observed had the thumb clasped onto the index and middle fingers in two ways, the first more loosely than the second in which the pen is held tightly in the web between thumb and index finger. Two other variations observed each in a single girl had the index finger held high or the index finger hyperextended. A more frequently observed pattern was that in which the thumb was held across the fingers without touching them, a pattern also observed in the lateral tripod. The final variation, again observed in a single pupil, is similar to a variant in the lateral tripod in which the index finger appearing to have only marginal contact. The table on the next page shows the pupils using each of the variations followed by photographs.

Table 6:15 Table showing variations of lateral quadrupod grip and gender and ability groups

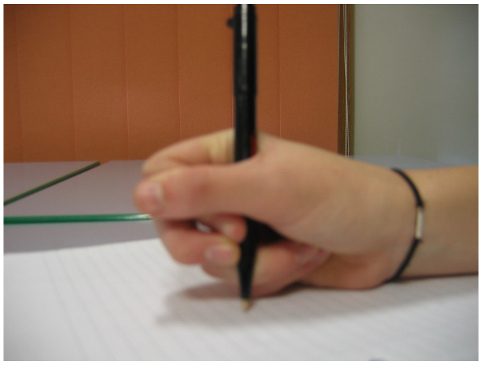
	Pupil numbers	% male / female	% high / middle / low sets
Thumb clasped over index and middle fingers	5, 8, 19, 53, 54, 62, 70, 81, 138, 140, 177, 184, 189	46 / 54	8 / 46 / 46
Pen in web space	10, 48, 119, 155	75 / 25	25 / 25 / 50
Index finger high	55, 82	0 / 100	0 / 0 / 100
Hyperextended index finger	33	0 / 100	0 /100 / 0
Thumb free	14, 40, 87, 111, 112, 135, 145	43 / 57	14 / 14 / 71
Marginal index	13	100 / 0	0 /100 / 0



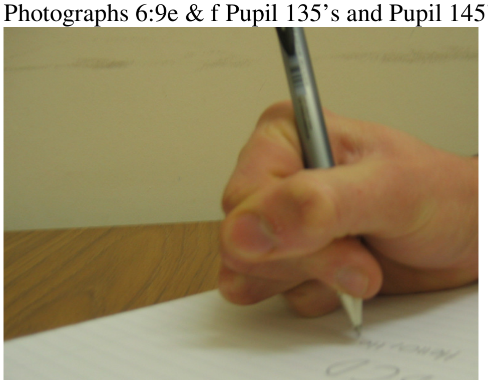
Photographs 6:9a & b Pupil 81's thumb clasped and Pupil 119's (tighter) pen in web space lateral quadrupod grips



Photographs 6:9c & d Pupil 127's high index finger and Pupil 33's hyperextended lateral quadrupod grips

Photographs 6:9e & f Pupil 135's and Pupil 145's thumb free lateral quadrupod grips



Photograph 6:9g Pupil 13's marginal index lateral quadrupod grip

Although the lateral quadrupod grip is so similar to the lateral tripod there are some interesting demographic differences. The ratio of girls and boys using both the lateral grips was very similar to that in the overall sample. Girls made up approximately 57% of the control tripod grips with a slightly higher rate in the quadrupod controls of 65%. The proportions for the lateral versions of these grips were 54% and 57% respectively. It must, however, be borne in mind that these pupils were selected and the higher proportion of girls in the sample is due to their greater willingness to participate in the study. However, fewer of the pupils using a lateral quadrupod came from the higher set groupings. This is shown in the table below.

Table 6:16 Table showing number and percentages of lateral tripod and lateral quadrupod grips and their ability groups

Set grouping	Number (%) pupils in total sample	Number (%) pupils using lateral tripod	Number (%) pupils using lateral quadrupod	Pupils using other unusual grips
High	28 (30.1%)	10 (38.5%)	3 (10.7%)	15 (39.5%)
Medium	32 (34.4%)	8 (30.1%)	10 (35.8%)	14 (35.9%)
Low	33 (35.5%)	8 (30.1%)	15 (53.6%)	10 (25.6%)
Total	93 (100%)	26 (100%)	28 (100%)	39 (100 %)

The distribution across the set groupings was very similar in the whole sample and the unusual grips other than the lateral tripod and lateral quadrupod grips. However, while there were slightly more pupils from the highest set group using a lateral tripod grip, there were very few using a lateral quadrupod. While these results cannot be considered wholly reliable owing to the way in which the pupils were selected, the selection methods were indistinguishable and the disparity does appear to indicate a relationship between lower attainment and use of the lateral quadrupod grip. This was tested using chi-squared (χ^2) statistical test. Neither the lateral tripod nor the other unusual grips were statistically different from the whole sample set pattern. The lateral quadrupod, however, was statistically different to the whole sample (χ^2=6.088 2df $p< 0.05$) and the lateral tripod (χ^2=10.550 2df $p< 0.01$) disproving the null hypotheses that the lateral quadrupod set pattern was the same as for these two groups (see Appendix C for details). With the rejection of the null hypothesis that pupils using a lateral quadrupod grip came from the same population, the alternative hypothesis is accepted: namely, pupils using a lateral quadrupod grip were drawn from different population. It thus seems that pupils using a quadrupod grip were less likely to be in the highest sets for mathematics, science and first language, although this conclusion must be tempered with caution, owing to the manner pupils were selected. Although a relationship between these two variables appears to exist, there is no causal link proffered. It could be that the adoption of a lateral quadrupod grip happens more often by less able students or the adoption of this grip makes it more difficult, for some yet undetermined reason, to achieve a place in the top set for all three subjects. The suitability of the lateral quadrupod grip is considered on pp 194-5 and in Chapter 7 pp 220-3, 231.

The quantitative data for all lateral quadrupod grips and each of the subgroups were tested using the Mann-Whitney U-Test on SPSS. The results for the individual subgroups will be considered separately below. One significant difference emerged for the whole group and this was for the number of adjustments for all pupils using a lateral quadrupod grip with this being highly significant at a level of 0.000, significant at the 0.001 level (Arsham 1988, p 132). The implications of this result together with similar albeit less significant results for the lateral tripod grip will be considered in the next chapter.

The findings for the variants of the lateral quadrupod grip will now be considered. The first of these is the most frequently observed variant when the thumb is clasped over the index and middle finger. This grip was used by thirteen pupils in the sample and statistical analysis indicted that the number of adjustments made was higher than that observed in the control group. This was highly significant at a level of 0.001. Six of these pupils reported pain after only six minutes writing compared to only four in the control group. Two pupils described the pain as being located in the base of the thumb, one also having the pain extending into the underside of her arm. This extension of pain was also reported by Pupil 177 whose pain extended from the back of her hand into her forearm while the Pupil 140 who explained the location of the pain said that the pain extended from her middle finger into her wrist. Four of the pupils in this group reported that they had been early writers, including the ambidextrous pupil commented on earlier in this chapter, while three reported dyslexic tendencies. These included mild dyslexia in junior school, problems with spelling and a family history and finally extra help for a year in primary school linked to letter reversal. Two pupils recalled using rubber tripod grips in infant school while another, Pupil 54 was given one in Year 4/5 although he refused to use it. In addition to this pupil, two had friends who were `concerned' or `thought it was weird' although the latter pupil did not really notice anything was amiss. The unusual grips of other pupils were noted by family members. One girl said that her mother had recently commented her grip while Pupil 138's grandmother had tried to alter his grip. This pupil also said when he was around 9 or 10 his headteacher had tried to improve his `messy' cursive writing (he now prints). The headteacher considered that were a number of reasons why the writing was so poor: he wrote too fast; his grip and the angle the paper which was straight rather than a slight angle. The last pupil in this group, Pupil 189, described how her Year 3 teacher had said during a handwriting lesson `what are you doing with your hand?' Although the teacher was not described as trying to remediate her grip, the pupil's mother tried hard to change it without effect.

When the pen is held in a lateral quadrupod grip more tightly, the pen lies in the webspace between the thumb and index finger. Four pupils used this grip, three boys and one girl. Two of these pupils experienced pain after six minutes of writing compared with only one of the controls. Interestingly, this control pupil appears to be dyslexic and told me that he would be getting a laptop computer later in the interview month having had problems with his writing for six years. He made slightly fewer adjustments than the research pupil, his writing speed was almost identical (0.1 w/min faster) and his writing was slightly less legible. The research pupil, during his interview, said that his parents had noticed his grip but did not try to change it. Another pupil said that his sister and her friend, in the small, two teacher primary school, noticed his unusual grip but that he had not known he was doing something different. The one girl in the group said that her junior school teachers had observed the grip she used but `as long as I could write they really didn't mind'.

The variants which were only observed once or twice could not be statistically analysed, as any analysis would be irrelevant. Neither the pupil who had a hyper-extended finger nor the boy with the marginal index finger contact experienced any pain. He made very slightly more adjustments to his grip, although Pupil 33's tripod control made eight minor adjustments: no pupil using a tripod grip made more minor adjustments during the timed writing exercise. His parents tried to get him to use a tripod grip when he was in the middle of junior school but by the time his parents had noticed his grip he had got used to it and could not change.

The two girls who had a high index finger in their lateral quadrupod grip experienced less pain than their controls. However, their writing speeds were 8 to 9% slower than their controls that used a tripod grip. These two pupils also made at least six minor adjustments each more than the controls that made no more than one.

The final variant of the lateral quadrupod grip was one in which the thumb did not make contract with the fingers. This was characterised by a thumb that would tremble during writing and was used by seven pupils. Interestingly, this grip was different to the other lateral variants in that these pupils wrote more slowly than their peers. This difference was statistically significant according to the Mann-Whitney U-Test at a significance level of 0.064, offering suggestive evidence against the null hypothesis that their writing speeds were the same (Arsham 1988, p 132). They also experienced pain after a shorter writing time with three of the seven pupils reporting pain after six minutes of writing compared with only one in the control group. The location of the pain was not equivalent being described as at the base of the thumb or from the little finger extending into both sides of the lower arm. One of these pupils appeared to have been an early writer, although another pupil said that she had never noticed that her grip was different to other people's grip. This pupil, Pupil 145, said that a teacher in commenting on his `messy writing' told him to make it neater without offering any advice as to how this could be done while another said that one of his secondary school teachers had mentioned his grip, although he could not remember who it was. The pattern observed of infant school teachers trying to effect a change in grip was confirmed by another pupil who told me that her Year 2 teacher had tried to get her to change her grip but that she had found it too hard (see pp 185-6 for discussion of legibility).

Four Finger Grip

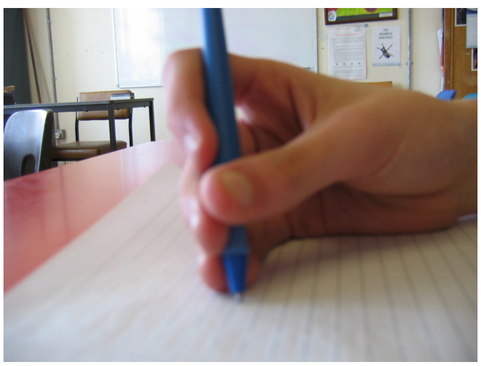
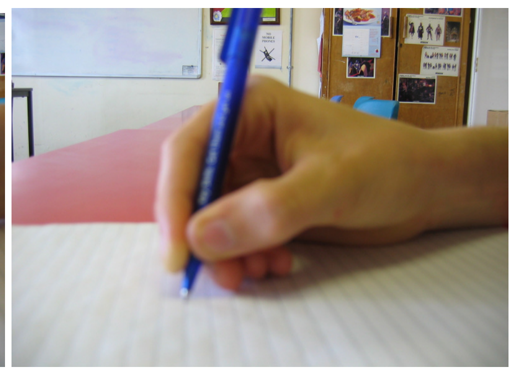
This grip was described in Chapter 1 (p 21). Four pupils used the four finger grip: pupils 3, 63, 66 and 193. Two of these are illustrated below.

Photographs 6:10a Pupil 3's four finger grip 6:10b Pupil 193's four finger grip

Although this grip appears awkward, it does not provide its writers with excessive problems. There was no pattern discernable with the Raven's score or timing other than the previously discussed link. Their thumbs were longer in three of the four pairs (means 73.00mm and 66.75mm), a result which was statistically significant (0.081), indicating suggestive evidence of a difference although the thumb is not the positioned differently than in a tripod or quadrupod grip. Only one of the four pupils, Pupil 63, reported pain during the six minute writing task as did one of the other matches, Pupil 3, so overall there was no difference in the pain described. The three who reported pain described the location of the pain: back of upper arm and base of thumb (Pupil 3); base of thumb (Pupil 63) and wrist and back of hand (Pupil 193). Pupil 3 said that a junior teacher had noticed her unusual grip but not tried to change it. Her father though did try to persuade her to alter it but she found a tripod grip `awkward'. The father of another pupil, Pupil 66, an education professional had also commented on her grip, linking it to her bad handwriting.

Index Grip

One pupil in the survey used the index grip, pupil number 175.

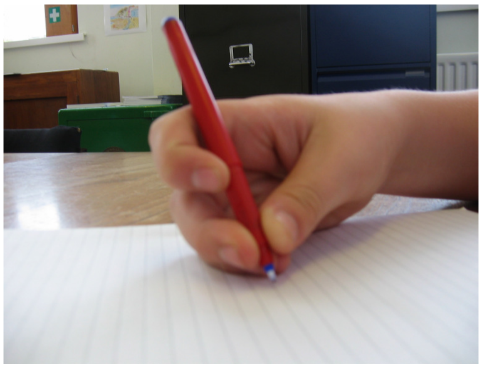
Photograph 6:11a Pupil 175's index grip 6:11b Pupil 172's tripod grip (straight index finger)

With only one pupil identified using this grip it is impossible to make any statistical conclusions from the data collected. This young man in Year 10 was categorised as having a middle set placing, being in set 1 for both mathematics and science but set 5 for his first language. His match was also in set 1 for mathematics and science but slightly higher, set 4 for first language. This ability was reflected in Pupil 175's high Raven's score of 52 in 12:43 min. Only three others in the entire project equalled or surpassed this score: 52 (13:57min); 53 (12:16min) and 55 (18:25min). However, his matched pupil, Pupil 172, was younger by eight months, and took over 15 minutes to complete the task, scoring only 46. Although this grip seems extremely uncomfortable, Pupil 175 reported that he would only find writing painful after an hour he made no adjustments during the timed writing exercise. His thumb was longer (82mm) than his match (74mm), and indeed was one of the longest recorded. This could have been because most of the sample was younger and or female. There were 14 other Year 10 boys whose thumbs were measured. They ranged between 60 and 88mm with a mean of 74.1mm. This mean was lower (68.9mm) if Year 11 boys were also included, as there was one pair that both had shorter thumbs. If the index grip is considered as an extreme version of the four finger grip discussed above, it does seem possible that the use of three fingers in opposition to the thumb may be an adaptation to a longer thumb. A comparison of photographs 9a, 9b and 10a demonstrates that it is the flexing of the thumb that allows the index finger to be positioned lower down the pen adjacent to middle and ring fingers.

Pupil 175's index grip was noticed by his parents but since both his father and sister had unusual grips they did not worry. However, teachers tried to remediate this grip for several years in primary school. Pupil reported that this was from Year 2 to Year 6. He would try writing with a tripod grip but found it `really slow' and would revert `as soon as their backs were turned'. He also reported that he fell behind his classmates in Years 3 and 4 but subsequently recovered. He was withdrawn once or twice during this time for 1:1 lessons. His match, Pupil 172, reported that he was withdrawn for extra help with reading in both infant and junior school and while his spelling still causes him difficulty his slower writing in junior school `didn't hold me back but it was slower'. Both these pupils use a fully cursive style and are both quite slow writers 22.6 words/ min (Pupil 175) and 20.1 words/min (Pupil 172). The mean for the eight other medium and low set Year 10 boys is 23.9 words/min while that for the six boys in top sets for all three subjects is slightly higher at 25.3 words/min. However, given that there is only one pupil using an index grip statistical significance cannot be inferred. However, at a purely subjective level, both these two boys' difficulty with writing seems to be affecting their performance. Although Pupil 172 uses a tripod grip it was noted that his index finger was kept straight throughout the written task (see Photograph 6:11b). This grip contrasts with the way the index finger usually flexes to control the pen in a tripod grip (see photographs 6:1a and c). This like the rigid thumb of Pupil 175 could be affecting Pupil 172's ability to write fluently. Both these pupils have a curious set pattern being place in set one for mathematics and science and one of the two lowest sets for their first language. Such a low set is likely to curtail their performance in their

GCSEs as they are likely to be entered in the lower band language paper, limiting their grade to a C, and may not be able to take the literature paper.

Quadrupod Index Grip




Photographs 6:12a & b Pupils 80’s & 150’s Quadrupod index grip

This grip was used by two boys who were both in Year 8. The boys using the quadrupod index grip differed very slightly from their respective matches. Pupil 80 made one major and three minor adjustments and Pupil 150 made just the one major shift in grip. However, the contemporaneous notes record that Pupil 80 was `really struggling’ to hold the pen and the angle varied hugely between 45° and 90° above the horizontal. Neither Pupil 80 nor his match, Pupil 91, reported any pain; this is in contrast to the other pair who both reported pain after 6 minutes.

There were very few differences in the quantitative data collected, although there was a difference between the research pupils and their controls in their behaviour with their behaviour rated at 2 and 7 compared with one for both the controls (almost significant – 0.102). However, given the small sample size no real import should be attached to this result.

The interviews, on the other hand, did reveal some interesting differences. The two pupils using the quadrupod index grip both reported being able to write before they began school while their controls said `not a lot’ when asked the same question. The unusual grip of the research pupils was noticed by their primary school teachers. Pupil 80 did try to use a tripod grip when he was in reception, reporting that he used it for around four months. Although no reliance should be placed on the accuracy of this period (Cohen et al 2007, pp 214-5), it seems likely that he did make a determined effort to use a tripod grip. The other research pupil in this group also reported that his unusual grip was detected in infant school and he was told to use a tripod grip. He demonstrated this grip so again it seems as though determined efforts were made to remediate his grip earlier in his school career. This pupil also reported that his writing is not very neat and his presentation seems to affect his marks. He is placed in lower sets with his match having had substantial 1:1 intervention in all aspects of literacy beginning when he was only five, following concerns raised by his mother. This pairing had a considerable difference between the Raven's scores (research pupil scoring 20% higher despite finishing almost a minute earlier (6:41 and 7:40). Although definitive conclusions cannot be drawn as there were only two pupils using a quadrupod index grip, the use of this grip does appear to be linked to poorer school performance (see p 186 for discussion of legibility).

Quadrupod Grip with Middle Finger Dominance

This grip has not previously been described. It is similar to the quadrupod index grip with opposition between the middle finger and thumb, although it differs because the index and middle finger are not spread out up the pen. Two pupils use this grip with both these pupils, numbers 49 and 196, coming from the lowest set groupings; not being placed in the highest set for any subject, and include the pupil previously described due to his ambidexterity. Both these pupils were early writers reporting that they could write sentences when they first started school, although their pairs said `not a lot' and `not much, just my name'. One of the pupil's Year 3 teacher attempted to remediate this grip saying that writing with one finger would increase control over the pen. The pupil did not believe her, so did not try to use this tripod grip.

There were few differences between the two pairs and their controls and with only two pupils using this grip, statistical conclusions are difficult to make. All four pupils reported pain after writing for only six minutes and the pupils' behaviour scores were identical within the pairs, although the girls in Year 10 had a score of one while the boys in Year 8 had quite a high score of six. There were differences in the pairs' handwriting speed with the research pupils writing about 5% slower than their controls. This difference was not statistically significant because of the small sample and the older girls much faster handwriting speed.

Quadrupod without Index Finger Opposition

A slightly more extreme form of the previous grip was observed and identified for the first time. In this grip, opposition is created between the middle finger and the thumb with the index finger being curled or hooked over the pen. This grip was observed in two slightly different patterns which will be considered separately in this section. The difference between these grips is in the alignment of the thumb. In the first the thumb is held as if in a tripod grip, providing good opposition to the second finger. In the second the thumb lies vertically down the pen and does not use the ball of the thumb to oppose the middle finger. In both there was a gradient in the positioning of the index finger from almost on the pen to very curled. This is indicated in the ordering of the pupil numbers, with the most severe distortion to grip being reported last. Each was observed three times in the sample; the first variant in pupils numbered 22, 99 and 170 and the second in pupils numbered 163, 106 and 124. A photograph of each variant is shown below.

Photographs 6:13a Pupil 170 (variant 1) Quadrupod without index finger opposition (most severe)
6:13b Pupil 106 (variant 2) Quadrupod without index finger opposition (medium severity)

The pupils using this grip were all girls from a range of year groups, although Year 8 dominated. The girls came from a range of set groupings, although three came from the highest group, meaning that they were in the top set for mathematics, science and first language.

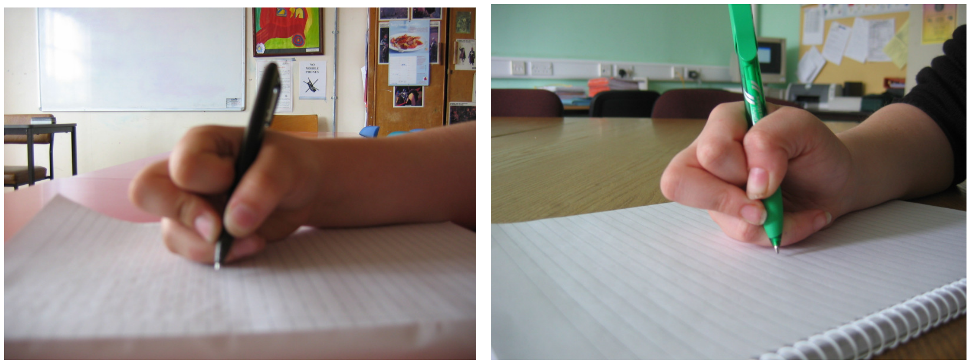
There were differences between the research and control pairs in some quantitative variables. However, when the two variants were considered separately and together, no statistical differences could be distinguished.

Two of the six girls from each of the research and control groups seem to have been early writers. Only one pupil, number 170, reported that anyone had noticed her unusual grip - a friend's mother, although another girl reported that a teacher told her to use a tripod grip, which she did during school years 4 and 5 before abandoning it. None of the control group reported any emotional response to the pain they experienced. In contrast three of those with using a quadrupod grip without index finger opposition reported adverse feeling to the pain despite their mean reporting of pain being less (1.5 compared with 1.83). These feelings were of upset - `horrible', annoyance, and frustration with their hand.

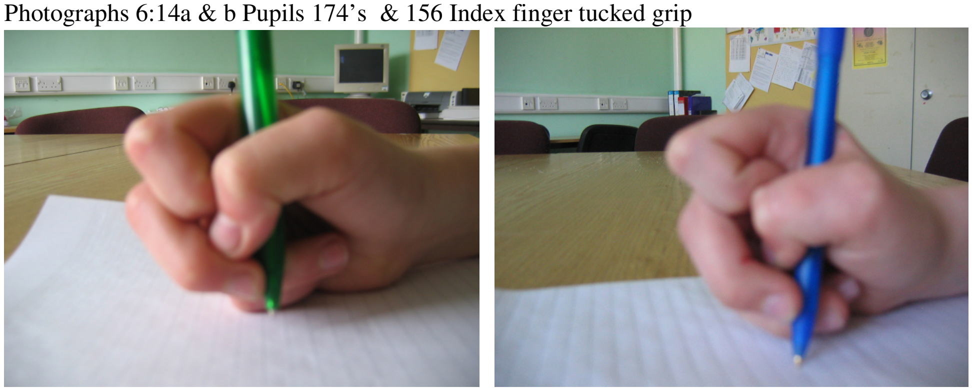
Index Finger Tucked Grip

This grip has not been recorded in recent studies, although Cole 1955 reported the left handed variation as `index finger tucker'. This grip is categorised by the index finger being bent up into the palm and the pen held (usually) between the middle finger and thumb.

Variants of this grip were observed four times. These seemed to demonstrate more extreme tucking of the forefinger that that illustrated by Cole, although they varied in the position of the thumb. Due to these differences, these four are all illustrated on the following page.



Photographs 6:14a & b Pupils 174's & 156 Index finger tucked grip



Photographs 6:14c & d Pupils 147's & 161's Index finger tucked grip

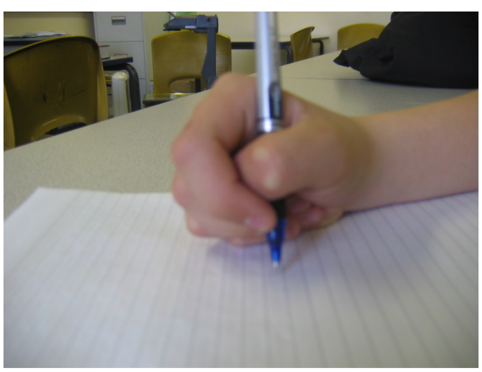
The most noteworthy difference between these pairs of pupils is in their experiences of pain. Two of the four reported pain after only six minutes of writing, with the other two considered that writing became painful after half an hour and an hour. This contrasts with the control group, only one of whom reported any pain; that after half an hour. This difference in pain perception was tested using the Mann-Whitney U-Test with a significance level of 0.076 suggestive statistical difference (Arsham 1988, p 132).

The pain was located in different places, which are listed in order of the extremeness of the grip: cramp `right through' her hand (Pupil 174); pain in the outer part of his elbow (Pupil 161); pain in her lower wrist (Pupil 156 – whose pain was least) and the top of her lower arm (Pupil 141). Although the pain was described as least severe by Pupil 156, she made the most adjustments during the timed writing exercise 3 shake or stretches and 7 smaller adjustments. None of these pairs' controls made any adjustments although one of the others made one bigger (Pupil 141) and another four small adjustments to their grips. Given the similarity in the grip it seems possible that Pupil's 156 continually shifting grip was easing her discomfort, allowing her to report less pain.

Two of these four pupils reported that their peers had noticed their unusual grip, with one reporting that they made fun of her. The teacher though, made `no comment'. The Year 3/4 teacher of another pupil made strenuous efforts to alter her grip although the Year 5/6 teacher subsequently noticed but accepted her different grip. Interestingly, two of the four pupils using this grip reported writing before they went to school with one asking her mother to write so that she could copy it. Although such early memories cannot be relied on (Cohen et al 2007, pp 214-5), these recollections offer an intriguing insight into these children's early development.

Thumb Tucked Grip

This grip has not been recorded in recent studies; although Cole 1955 reported the left handed variation as `thumb tucker'. This grip is categorised by the thumb being folded over the pen and tucked under the index finger. Four pupils used this grip, three using the tripod form (pupil numbers 61, 97, and 169) and one the quadrupod (pupil number 117). These will be considered together with one of the tripod grips and the quadrupod grip being illustrated below.




Photographs 6:15a Pupil 61's Thumb tucked grip (tripod)
6:15b Pupil 117's Thumb tucked grip (quadrupod)

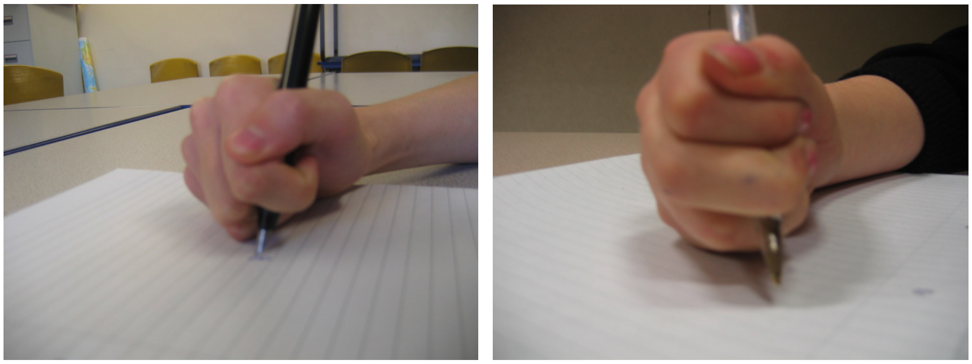
Very interestingly, just as the quadrupod without index finger opposition was only observed in girls, all four pupils who used the thumb tucked grip were boys. One boy was in Year 8 with the other three who were all in Year 10, additionally sharing the attribute that they were in top set for mathematics, science and first language.

The boys using the thumb tucked grip all experienced high levels of pain, two reporting pain after only six minutes the other two after half an hour. None of the controls reported experiencing pain in less than an hour. The level of pain was tested with the Mann-Whitney U-Test. The result showed a moderate evidence of significance at 0.029 (Arsham 1988, p132). Similar results were shown when the number of adjustments made during writing were analysed. Only one out of the four control boys made any adjustments and that was just one minor adjustment. His research pair made the second highest overall adjustments in the entire study: two stretches or shakes and 19 minor adjustment to his grip. Two of the other boys made two or three minor adjustments resulting an overall significance of 0.091.

This grip not only appears awkward but is uncomfortable to maintain and results in a great deal of pain. An examination of the interview records provided slightly more information about into how these boys deal with the grips they have adopted. Overall the quality of information is less detailed than that available in the interview records for some of the other grips. One pupil said that he had been observed writing once or twice in junior school and the teacher had told Pupil 61 that it his grip was `OK' if he was happy with it. Only two of the boys explained their emotional response to the pain they experienced, one saying that it annoyed him while another said that the pain he experienced after half an hour was normal (see pp 186, 190 and 191-2 for discussions of legibility, style and spelling).

Interdigital Grip

Only one pupil in this study used an interdigital grip although, as noted previously, the researcher has observed it once in the wider demographic study and twice in sixth form pupils she has taught. Each of these three used the interdigital grip with the pen projecting ulnarly between the ring and little fingers. One pupil who now used a tripod grip reported that she had used interdigital grip with the pen projecting between the middle and ring fingers. She reported that her reception teacher noticed that she was holding the pen incorrectly and she quickly changed it and used a tripod grip by Year 1. A photograph of this grip is shown below together with that of Pupil 75 who used an index/ middle finger interdigital grip.



Photographs 6:17a & b Pupil 75's current interdigital grip and Pupil 143's early grip

With only one pupil using this grip it is not possible to make any significant statistical observations on the information collected about this grip. However, this grip does not seem to be causing this pupil any difficulty as she did not report any pain has been placed in the top set for all three subjects. The only anomaly is a longer than average thumb length (70 mm compared with her control - 55mm and the Year 9 female control mean of 62.3 mm).

Interdigital Grip with Middle Finger Control

Although only one example of the interdigital grip was present in the research a very similar grip did occur five times. This grip has not been previously recorded and it is provisionally named as the interdigital grip with middle finger control. The grip observed was an interdigital grip in which the fingers are fisted into the palm with the pen projecting ulnarly between the middle and ring finger, although the middle is flexed so that the tip rests on the pen and exerts control. The grip of the five pupils varied slightly. This gradation was in the position of the thumb which clasped the index finger in various positions. In the most intricate of the grasps the thumb was held over the index fingers metacarpophalangeal joint (Pupil 121), while in the simplest (Pupil 29) the thumb positioned firmly over the proximal interphalangeal joint. These are both illustrated below. The five pupils using this grip were pupil numbers (listed according to the thumb placement) 121, 185, 2, 37 and 29.

Photographs 6:18a & b Pupil 121's and 29's Interdigital grip with middle finger control

The pupils who used this grip were predominantly female and came from a range of set groupings. Although there was not a statistical difference between the quantitative data of these pupils and their matches from the control group, there were some results that indicated that some of these pupils were performing in a different way to their peers. Three of the five had handwriting speeds that were substantially slower than their classmates who used a tripod or quadrupod grip. These results are shown below:

Table 6:17 Comparison of handwriting speeds between pupils using an interdigital grip with middle finger control and control pupils

Research pupil	Hw speed (w/min)	Control pupil	Hw speed (w/min)
121	**19.0**	129	**23.6**
185	26.8	186	25.8
2	**29.4**	1	**37.0**
37	**19.4**	26	**22.0**
29	20.2	35	19.8

Three of the five (Pupils 121, 185 and 29) had memories that they were writing before they began school although none of the matched pupils reported being early writers. These memories seem authentic with one pupil reporting tht she wrote a lot before she went to school while another that she wrote the letter `s' backwards. This group of pupils seem to have been more aware of their atypical grip. One reported that friends had commented on it and that she had tried other grips when she was in Year 3/4, while another said that her mother had had the same grip but that she had changed it when told by her teachers. That the daughter knew about this incident in her mother's life indicates that her mother had observed her grip and that they had discussed their respective experiences. This pupil did not feel the need to change her grip as early in her schooling she was ahead of her peers, and interestingly, her match, who had come from outside the immediate area, had been put into booster classes due to her high ability. A third pupil in this group reported that she had tried to change her grip but found it too hard. She reported that she had been kept in nearly every break in Year 5/6 and had to complete work missed as homework. She felt her slow writing affected her performance, especially in primary school as it meant that she had to rush her endings, thereby losing marks. The one boy in this group also reported that others had commented on his grip with his parents had describing it as `weird'.

Although none of the statistical tests showed revealed significant differences, if the one boy (Pupil 29) who was writing at a rate very similar to those of his peers is excluded an interesting pattern in the Raven's matrices scores and timing emerges. This is shown in the table below. Pupil numbers will not be used in this analysis, lest pupils may be identified by the information discussed previously.

Table 6:18 Comparison of Raven's matrices scores for girls using an interdigital grip with middle finger control and control pupils

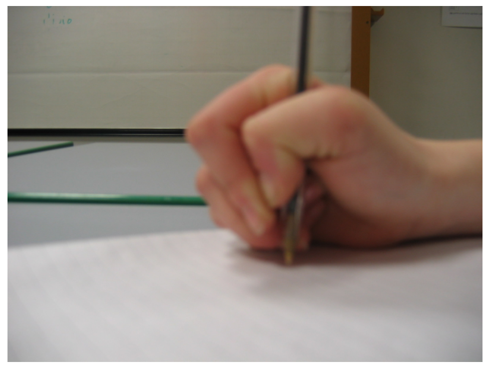
Experimental pupil Raven's matrices score	Experimental pupil Raven's matrices time (to the nearest minute)	Control pupil Raven's matrices score	Control pupil Raven's matrices time (to the nearest minute)	Summary of observations
43	13	35	6	Higher score took longer
35	14	48	21	Higher score took longer
41	8	34	8	Similar times, research pupil higher score
49	14	38	15	Similar times, research pupil higher score

Two of the pairs took very dissimilar times to complete the Raven's matrices task. For these two pairs the pupil who took longer obtained a higher score which is in line with the results discussed previously. However, in the other pairs the two pupils took very similar times with the pupils using an interdigital grip with middle finger control obtaining higher scores. For the first two pairs no conclusion could be drawn about their ability, although for the other two the pupil using this previously unreported variation of an interdigital grip demonstrates superior performance on this ability test.

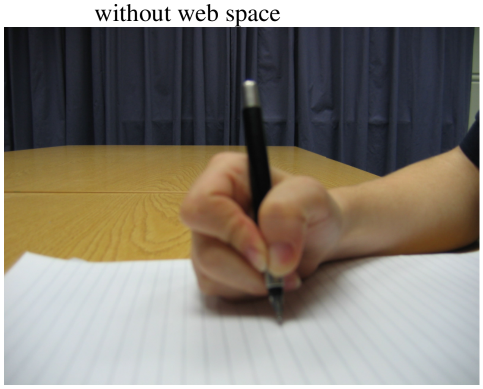
Tripod (Quadrupod) Grip without Web Space

These grips were observed eight times in this research sample, albeit with some variation. Four of these are illustrated below showing the subtle variations in this grip adopted by these pupils.

Photographs 6:19a Pupils 17's Quadrupod without web space



6:19b Pupil 133 Tripod without web space



Photographs 6:19c & d Pupils 183's & 149 Tripod grip without web space

Photograph 18b mostly closely illustrates the grip described by Dennis and Swinth. Four pupils use the quadrupod variation, due to the similarity in these grips they will be grouped with the tripod grips for statistical analysis. Pupil 149 uses the knuckle rather than the ball of the thumb under the index finger. Pupils 133, 149, 167, 183 use the tripod version while 17, 86, 116 and 157 use the quadrupod version.

The three boys and five girls who used this grip came from a range of set groupings. Although two pupils (numbers 86 and 167) reported no pain, another (Pupil 183) pain after an hour's writing and a fourth (Pupil 157) pain after half an hour's writing, the other four reported pain after only six minutes. Indeed two pupils [Pupils 116 (quadrupod) and 133 (tripod)] were the two pupils in the research who reported pain after only three minutes of writing. Pupil 133 described the pain she experienced as numbness all around her wrist, while Pupil 116 said that the pain was her whole palm and that she had a callous on her third finger, as did Pupil 157, whose pain was in his wrist. When Pupil 116 was observed writing, her inclusion in the sample had to be considered carefully because the digits were on the pen for a tripod grip but after six minutes of observation it was obvious that there was no opposition. During the interview she reported extreme pain. Only two weeks later Pupil 133 was observed and her response that she had pain after only three minutes of writing was unsurprising. It is these similarities that have caused the tripod and quadrupod versions to be brought together for statistical analysis. The difference in pain perception was tested using the Mann-Whitney U-Test with a significance level of 0.066, offering suggestive evidence of a statistical difference between pupils using this grip and their peers in the control group.

Two of the pupils who reported the most pain adjusted their grip a large number of times. Pupil 17 was observed to release his pen and rotated it with his middle finger at the end of every line and occasionally in the middle, making a total of 21 adjustments, three of them rotations of his wrist and hand. Pupil 133 made 15 adjustments during her six minutes of writing. However, since the other pupils made very few overall, the level was not statistically significant.

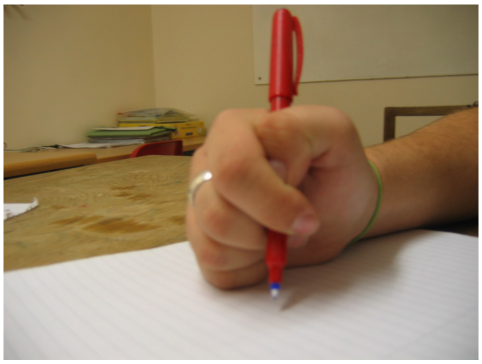
One of the controls to this group reported that her mother said that she had begun writing at the age of three while three of the pupils using these grips seemed to have been early writers. Pupil 133 said that she remembered writing her name in a book at the age of two with her sister helping her while Pupil 17 said that he started writing at three. This pupil was the only one of the group who reported that a primary school teacher (Year 4) tried to get him to alter his grip. However, he found his tripod grip without web space more comfortable. Although he was one of those who reported the most pain he considers it normal to have pain while writing and will carry on because that what that's what you should do. He did, though, express some annoyance, primarily with himself. His match, Pupil 18, who reported pain after half an hour's writing also felt that pain was normal – `everyone has pain' and had similarly been taught cursive but now printed because he did not like cursive writing. Pupil 133 who described feeling pain and numbness after only three minutes writing also expressed feelings of anger with herself because she `can't write tidy'.

One of the pupils using the tripod grip without web space had extra support in both infant school and immediately prior to secondary school transfer. She reported that this primarily addressed at improving her reading skills although this pupil, number 149, perceived that she had had messy writing and currently her `spelling is really bad'. A curious point emerged during the interview with Pupil 86. He reported that his father, born around 1970, had been naturally left-handed, but his father's father had tried to make him write with his right-hand, which his father now does. This incident is interesting following all the interviews in which pupils would report how parents and teachers had tried to persuade them to alter their grip without success.

Pupil 17 was taught to write cursively but has now regressed to printing as he felt it was easier for teachers to understand (read) and easier for him to write. Another (Pupil 133) reported similar experiences describing how they `had to write double in primary school' but that before beginning secondary school decided to change to printing because she `thought her writing was messy'. This seems to be a typical pattern also reported by other pupils, including from this group, Pupils 167 and 183 who commented that in Year 7 `I didn't have to do it and it was faster to print'.

Two Mixed Feature Grips

Two pupils used grips that were totally unique. Neither of these seem to have been identified previously. They are each illustrated below:



Photographs 6:20a & b Pupils 103's interdigital grip with tucked thumb & Pupil 84's grip

Pupils 103's grip is a variation on the interdigital grip that was previously described. However, instead of the thumb being held loosely over the fingers (see photographs 18a and 18b) it is instead tucked under the index finger. It is therefore an interdigital grip with tucked thumb. Like the four boys who used a thumb tucked grip this pupil was also male. Statistical analysis is obviously impossible on a single individual's quantitative data, although he did report pain after only six minutes of writing. This high achieving pupil seems to have been an early writer although he did not attend school until Year 2. He was urged by primary school teachers to adopt another grip but he said that `the other way hurt my fingers too much'. Although he wrote more quickly than his match (21.2 w/min compared to 19.3 w/min), this Year 11 pupil felt his writing was slower than he would like and that he was stressed by his inability to write quickly as he was always the last to finish. Whether this is true or not is irrelevant, it is his perception is that this is the situation that affects him. He felt annoyed with his teachers that he could not write at the speed required and annoyed with himself for the pain he experienced. This annoyance with himself he partially attributed to his habit of clicking his fingers which he felt would lead to arthritis. He reported that in primary school the teachers were `always having a go at him' and when asked what he did about the pain he experienced while writing he reported that he would carry on. He had previously used the cursive style taught in primary school but his teachers had asked him to stop, and print instead. His style was assessed as mostly printed with a legibility level of 3 (rather untidy).

Pupil 103's match used a mostly printed style and felt that in primary school he would always have to write right up to break due to his slower writing and because he was talking. So, although his writing was slower than Pupil 103's writing, and he reported that his parents say that it is not neat enough, Pupil 110 does not perceive that he has any significant problems. Pupil 103 with his interdigital grip with tucked thumb, probably reported a higher level of stress than any other pupil in the survey. However, this pupil was interviewed at the beginning of his GCSE year and being placed in top set for his first language, mathematics and science was undoubted expected to achieve and is probably himself ambitious.

The second mixed feature grip was shown by Pupil 84, a Year 8 girl. Her grip used the same digits as a tripod grip, namely the balls of the thumb and index finger and the distal interphalangeal joint of the middle finger. However, the index finger was held very high so that control of the pen was achieved by the thumb and middle finger. In this it was similar to the quadrupod index grip described above (see Photograph 6:13a) although in that grip it was the ball of the middle finger rather than its joint that controlled the pen.

Like Pupil 103 with his idiosyncratic grip, Pupil 84 also experienced pain after only six minutes of writing, reporting pain at the base of her little finger after writing only 3 or 4 sentences. She made six major changes to her grip including putting the pen down and stretching and rubbing her hand on her trousers and subsequently reported that stretching her hand before carrying on was how she dealt with the pain she experienced. She described that she had used a quadrupod index grip when she first started primary school, holding her pen between the ball of the middle finger and her thumb. She found this difficult because her finger was too moist so she decided to hold it tighter between the thumb and the knuckle. Her grip was very tight as can be observed in the photograph as her knuckle is whitened by the pressure. This pressure was also evident as her writing indented the paper four pages down.

Her writing speed was slower than her match or the control mean (16.0 w/min compared with match 18.8 w/min and low set Year 8 female mean 20.6 w/min) and she perceived that it was the pain that slowed her down, reporting feeling irritated with her hand.

HANDWRITING LEGIBILITY

Generally analysis of handwriting legibility is carried out by matching the specimens to graded examples of writing rather than other aspects of writing such as size, slant, appropriate use of ascenders and descenders, word spacing used by Stott et al (1987, p 141). Graham et al (1998) matched writing samples to nine specimens; Ziviani and Watson-Will (1998) scored handwriting legibility using a seven-point scale, while Summers and Carraro (2003) divided writing into three legibility groupings.

In this research, handwriting legibility scoring will be carried out by looking at the overall effect of the script on the page. Scoring will be on a scale of 1-4, with one being the neatest.

1 Very neat and legible, allowing easy reading
2 Legible but not as neat/regular
3 Untidy but with all letters and words decipherable, occasional pauses needed during reading
4. Untidy, letters and sometimes words are difficult to read

The legibility of the writing was assessed by the researcher. Inter-rater reliability was then determined. Since not every individual in a study need be reassessed in order to establish inter-rater reliability and given the large number of pupils in the survey, only part of the sample (about 17%) was independently reassessed. This reassessment was conducted by a retired English teaching colleague using the categories above. Of the thirty-two samples reassessed there was agreement on 28, a consistency level of 0.875 which equates with an inter-rater reliability (Cohen's kappa) of 0.823. The differences between the two raters lay in the second rater four times giving a lower legibility score (twice 2 instead of 3 and twice 3 instead of 4). The full results are displayed in Table C:10 in Appendix C.

This inter-rater reliability is commensurate with those found in other published research, although not all researchers have found it necessary to carry out an inter-rater reliability test (Ziviani and Elkins 1986). Some researchers have used larger numbers of categories than were used in this research: nine (Graham et al 1998) or seven (Ziviani and Elkins 1986; Ziviani and Watson-Will 1998). Others have used published criteria such as ETCH which requires raters to achieve a reliability of 0.90 before scoring the research samples (Dennis and Swinth 2001). In their research the word legibility was reported as being from 86.7% to 100%. Graham et al (1998) had an inter-rater reliability of 0.87 while Ziviani and Watson-Will (1998) calculated their reliability coefficient for legibility at 0.79, reporting that values higher than 0.75 represent good reliability. Burton and Dancisak 2000, in their study of line drawing activity with three to five year-olds using a six-point scale had an inter-rater reliability of 0.80 (kappa 0.73).

Since not all the samples were reassessed, it is the primary researcher's categorisation that is shown below and will be used for statistical analysis.

Table 6:19 Legibility of writing by pupils using different grips

Style	Unusual grip	Control grip	Overall (%)
1 Neat and legible	32	16	48 (25.8%)
2 Legible	29	35	64 (34.4%)
3 Untidy but decipherable	23	29	52 (28.0%)
4 Untidy difficult to read	9	13	22 (11.8%)

Samples of the four legibility scales are shown below. Each had a style rating of 1 and three of the four (styles 1, 2 and 3) were scored by both raters.

Handwriting 1: Pupil 122 (style 1 legibility 1)

get into the kitchen there is a wood
table and there is a dishwasher. Next
to the dishwasher going up there is stairs.
When we get to the top of the stairs
on the right there is my room. I have
a tv a bed and a cupboard in it.

Handwriting 2: Pupil 138 (style 1 legibility 2)

You walk in through the back door and
come into the utility room, at this point you
have a choice. A take the door right infront
of you or B go to the right into the
kitchen. im going to take the second option
B. As you come into the kitchen, opposite you

Handwriting 3: Pupil 97 (style 1 legibility 3)

round, it is the same shape as an
egg. This is to make the ball easier
to pass and carry. There are 15
players in a Rugby Team. 6 backs and
9 forwards. The forwards are the
bigger, stronger part of the team,

Handwriting 4: Pupil 60 (style 1 legibility 4)

is this: Vandalism. The main way is through the use of
viruses. A virus is a computer program used to infest other
computer programs. There are many types of virus, some
of the main types are Spywere, Trojan horces and
fire viruses. Viruses are used for many diferent things, here
are some examples, plain vandalism, advertising, data

Other researchers (Ziviani and Watson-Will 1998, p 63) have found that girls' writing is more legible than boys' writing. This pattern was also detected in this research with girls' mean legibility score being 1.95 while the boys had more illegible writing with a mean score of 2.68. Firm conclusions on writing styles and gender cannot be made from these results since the genders were not balanced for ability or age.

An important aspect of this study was to investigate whether the whole sample or any of the individual grips identified above are linked to a different writing style. Each style was tested using the Mann-Whitney U-Test on SPSS.

A statistical difference was detected for the whole sample of 0.021, indicating that when considered as whole group, pupils who were using one of the range of unusual grips under consideration, had writing that was more legible than their matched classmates. It is perhaps more relevant to consider which of the specific grips were performing differently.

Statistical differences were detected in three of the handwriting sub groups: the lateral tripod, lateral quadrupod and thumb tucked grip. The writing for the each of these grip patterns was more legible than that of their matches.

Pupils who used a lateral tripod grip have more legible writing than those using a tripod grip. The statistical difference was suggestive of a difference when tested with the Mann-Whitney U-Test, the difference being 0.078 (Arsham 1988, p132). The mean legibility for the pupils with a lateral tripod grip was 2.00, while that for their peers was 2.42. The precise reasons for this is unclear but style did differ with the pupils using a lateral tripod using a more cursive style (mean 1.96 compared with a control mean 1.88), moreover they wrote more quickly (mean 23.5 w/min compared with a control mean 22.3 w/min).

There was also a difference between pupils using a lateral quadrupod and their control group. The statistical difference for the lateral quadrupod was higher than that for the lateral tripod at 0.034, meaning that even greater reliance can be put on the result that pupils using a lateral quadrupod grip have more legible writing than those using a more orthodox tripod grip. The mean legibility for the pupils with a lateral quadrupod grip was 2.00 while that for their peers was 2.57. The precise reasons for this is unclear but style did differ with the pupils using a lateral quadrupod using a more cursive style (mean 2.32 compared with a control mean 2.04) although they wrote more slowly (mean 22.2 w/min compared with a control mean 23.6 w/min).

A statistical difference was detected for the thumb tucked grip of 0.040. The four boys using this grip were mostly from higher sets and used more printed style (for a more detailed discussion see below). However, the writing of the pupils using the thumb tucked grip was more legible (all scoring 3) than that of their peers (one scoring 3, the others scoring 4). These boys wrote with a much more printed style (mean 1.75 compared with a control mean 3.50) and they wrote more slowly (mean 23.8 w/min compared with a control mean 26.6 w/min).

Another interesting difference was also identified in another group, the quadrupod index grip. The statistical analysis did not meet the level of significance generally applied in this research (0.10), but lay just outside at 0.102. However, since there were only two pupils in this group, statistical significance of 0.10 would be hard to achieve. The two pupils in this group both had legibility scores of 4, compared to their classmates' assessments of 2 and 3. Although not statistically significant, it does seem that legibility is another factor which is indicative of this being an inefficient grip. These pupils wrote slightly slower than their controls (mean 21.9 w/min compared with a control mean 22.6 w/min) and used a more cursive style (mean 3.00 compared with a control mean 1.50).

Other factors may affect legibility, for example, body posture (Rosenblum, Goldstand and Parush 2006, p 35) while `some children discard the `helping' hand in writing with the associated consequence of insecure paper positioning' (Alston and Taylor 1986, p 10). This was observed once in the research when a Year 9 boy using a tripod grip did not use his left hand during the writing exercise to stabilise the paper. His writing was assessed as `untidy, letters and sometimes words are difficult to read'. Although his poor writing cannot be definitively linked to his practice of not using his left hand, his writing was less legible than the majority of other control Year 9 boys' writing and the insecure paper seems to be a factor in his less legible writing.

HANDWRITING STYLE

Although handwriting style is not central to this study, it was considered worthwhile to investigate whether pupils in the research and control groups differed in their writing style. Pupils in this research reported that they had been first taught to print, then taught a cursive style, although many reported that as soon as this was not insisted upon (after the transfer to secondary school), they either consciously or unconsciously reverted to printing as it was faster and more legible.

Different researchers have used different numbers of categories in which to divide the handwriting style that they studied. Mason (1992) used three categories: print in which writing was wholly print or mainly print with some two letter joins, mixed with joins of three or more letters and cursive in which the majority of letters were joined although allowing for natural `stops' taught in some published texts (p 109). Three groupings were also used by Summers and Catarro (2003) in their Australian research. They, however, only analysed 20 consecutive words from the middle of their extended writing tasks. Graham et al (1998) classified samples of handwriting for style into four groups: manuscript, mostly manuscript, mostly cursive and cursive.

As with handwriting legibility, handwriting style in this study will be scored on a scale of one to four, with four being fully cursive and one being entirely or with only minimal linkages. The following four definitions were used:

1 Fully printed with only very occasional links between letters
2 Mixture of styles but with printing dominating
3 Mixture of styles but with cursive dominating
4 Fully cursive with only very occasional separations between letters

The writing style of every pupil was assessed by the researcher. Inter-rater reliability was then determined. Since not every individual in a study need be reassessed in order to establish inter-rater reliability, and given the large number of pupils in the survey, only part of the sample (about 17%) was independently reassessed. This reassessment was conducted by a retired English teaching colleague using the categories above. Of the thirty-two samples reassessed, there was agreement on 27, a consistency level of 0.844 which equates with an inter-rater reliability (Cohen's kappa) of 0.778. These results are all displayed in Table C:10 in Appendix C. The differences lay primarily in the second rater, determining that sample was fully cursive rather than mostly cursive, although on one occasion it was considered fully printed rather than mostly printed. This seems to indicate that the primary researcher was more prepared to assign a mixed style than the second rater. Since not all the samples were reassessed, it is the primary researcher's categorisation that is shown below and will be used for statistical analysis.

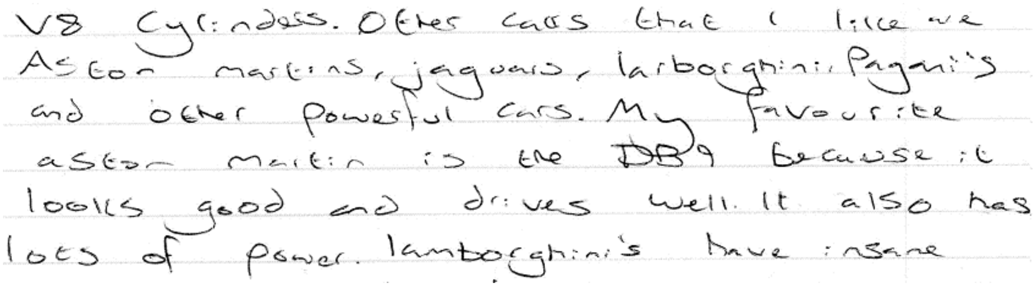
Table 6:20 Style used by pupils using different grips

Style	Unusual grip	Control grip	Overall (%)
1 Fully printed	36	38	74 (39.4%)
2 Mostly printed	26	25	51 (27.4%)
3 Mostly cursive	12	13	25 (13.4%)
4 Fully cursive	19	17	36 (19.4%)

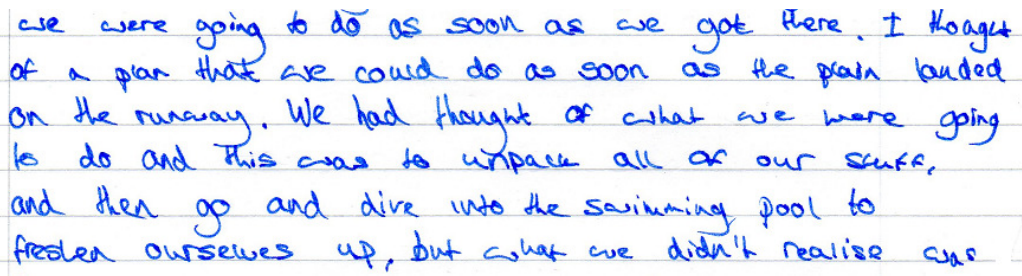
As can be seen in the table above, there was very little difference in the style used by pupils using different grips nor was there any statistical difference when the results were analysed using SPSS. This means that there is no evidence for the hypothesis that pupils with greater writing difficulties, namely pupils in the research group, may have less mature writing, using printing or using semi-cursive style, rather than the more mature and fluent fully cursive.

Samples of the four styles are shown on the next page. Each had a legibility rating of 2 and three of the four (style 1, 3 and 4) were scored by both raters.

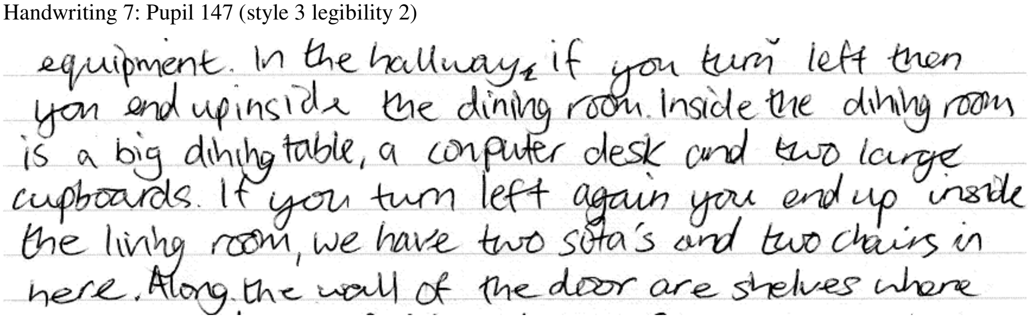
Handwriting 5: Pupil 10 (style 1 legibility 2)



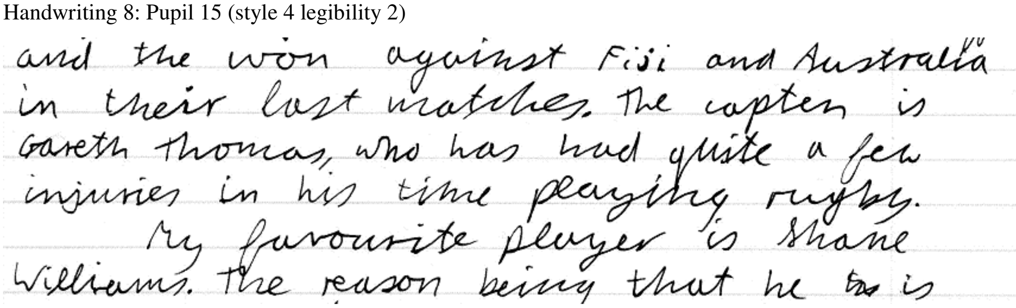
Handwriting 6: Pupil 68 (style 2 legibility 2)



Handwriting 7: Pupil 147 (style 3 legibility 2)



Handwriting 8: Pupil 15 (style 4 legibility 2)



It is interesting to compare the results obtained in this study with those from other researchers. Mason's results in pupils aged 11 showed that print was used by 34% of pupils, a mixed style by only 8% and cursive by 58% (1992, p 109). Graham et al's

1998 study of US fourth to nineth graders found printed, mostly printed and cursive styles were equally common with fully cursive levels lower at 9%. This study calculated an inter-rater reliability of between 0.98 and 0.99 (p 292), considerably higher than those obtained in this study, with the assessment being done independently. The relative proportions of an Australian survey of university students showed 21% printed, 44% mixed and 35% cursive (Summers and Catarro 2003 pp 151-2) while the closest age match to this research, a study by Allcock (2000) found that 23% used printing, 46% mixed and 31% fully joined cursive styles (pp 103-5). In Allcock's study, boys were more likely to use a joined style (45%) - a tendency also shown in this study - as the mean style score for boys was 2.27, higher than that for girls (2.02). Firm conclusions on writing styles and gender cannot be made from these results, however, since the genders were not balanced for ability or age.

A more important aspect of this study was to investigate whether any of the individual grips identified above are linked to a different writing style. Each style was tested using the Mann-Whitney U-Test on SPSS. There was suggestive evidence (Arsham 1988, p 132) of a statistical difference for the thumb tucked grip of 0.052. The four pupils using this grip were mostly from higher sets and were using more printed styles (two printed, one mostly printed and one mostly cursive) than their peers who used a tripod grip (one mostly printed and three fully cursive). However, the writing of the boys using the thumb tucked grip writing was generally more legible than that of their peers, as was considered in the previous section.

SPELLING AND OTHER ERRORS

The number of spelling errors was determined by assessing the number of spelling errors in the whole text. This was performed by the researcher for the English passages and a Welsh speaking colleague for the seventeen Welsh pieces of writing. Certain rules were applied. Capitalisation and punctuation (apostrophes) were ignored, when poor writing made it impossible to be certain about a certain letter (eg `rats' or `rots') the spelling was assumed to be correct and two misspellings were accepted `alot' and `aswell'. The reason for this was that those who used a printed style, the spacing could be interpreted either as correct or incorrect and this could have led to cursive writers having a higher rate of spelling error. Foreign and trade names (eg `Pearl Harbour' and `Center Parks') were accepted although other variants of these words (eg `Harbor', `Centre' and `Parcs') would also have been accepted.

The results are shown in Table C:10 in Appendix C. The results are shown as the number of errors per 100 words. The results for the research and control groups were compared using SPSS. The hypothesis being tested was that pupils using unusual grips were making more spelling errors than their peers, indicating that their grip patterns were one manifestation of a wider pattern of difficulties.

As would be expected, pupils from higher sets made fewer mistakes: 1.21/100 words (high), 2.15/100 words (middle) and 3.52/100 words (low). Girls made fewer mistakes (2.06/100 words) than boys (2.71/100 words). A slightly less clear cut pattern was revealed when the mean spelling errors for each year grouping was explored, although this could be related to the differing gender and set groupings. These results are shown below:

Table 6:21 Spelling errors for pupils (year grouping, set grouping and gender)

	Number of spelling errors/100 words
Year 8 10 high (1 male) 13 middle (6 male) 29 low (11 male)	3.38
Year 9 10 high (3 male) 10 middle (4 male) 6 low (3 male)	1.40
Year 10 5 high (3 male) 8 middle (4 male) 5 low (1 male)	1.53
Year 11 3 high (1 male) 2 middle (1 male) 1 low (0 male)	2.38

The Mann-Whitney U-Test of all the results and the separate grip sub-groups revealed only one significant result. This was for the all male thumb tucked group. The only Year 8 pupil (middle set grouping) made more spelling mistakes (2.76/100 words) than his match (1.39/100 words). Two of the three high set Year 10 boys made 2.99 and 1.55 errors. The remaining high set Year 10 boy and the three controls made no spelling mistakes giving a significance level of 0.091 offering suggestive evidence (Arsham 1988, p 132) that the boys using a thumb tucked grip were making more spelling mistakes than their control matches.

The rate of spelling errors for all pupils is shown in Table C:10 in Appendix C. Overall 22 pupils, 12 from the research and 10 from the control group had a spelling error rate higher than 5 errors per 100 words (Montgomery 2008, p 6) indicative of dyslexia. Thus 11.8% of pupils had a spelling error rate that causes concern, a lower rate than Montgomery observed in her Year 7 sample (pp 7-8). Only one dyslexic type mistake was observed, this in a control pupil (number 153) who wrote `bifrent' for `different'. Letter inversions of this type is one of the dyslexic type errors identified by Proustie et al (1997, p 89).

In addition to the statistical tests preformed, other linkages were considered, although, not central to the research objective. There was a positive correlation between legibility and spelling: the more illegible the writing the worse the spelling. Style and spelling were not linked, although faster more fluent writers made fewer spelling mistakes. Interestingly, those with worse spelling also apparently had worse behaviour although it is not suggested that any of these relationships are causal. These relationships and their level of significance are shown in the table below:

Table 6:22 Significant correlations between spelling and other variables (whole sample)

	Pearson correlation and significance	Correlation significance
Spelling and speed	-0.375 (0.000)	Correlation is significant at the 0.01 level
Spelling and legibility	0.254 (0.000)	Correlation is significant at the 0.01 level
Spelling and behaviour	0.166 (0.024)	Correlation is significant at the 0.05 level

SUMMARY AND CONCLUSIONS

This chapter has investigated the effects of a number of previously identified and newly identified grips. Although many other methods of communication are employed by young people and much coursework is now word-processed, handwritten classwork and examinations are still the norm. Handwriting is an important skill which is usually learnt in the initial years of schooling. Progress continues with the introduction of cursive writing and the use of pen with the aim of pupils being able to write fluently and automatically by the time they reach secondary school. However, recent research (Montgomery 2008) indicates that the majority of children beginning secondary school are not able to write quickly enough to meet the requirements of the school curriculum (pp 6-7). As shown in Chapter 4, many young people have adopted novel grips the consequences of which have not previously been investigated. This chapter has tested the research hypotheses that pupils who use unusual grips may be performing differently to their classmates.

The process of identifying pupils for inclusion in this part of the research proceeded relatively smoothly. Ten participants, around 5%, were excluded from the data analysis. This number was not higher than would be expected in this type of research. The assessment tools worked effectively, producing both quantitative data which allowed statistical analysis and qualitative information that provided insight to the experiences of the pupils involved.

Seventeen of the research pairings included a pupil using a dynamic quadrupod rather than a dynamic tripod grip as the control pupil. Statistical analysis indicated that pupils using quadrupod grips did not perform differently on any of the key research issues – Raven's matrices scores, the time taken to accomplish that task, handwriting speed or levels of pain experienced. However, it was demonstrated that pupils using a quadrupod grip hold their pens at a steeper angle, possibly related to the higher incidence of ball-point pen use, although no causal link was suggested. As the angle of the pen was the only statistically significant difference, it was possible to use pupils with either quadrupod or tripod grasps as controls in the remainder of the research analysis.

Data analysis on 186 pupils in 93 matched pairs was carried out. Similar numbers of boys and girls were initially identified, although a slightly higher number of girls were included in the final sample, as more girls responded favourably to the research request. Pupils in the research and control groups were compared using both quantitatively and qualitative methods. These comparisons brought out significant differences with respect to handwriting speed, pain levels and their feelings and responses to pain as well as the number of adjustments to their grip while writing. The legibility and writing style were also analysed, as was the number of spelling mistakes. These factors were considered in relation to a variety of grips previously identified as well as some not previously recorded in the literature.

There were sufficient numbers of pupils with the two most frequently observed unusual grips, the lateral tripod and lateral quadrupod, to allow these to be subdivided. However, when the data for these two grips was analysed an unexpected disparity between them emerged. There were slightly more pupils using a lateral tripod grip from the highest set groupings but very few using a lateral quadrupod had been placed in set one for all three subjects. These results for the two lateral grips cannot be considered totally reliable owing to the way in which the pupils were chosen, although the groups had been selected in an identical way. Statistical analysis indicated a link between lower attainment and use of the lateral quadrupod grip.

This was an unexpected result, although the identification of the lateral quadrupod is relatively recent (Dennis and Swinth 2001, p 180). Prior to this, Schneck and Henderson (1990), Carlson and Cunningham (1990) and Tseng (1998) had considered the lateral tripod a mature grip and an acceptable alternative to its dynamic counterpart. Amandson and Weil (2005, pp 590-1) concurred with this opinion, adding the dynamic and lateral quadrupod grips to the list of acceptable grips. Carlson and Cunningham (1990), however, considered that the grips that appear from the description to be dynamic and lateral quadrupod, to be of intermediate maturity. The acceptance of lateral grips as mature seems to be primarily on the basis of their use by adults (Schneck and Henderson 1990, p 896; Bergmann 1990) although Koziatek's and Powell's research (2003) with U.S. fourth-graders considered these grips to be mature on the basis of legibility and speed.

The differences between the lateral tripod and quadrupod is so slight that Dennis and Swinth (2001, p180) believed that the lateral quadrupod may have been `included in the lateral tripods of previous studies'. This is a result which must be the subject of further research, for although these differences in grip are small, there appear potentially serious effects to the adoption of the lateral quadrupod grip.

In addition to previously observed grips, a number of new grips were identified for the first time and named. These were: the quadrupod grip with middle finger dominance, the quadrupod without index finger opposition and the interdigital grip with middle finger control. Two grips appeared gender specific as the quadrupod without index finger opposition was only observed in girls, while all four pupils who used the thumb tucked grip were boys. Some of the other previously identified grips were recognised as being problematic. These results and their significance for teachers, especially of early years, will be discussed in the following chapter.

CHAPTER SEVEN

DISCUSSION OF RESEARCH RESULTS

INTRODUCTION

This chapter will draw together the research findings of the two parts of this research project: the initial investigation into demographic changes in the way writers hold their pens and the more detailed investigation into the effects the adoption of a non-tripod grip may have on the user. This second and major part of the research identified ninety-three secondary school pupils who used a range of unusual grips and considered how thirteen named non-tripod grips affect the writers using them.

This research is important as writing grip and its effect on handwriting performance is still be considered as an afterthought to even quite detailed research (O'Mahony et al 2008, p 175) with Rosenblum et al (2006, p 34) considering that `the effects of pencil grip on writing performance is still unresolved'. Unlike other fundamental aspects of education such as reading and numeracy, handwriting has had a low priority. Young children often adopt a grip which enables them to begin writing but the grip may be unsuited to the writing required of them by the time they reach secondary school. This research is centred on concerns that non-tripod grips are becoming more common and that these pupils may have undiagnosed difficulties and may consequently be performing differently to their classmates, perhaps due their poorer recording skills.

The initial part of the research was a demographic survey which investigated the grips used by individuals from five to sixty five years of age. This cross-sectional approach is the method by which most similar research is conducted, owing to the time and cost implications of longitudinal studies. A further benefit of a cross-sectional approach is that it is more likely to gain the respondents' cooperation thus be `less likely to suffer from control effects' (Cohen et al 2007, p 217). The second part of the research identified ninety-three pupils with unusual penholds who were carefully matched with pupils showing similar levels of school performance. Each of the pupils' abilities was tested and their writing speeds measured. Interviews concerning their early educational experiences and any current writing problems were also conducted.

As described in the previous chapters, two linked hypotheses have been investigated in this research. The first is that non-tripod grips are becoming more common and was planned in Chapter 3 with the results in Chapter 4. The second hypothesis considered in Chapters 5 and 6, suggests that pupils with unusual penholds have undiagnosed difficulties, including developmental coordination disorder and consequently may be performing differently to their classmates. This is a classic, theory-testing research project with a quantitative approach. The null hypotheses that are central to this part of the research are that the matched pairs of pupils will have the same ability and writing speed. Disproving these hypotheses would result in support for the initial hypothesis that pupils in the control group have higher (or lower) skills and are thus under performing (or over performing).

The whole concept of achievement and underachievement is filled with confusion. It is expected that pupils will enter the educational system and achieve to their full potential: but what is a child's potential? In an educational system where ability is rarely if ever tested, and rightly so, then a child's potential is only ever going to be guessed at. A teacher's expectations are going to be based on proxy measures, for example, comparing between subjects or expecting a pupil who does well orally to perform equally well in written examinations, but these expectations are often unfulfilled.

The results for the pupil assessments and interviews concerning their early educational experiences and any current writing problems were analysed. The comparisons brought out significant differences in respect of handwriting speed, pain levels and their feelings and responses to pain, as well as the number of adjustments to their grip while writing. The legibility and writing style were also analysed, as was the number of spelling mistakes. These comparisons were considered in relation to the grip used by each pupil. A variety of grips previously identified were present in the sample, as well as some not previously reported in the literature.

In this final chapter, the suitability of each aspect of the study is evaluated before the results obtained from both parts of the research are discussed, considering their significance for teachers.

THE DEMOGRAPHIC SURVEY

The demographic survey investigated not only the grips used by secondary school pupils but also those by younger pupils. The grips of fifty boys and fifty girls were observed and recorded in each year group from Reception to Year 13. The survey was also extended to include adults, with data being collected in five year age groups, again for fifty men and fifty women. The degree of reliance that can be placed on the sample was discussed in detail Chapter 4 (pp 84-7), although for the school pupils it does seem as though the grips observed do represent the grips used in the geographical area being investigated. Less reliance should be placed on the findings for the adult grips as the sampling technique did not cover a single defined population, although strenuous efforts were made to make it as representative as possible. Unlike Bergmann's 1990 survey, it did not include a disproportionate proportion of high achieving students and it did stratify for age.

A number of conclusions were drawn from the data collected. Most significantly, the grips used by adults over the age of thirty were statistically demonstrated to be unlike those of younger writers, under the age of twenty five. The probability of even the 20-24 year-olds and 30-34 year-olds having been drawn from the same population with respect to their handwriting grip, varied between 0.001 and 0.002 depending the precise grips being investigated (see Table 4:13, p 97). The transitional stage thus comprised people aged twenty-five to twenty-nine in the summer of 2005. Assuming they entered primary school in Year 1 in the September after they were five, they would have begun their education between the years 1980 and 1984. The changes to early years education at this time are considered below (pp 237-9).

THE SECONDARY SCHOOL SAMPLE

The research was conducted in state secondary schools in West Wales local to the researcher's home. Although it was initially intended to include ten schools in the research, sufficient pupils were identified from only nine. The schools surveyed included six of the seven secondary schools in Ceredigion and three secondary schools in the neighbouring county of Carmarthenshire. This was an opportunity sample, that is one that is convenient to the researcher and this is way that the majority of research of this type has been conducted (Dennis and Swinth 2001; Burton and Dancisak 2000; Summers 2001 and Koziatek and Powell 2003), owing to the considerable investments of time involved in repeated school visits.

The aim of the research was to identify and then investigate secondary school pupils who used unusual grips when writing and this was achieved, although further research may be required to determine the national relevance of the conclusions. However, the adoption of a certain grip pattern has the potential to produce a range of consequences internal to the person concerned which are completely separate to those that may be imposed externally by the system in which they are educated. Internal factors would be variables dependant on the efficiency of the grip would be characterised by, for example, the number of adjustments made while writing, the individual's perception of pain and how well and how fast they can write. External factors would be the consequences of the adoption of the grip; issues such as does slower or more untidy writing affect the set placements in a school. While the external consequences of a grip will be considered, it is primarily the internal consequences that this research is interested in and these would not be location specific.

Owing to the location of the research a complication was added as the schools differed in the language used. Three were Welsh medium and three English medium with overlapping catchment areas, while the remaining three schools were traditional bilingual schools providing a choice of three education streams: all schools educated pupils from 11 to 18.

The main consequence for this variation in language was that some pupils chose to write in Welsh rather than English. This was an unavoidable consequence of the selection of schools in this area for even the English medium schools produce all their letters and other public relations material bilingually. It was thus imperative that the parental request be produced bilingually and that reassurance be given to the headteacher of each school that while the interviews would be conducted in English the pupils could freely choose the language in which to write. The bilingual nature of schools in West Wales is deeply ingrained and this aspect of the research was an established and accepted component.

Subjective impressions as well as information gathered during the demographic survey indicate that unusual grips are not localised to West Wales and such a relatively isolated community does have research advantages. The population is relatively stable and this has research advantages over a more mobile intercity research location. Thus for purely practical reasons, coupled with time and travel constraints, it was decided to gather data from schools in the one geographical area.

THE ASSESSMENTS

Raven's matrices is a sixty question test that can be used in a variety of ways either as an individual, untimed test of capacity or as a 20 minute speed test. Since the speed test discriminates against slow and careful workers (Raven et al, 1996, p 5), it was decided to use the untimed test. However, previous experience of using the test in this way had indicated that pupils adopt different approaches, and as this variation may affect the outcome of the test, the time taken by pupils to complete the task was recorded. The test was used to investigate the research hypothesis that pupils with unusual penholds have undiagnosed difficulties and consequently be performing differently to their classmates. The null hypothesis was that achievement matched pairs of pupils, differing only in the way they hold their pens, will have similar abilities.

Pupils varied in the time taken to complete the test from 4:38 and 38:09 minutes with a mean of 11:41 minutes. The pupils in this research completed the test more quickly that the Icelandic pupils (Pind et al 2003) who spent between 11 and 68 minutes on the test - average 32.3 minutes although the pupils in that research had had the test administered differently, as they used a self completed group test.

The test is designed as an untimed test with individuals able to determine how long they spend on each question, with the time taken by individuals not affecting their score. However, in this research, pupils who spent longer on the test scored more highly with this link indicted by a Pearson correlation of 0.559, significant at the 0.01 level. This correlation impacts on the results of this research as pupils using an unusual grip also scored slightly higher on the test (39.59 compared with the control group mean of 38.39). Although this difference was not significant (0.154), pupils using an unusual grip also took longer to complete the task (12.12 minutes compared with the control group's time of 11.21 minutes), with this difference indicating suggestive evidence of significance (0.083) when tested with the Mann Whitney U-Test. Thus it seems as though pupils with an unusual grip approach the test differently than their peers who use a more orthodox grip. However, analysis of the individual grips did not reveal any support for the initial hypothesis that pupils in the experimental group have a higher ability and thus are under performing as they are more able than their paired classmates. Thus it may be concluded that pupils who have adopted unorthodox grips tackle tests differently taking a more considered approach, although this finding was not replicated for individual grips. This result is interesting, although ability is only one aspect that explains variability in achievement (Gurney 1988, p 53; Brown 2003, p 88).

Handwriting Speed

Handwriting speed was calculated by counting the words written during the six minutes of observed writing. The test chosen was a balance between a short test that could be accommodated in the one lesson per pupil available for all the assessments and a desire to create a task that might predict the handwriting examination performance with thinking and planning time as well as including concentration lapses. In addition, it is important that the task replicates genuine writing experiences. A personal communication by S.J.Admundson cited in Dennis and Swinth (2001, pp 181-2) suggests that students revert to immature or atypical grasps when presented with more challenging tasks such as creative writing.

Pupils generally approached the writing task with enthusiasm and there were very few pauses for contemplation or prolonged thought. In essence, the pupils approached the task as they would an examination in which they had sufficient information to write fluently and without distraction.

The calculation of handwriting speed are normally dependant on word counts with only the shortest writing exercises involving letter counts (Graham et al, 1998; Ziviani and Elkins, 1986 and Ziviani and Watson-Will, 1998) due to the volume of work involved. As described in Chapter 6 during the comparison of letter numbers in English and Welsh words, and illustrated on Graph 6:1, there is a negative correlation between handwriting speed and the number of letters. This means that those who wrote more quickly tended to use shorter words. However, although letter counts offer a more accurate measure than words (Sawyer, Francis and Knight 1993, p 11) it is exceptionally time consuming for long writing tasks and if letter counts were used as the principle measure of speed they would not allow comparisons with other research into secondary school writing speeds. The results obtained by other researchers for handwriting speed were shown in Table 2:1 in Chapter 2. The closest comparable assessment was Mason's five minute test (1992), in which Year 7 pupils wrote 17 words/minute while Allcock used a longer 20 minute test resulting in an average speed of 13.9 words/minute for pupils of the same age (2000, p 73). Montgomery (2008), using Allcock's 20 minute test in two additional schools, recorded 12.75 and 13.64 words per minute (p 6). The writing speeds for older pupils were generally calculated using the longer 20 or 30 minute test, which produced slower writing speeds than that found in this research, for example, Year 11 pupils 16.9 words/minute (Allcock 2001b); 17 words/minute (Taylor 2001) and 18.4 words/minute (Dutton 1992).

It is not unexpected that the current research obtained writing speeds that were higher than the results based on a longer test. A similar pattern of higher writing speeds in shorter tests was found by O`Mahony et al (2008) in research analysing the writing speeds of children, using 3 minute and an additional 9 minute versions copying `The quick brown fox jumps over the lazy dog' (pp 170-1). The precise point at which writing speed becomes a problem remains contentious. Montgomery (2008) considers that secondary school children need to be able to `write at a speed of 25 words per minute in order to cope with the curriculum' (p 3). Other researchers have put the figure far lower. Roaf, for example, thought that the 25% pupils with writing speeds of less than 15 words per minute are disadvantaged in secondary education (1998, p 41). Dutton (1992, p 80) found that at that time there was little reliable evidence of the handwriting speed to be expected of pupils in secondary school and that the `rule of thumb' of writing speeds of 16 words per minute used by educational psychologists as a basis for extra time in examinations was `apocryphal' and not citable. The writing speeds of twelve pupils with unusual grips as well as four pupils from the control group fell below this speed. However, the speeds obtained by some others cause concern as higher achieving pupils generally have higher faster handwriting (Allcock 2001a, p 25) and others had high scores on the Raven's matrices test and relatively slow writing speeds. Pupil 17 is a high achieving Year 9 boy whose writing speed was only 16.6 words/minute. He uses a quadrupod grip without webspace and scored 44 on the Raven's matrices test in 14:07 minutes. Pupil 95 is a Year 11 boy whose writing speed was 17.6 words/minute. He uses a lateral tripod grip and scored 44 on the Raven's matrices test in 11:55 minutes. Coincidentally, Pupil 189 obtained an identical score in an identical time. She, however, is a high achieving Year 8 girl using a lateral quadrupod grip whose writing speed was 16.5 words/minute.

In addition to these individuals, the research indicates that certain grip patterns are associated with differences in handwriting speed. Pupils using a lateral tripod grip wrote slightly quicker than the matched control pupils (23.50 words/min compared to 22.30 words/ min), although this difference was not statistically significant. This was a different result to that found in Summers and Cattaro's (2003) research in which students who a lateral grip (tripod or quadrupod) had writing speeds approximately 3 word/min slower than those who used the corresponding dynamic grips.

However, the lateral tripod grip was unusual in allowing faster writing as for most grips in which a difference was present pupils wrote more slowly with one of the differences being statistically significant. These grips were the lateral quadrupod with high index finger (8-9 % slower); lateral quadrupod with free thumb (slower, 0.064); quadrupod grip with middle finger dominance (5% slower); interdigital grip with middle finger control (over 10% slower) and the thumb tucked grip (over 10% slower).

Thus the thesis that there are grips which affect the pupils' handwriting speed is substantiated. This research, finding that pupils with some unusual grips write more slowly than those with regular tripod grips, is of importance since the published research indicates that `unconventional penholds permit writers to produce as high an average letters per minute as conventional tripod grips' (Wann et al 1991, p 60). The precise details of how even named unorthodox grips have varied was discussed in detail in Chapter 6 (p 154). Thus many of those included in Wann et al's definition of unusual penhold, would have been accepted for this research as using an orthodox grip. In addition, the demographic study conducted and discussed in Chapter 4 indicates that the incidence of unusual grips has changed over recent years and is most common in school pupils and young adults and is rare over the age of thirty.

The adoption of a grip that disadvantages an individual vis-à-vis his or her peers will have an impact on school performance. Handwriting speed is a critical factor to performance in external examinations although Sawyer's 1993 survey with pupils immediately after their GCSE examinations indicates that only 31% of the 124 students had sufficient time in all their papers. Moreover, they believed they could have improved their performance if they had had more time. Thus `regardless of academic ability the results of examinations are affected by handwriting speed' (Allcock 2000, p 40).

On transition to secondary level, the quantity of handwriting required of pupils increases steadily throughout Key Stages 3 and 4. However, it is spelling rather handwriting speed determines who receives Special Needs Support in secondary school as the recommendation comes from the child's primary school. Handwriting speed is not a criteria used in determining support in primary school (Allcock 2000, p 92) and once in secondary school writing speed is rarely assessed (Roaf 1998, p 39). This concern about writing speed must be tempered with caution as `speed norms are neither accurate indicators nor particularly desirable' (Sassoon 1990b, p 59) and vary internationally due to a variety of cultural factors (O`Mahoney et al 2008, pp 167, 174). Allcock (2000, pp162-3) recommends that the handwriting speed of all children is considered, as this is not routine and some mainstream children may need extra time. This research supports the principle that writing speeds should be included in the routine tests administered to pupils in secondary school. Although pupils were questioned about any difficulties they had with their writing speeds, their responses were inconsistent not revealing any pattern related to grip.

Handwriting Pain

Pupils were specifically asked if they experienced pain while writing. When asked, they had each just completed six minutes of writing and reports of pain during this short a time was considered as the most severe. Two other choices were available to pupils: pain after an hour's writing, the lesson time in the majority of schools or an intermediate figure of half an hour. Since pupils themselves determined the length of writing before pain began, this result should be reliable. Yet pain perception is very subjective and pupils were not questioned about the severity of their pain, as the analysis of multiple variables would have added substantially to the complexity of analysis of pupils' pain. However, a lower proportion of pupils reporting severe pain reported being able to continue writing through their pain if they used an unusual grip, offering tentative evidence that the pain experienced by pupils with unusual grips was more severe. The strategies the two groups use to deal with pain did not seem to differ, although anger and frustration were more often expressed by the pupils using unusual grips.

A large proportion of pupils reported pain with the proportions and severity differing between pupils using an unusual grip and the control pupils who used a more orthodox grip. The significance of these results was tested using Mann-Whitney U-Test revealing a statistically significant difference of 0.036, showing moderate evidence (Arsham 1988, p 132) that pupils from the two groups were not showing similar levels of pain and indicated that those using an unusual grip were showing greater pain.

Pupils were asked about their feelings when they found writing painful as well as how they dealt with the pain. The responses of the two groups were similar, although because more pupils using unorthodox grips reported experiencing pain, their responses dominated. These responses were discussed in great detail in Chapter 6.

Although the results indicated that pupils using unusual grips were more likely to experience pain, a critical part of this research was to establish which grips were more likely to result in pain for their users. An interesting pattern was noticed in pupils using the quadrupod without index finger grip opposition. These pupils reported less pain than the control group; although none of the control group reported any emotional response to the pain they experienced. In contrast, three of the six pupils using a quadrupod grip without index finger opposition reported adverse feelings to their pain. These feelings were very strong and appear to indicate a discrepancy in the ways that these two groups perceive pain.

In contrast, the four boys who used the thumb tucked grip all experienced high levels of pain with the result of the Mann-Whitney U-Test indicating a moderate evidence of significance at 0.029. These pupils also made significantly more adjustments while writing, leading to the conclusion that this grip not only appears awkward but is painful if used for sustained writing.

Four of the eight pupils who used a tripod or quadrupod without web spacing grip reported pain after only six minutes. Indeed, two of these were the only two pupils in the entire research project who reported pain after just three minutes of writing. This difference in pain perception was tested using the Mann-Whitney U-Test with a significance level of 0.066, offering suggestive evidence of a statistical difference between pupils using this grip and their peers in the control group.

Six variants of the lateral quadrupod were identified, although only two variants were observed in more than four pupils and both were associated with pain. The thumb clasped over the index and middle finger was used by thirteen pupils, with six of these pupils reporting pain after only six minutes writing, although since a much higher percentage than was usual of the control group also reported pain (4/13 – 30.7% rather than the expected rate for control pupils of 16.1% see Table 6:10 on p 144), this level of pain was not significant. Three of the seven pupils using the second most frequently observed variant, the lateral quadrupod with free thumb, reported pain after six minutes of writing compared with only one in the control group, although again this level was not statistically significant.

The link between pain, various grips and the pressure or tension required to maintain these grips has been made by other researchers. Amandson and Weil (2005, p 603) recommended modifying a grip in a number of circumstances: if muscular tension or writer's cramp is present; when the grip restricts precise finger and thumb movements of the pen; excessive pressure indicted by breaking pencil lead or holes in the paper, or if there is repeated shaking of the writing hand. Sassoon had earlier (1993) related pain to faster writing (p 101) and tension, considering that even a conventional grip, if too tight, may cause problems (p 36). She also suggested that `relaxed penholds, whether relatively conventional or completely unconventional, produce more relaxed writing' (p 36).

Although was not measured quantitatively during this research, pressure, if observed, was noted. Two of the three pupils who used a lateral tripod grip and reported severe pain while writing, were recorded as using severe tension to maintain their grip, while another pupil using this grip wrote with so much pressure that paper two sheets down were indented. She commented that she would `write less hard' to relieve the pain she experienced after half an hour's writing. Pupil 84's writing indented the paper four pages down. She used a unique grip and experienced pain after only six minutes of writing, despite making several major adjustments to her grip including putting the pen down and stretching and rubbing her hand on her trousers.

The pupils' responses to pain reported in Chapter 6 indicate that many perceive it to be an unexceptional part of schooling. Young people need to appreciate that pain is the body's warning system and that pain can be a consequence of poor writing strategies (Sassoon 1999, pp 156-9). The tension exhibited by some pupils while writing also needs to be measured although this can be very difficult. One possible way would be to standardise the choice of pen to a ballpoint, then excessive tension and pressure could be measured by recording how many sheets of paper were indented, a modification of the technique suggested by Taylor (2001, p 50). An alternative method used by Rosenblum (2008a) is an electronic tablet (digitizer) that allows normal writing on paper but with the pressure being applied registered on the connected computer. As with counting of the number of pages that are indented, such an arrangement requires the use of a particular pen, which could have an effect on the angle of writing. However, these technological advances remain in the future as the data analysis software is still under development (p 18).

Writing Adjustments

The number of times a pupil adjusted their grip during the timed writing exercise was recorded. The amalgamation of the two types of adjustment seems appropriate as it comprised only one aspect of this study. In a more focused study of adjustment during writing, perhaps relating adjustment in grip to pain or grip choice then differentiating the types of adjustment would be more appropriate.

Pupils from the research group using unusual grips made more adjustments than their matched peers, with the mean number of adjustments for the two groups being 4.18 and 1.56 respectively. The significance of these results was tested using the Mann-Whitney U-Test as described above, revealing that there was a very high statistical significance to these results, with the probability of these two groups making the same level of adjustments being 0.000 significant at the 0.001 level. There was a positive statistical correlation between the number of adjustments and the pupils' perception of pain. Different grips produced different levels of adjustment and it is this that is the major interest in this study: grips which are so uncomfortable to maintain that the writers are forced to continually adjust the grip in order to be able to continue writing.

Two grips, the lateral tripod and lateral quadrupod, each formed approximately a third of the sample. Both of these grips were distinguished by the number of adjustments that their users made. Indeed, the lateral tripod was considered an acceptable grip as its users were able to write more quickly (23.5 compared to 22.3 words/min) than their control group and many were present in the highest sets (top set pupils comprised 38.5% of pupils using a lateral tripod grip compared with only 30.1% of the whole sample).

There was also a significant difference in the number of adjustments for all pupils using a lateral quadrupod grip, with this being highly significant at a level of 0.000, significant at the 0.001 level (Arsham 1988, p 132). The most frequently observed variant of the lateral quadrupod grip, where the thumb is clasped over the index and middle finger, also showed that the number of adjustments made was higher than that observed in the control group. This was also highly significant at a level of 0.001. However, several variants of the lateral quadrupod were only observed once or twice, which meant that statistic analysis would be irrelevant although for a second variant, the lateral quadrupod with index finger high, seems to be associated with greater adjustments as both pupils also made at least six minor adjustments more than their control pupils.

The lateral tripod and lateral quadrupod, however, shared a common feature that the thumb was not in contact with the pen. In this they differ from the majority of grips observed. The decision was to whether a grip had been released was quite subjective, and based on whether the pressure of digits in contact with the pen was relaxed. Obviously, this was more likely to have been judged to happen when fewer digits were in contact at the outset. There is thus the concern that the significant difference in the number of adjustments was either illusory or an integral part of the way these lateral grips operate.

The four pupils using the index finger tucked grip experienced significant levels of pain. The pupil who made the most adjustments during the timed writing exercise described pain as least severe, thus it seems possible that her continually shifting grip was easing her discomfort allowing her to report less pain.

The four boys using the thumb tucked grip also experienced statistically significant levels of pain. However, when the number of adjustments made during writing was analysed, this indicated statistical significance, despite the small sample, of 0.091. This result indicates that there is suggestive evidence (Arsham 1988, p 132) that the pupils using a thumb tucked grip were not making the same number of adjustments as their control group.

Although it was impractical in this research to have another researcher present during the assessment of the judgements about writing, adjustments was one aspect of this study that could have benefited from a second rater's opinion. An alternative would have been to video record the writing task. However, in this research video recording, while allowing reassessment of grip adjustments, could have affected pupil participation, thereby eliminating some of the more interesting grips from the research or affected pupil matches. However, Herrick and Otto in their very early study involving the pressures exerted on the barrel of a pen, used a grip pressure transducer pen (1961, p 217), which allowed the variation in pressure between the three digits involved in a regular tripod grip to be analysed. Thus further research into grip pressure should involve the use of a pen capable of measuring variation of digit pressure which would enable definitive judgement concerning pressure without the need for filming or the presence of a second rater during pupil assessments. Recently, a digitising tablet was successfully used by Rosenblum et al (2006) to link frequent pauses to lower writing proficiency (pp 34-35). With adaptation, this technique could detect not only pauses but the adjustments to grip that are indicative of a less secure grip. This would be the preferred method in any future research, although a risk involved in using an adapted pen would be that it might function at different angles, thus affecting the grip used. Ziviani linked the choice of pen to the angle at which it was held and the grip readjustment (1987, pp 34-5) while Wann et al considered that the choice of pen can affect the way it is held and writing speed (1991, p 60). It was important in this research that participants are allowed a choice of pen as other research into handwriting speed has not permitted this choice

(O`Mahony et al 2008, p 169). In light of Wann et al and Ziviani's findings, this compulsory use of biro pens may have affected the handwriting speeds recorded for the secondary pupils, especially if pupils were inexperienced in their use.

The analysis of the number of adjustments in grip was an important part of this study and one which is not often undertaken as it requires individual observation of a single individual as they write. Links were detected, not only to certain grips but also to pupils' perception of pain. Even if other aspects of the study such as handwriting speed and legibility indicated that a grip was acceptable, any grip which requires constant readjustment to alleviate pain cannot be considered to be totally appropriate.

Thumb Length

The method of measuring thumb length was different to the method used by Sassoon who took hand tracings, although they were not analysed (1993, p 32). However, the method used in this research was effective. Minor differences in the thumb length measured could have resulted from differences in pupils' ability to stretch their thumbs at the required angle but these would have been minimal in comparison with the range of measurements recorded (50-88 mm). The pupils were all encouraged to stretch their thumbs as far as possible and achieve their maximum recording which was verified by the pupils themselves. Increased reliability would be present if a second rater had been present, although this may have been more intimidating to the pupils and have affected other aspects of the study.

Although no discernible pattern emerged in the measurement of thumb length for the data taken together, longer thumbs were associated with two grips – the four finger and interdigital. There was a statistical difference in thumb length for the four finger grip that was suggestive (0.081) of longer thumbs in the four pupils using this grip. Since there was only one pupil using the interdigital grip, no such association could be made for this grip – although her thumb was longer than her paired match and all but two of the other seventeen girls in the Year 9 control group. It has been suggested that long fingered children may have a prehensile advantage with greater dexterity and speed of manipulation (Alston and Taylor 1986, p 12). This research only investigated thumb length, not finger lengths and it cannot be assumed that these two factors are linked. However, even though longer thumbs were associated with two different grips, these grips did not appear, at least for the four finger grip to be associated with educational disadvantage. A number of concerns were present for the interdigital grip into which further research should be conducted.

The vast majority of pupils had no difficulty in stretching their thumb at a right angle to their index fingers, although one pupil (Pupil 187) who used a lateral tripod grip found it impossible. He was only able to extend it to an angle of about 45º. He was a Year 8 pupil and was placed in the lower sets. He wrote very slowly (15.2 w/min), was slower than any of the ten Year 8 boys in low sets (range 17.6-23.5w/min; mean 20.4 w/min) although he did not seem to differ from these pupils in any other variable measured. It seems that his lack of mobility could be affecting his writing speed. This result was peripheral to the main areas of study but it does seem to be an area for further research. Unusual malleability and flexibility has been the subject of earlier research (notably Sassoon et al 1986) who undertook intensive research into this topic. However, it seems desirable for a system of coding to be developed to allow this information to be used if a correlation is to be sought between finger/ thumb flexibility, grip and writing speed.

Behaviour

A member of the senior management team was asked to rate each pupil's behaviour. Those using an unusual grip were reported as having slightly less behaviour problems, thus the hypothesis that those with unorthodox grip would have more behavioural problems in school is disproved, although when the relationship was tested using Mann-Whitney U-Test there was no significant difference in these results. Two grips, the quadrupod index grip and the interdigitial grip could be linked to poorer behaviour, although they were only observed twice and once respectively and therefore any linkage remains unsubstantiated.

The method of assessment, albeit subjective, was appropriate and indeed was apposite in that it asked for a teacher's impression of pupils and the teaching profession do not always view an identical misdemeanour committed by a different pupil in the same way. Any investigation into the effect of painful grips must consider pupil behaviour, as painful writing, like other types of writing problems, could result in the avoidance of work set which can in turn be perceived as misbehaviour (Proustie et al 1997, p 88). This pattern of multiple problems caused by an unorthodox grip was represented by one pupil whose behaviour was a cause of concern (5 on the scale of 1 to10) and who felt his writing was slow which caused him considerable stress. His perception of teachers always being critical and judgemental was shown when he reported that in primary school the teachers were `always having a go at him'. When asked what he did now about the very high level of pain he experienced while writing using his idiosyncratic mixed feature grip (interditial and thumb tucked), he reported that he would `carry on. If I stop, I'll get in trouble as usual'.

Handwriting Legibility

The analysis of handwriting legibility was purely subjective as experienced teachers are good judges of handwriting (Rosenblum 2008b, p 305). This was an identical scoring method to that used in Rosenblum et al's recent research into the effect of ergonomic factors on handwriting (2006, p 32). This scoring method was thus not related to uniformity of letter size, slant, appropriate use of ascenders and decenders and word spacing that other researchers have used (Stott, Henderson and Moyes 1987, p 141). The analysis was conducted by the researcher with a second rater independently assessing a proportion of the writing samples. There was 87.5% agreement, which corresponds with that found in other research. Improvements could involve increasing the number of legibility grades to nine (Graham et al 1998) or seven (Ziviani and Elkins 1986).

The assessment of writing legibility was included in this research to discover whether any grip was associated with less legible writing. The assessment of handwriting legibility was thus a peripheral part of this study. More complex assessment strategies could not be justified as the potential outcome was not integral to the study.

Only one grip, the quadrupod index grip, seemed to be associated with poorer legibility. The two boys identified as using this grip also wrote more slowly and used a more cursive style. However, since there were only two pupils in this group, statistical significance was not met, lying just outside the level of significance of 0.10, at 0.102. However, despite not meeting the test of statistical significance it seems that legibility is a factor which indicates this is an inefficient grip.

Three grips were associated with increased legibility: the lateral tripod; lateral quadrupod and thumb tucked grips. The last had been statistically associated with difficulties such as pain and the number of adjustments while writing. However, for the four boys using this grip there was moderate evidence that their writing was more legible than their control group (0.040). The boys using this grip were mostly from higher sets used a more printed style and wrote more slowly than their peers, although the latter was not statistically significant.

Pupils who used a lateral tripod grip also had more legible writing than those using a tripod grip. This statistical difference was suggestive of a difference (0.078). The reason for this is uncertain but these pupils used a slightly more cursive style and wrote more quickly, although neither of these differences was statistically significant.

Pupils using a lateral quadrupod also wrote more legibily than their control group. This statistical difference was higher than that for the lateral tripod (0.034), meaning that there was moderate evidence that these pupils did not produce writing with the same legibility as their control group. The reason for this difference in legibility is unclear. The pupils using a lateral quadrupod used a more cursive style but wrote slightly more slowly, although neither of these differences was significant.

These relationships between grip and legibility indicate how complex the interrelationships between legibility, style and writing speed are. This was discussed in detail in Chapter 2, where it was described how even the tone of voice using in giving the instructions the test may affect the speed/ legibility trade-off with Ziviani and Watson-Will (1998, p 63) finding that writing quickly affects legibility.

Clear legible writing is important because many subjects rely on teachers and examiners to gauge the quality of handwritten work and poor handwriting has been shown to affect teacher perception of content (Soloff 1973, pp 51-2). Thus legibility cannot be dismissed as of purely aesthetic importance. If legibility was to be an integral part of another study, the precise factors that affect handwriting legibility could be investigated in addition to the subjective impression of overall legibility. These could include accuracy of letter formation, inaccurate entry and exit point to letters, word spacing, inadequate ascenders or descenders and the inappropriate use of capital letters. Given the time-consuming nature of such research it would most appropriately conducted on a few words in a longer writing task, or on a short copying task.

Handwriting Style

The assessment of writing style was included in this research to discover whether any grip was associated with a more printed less mature writing style. Only one grip, the thumb tucked grip, was statistically linked to a difference in style with the pupils who used this grip using a more printed style. These boys came from higher sets and although they wrote more slowly, their writing was more legible than the control group so their printed style did not appear to be affecting their education.

This research indicated that relatively few pupils used a fully cursive writing style with the results not being dissimilar to those by Allcock (2000) and Montgomery (2008) as the closest age matches to this research. Pupils in this research reported that they had been first taught to print, then taught a cursive style, although many reported that as soon as this was not insisted upon (after the transfer to secondary school) they either consciously or unconsciously reverted to printing as they found it faster and perceived it to be more legible. This finding reflects a long observed `general trend towards unjoined letters in secondary schools that can be seen all around the world' (Sassoon 1993 p 140). It appears that when children first learn a printed style of writing, with cursive script only being introduced later, this causes problems (Allcock 2000 pp107-8; Montgomery 2008, p 8). A possible reason for a printed or a mixed style being faster than a fully cursive style may be that pupils have not had sufficient practice with cursive script for it to become the faster style and thus the preferred style - once secondary schooling demands faster writing.

After the implementation of a National Literacy Strategy in 1998, Allcock anticipated that all aspects of pupils' handwriting would improve (2001a, p 23). However, recent assessments of Year 6 pupils (Medwell, Strand and Wray 2008) and Montgomery's 2008 survey of the writing of Year 7 pupils after the implementation of the National Literacy Strategy, indicated that the anticipated improvements had failed to materialise. Montgomery found that even after seven years approximately one third of Year 7 pupils have difficulties producing fluent, legible handwriting (p 8). She believed, on the basis of her analysis of pupils' writing, that the introduction of a cursive writing style at the outset would benefit all pupils, including those with developmental coordination disorder. Thus the British system still needs to learn from the experiences of other countries (Thomas 1998, pp 43-5) where `many schools begin with joined-up writing from the start' (Jarman 1993b, p 9) although enquiries among primary teaching colleagues indicate that many schools are still adopting an individual approach to writing styles a finding endorsed by Montgomery (2008, p 3).

Although style and legibility assessments had inter-rater reliabilities that were not inconsistent with those found in other research, if they were to be included in future research, further refinements to the scoring methods could be developed. It would be improved if another rater independently scored the writing and the mean scores were then used for analysis.

Spelling and Other Errors

Spelling was assessed by counting the spelling errors made during the timed writing exercise which was generally between one and two hundred words. Pupils from higher sets made fewer mistakes, as did girls. When the different grip types and subgroups were considered using the Mann-Whitney U-Test, only one statistically significant result emerged. This was for the all male thumb tucked grip with a significance level of 0.091, offering suggestive evidence the boys using a thumb tucked grip were making more spelling mistakes than their control matches.

A single dyslexic type spelling mistake was observed with the letter `d' inverted to `b', indicating that transcription can remain a problem even for older students (Connolly et al 2006, p 192).

Interestingly, over the whole sample, poorer spelling was correlated with a slower handwriting speed, poorer legibility and poorer behaviour, although it is not proposed that there is a causative link between any of these factors.

GRIP TYPES

It was the aim of this research to obtain information from a number of individuals each using the same grip pattern. This was successfully achieved, although it was obvious from the outset of the research that some unusual grips such as the lateral tripod and lateral quadrupod were far less unusual than others. For some grips, substantial numbers of pupils using them were identified, allowing tangible conclusions to be drawn, although for others when only one or two representatives were available, the conclusions were less substantial.

Quadrupod

The quadrupod grip was treated differently than the other grips which were the main focus of this research. Although it would have been desirable to match pupils with an unusual grip with an orthodox dynamic tripod grip, this was difficult because of the high frequency of quadrupod grip. To have used only tripod matches would have impacted on the wider research design, which required the closest possible set matching between the research and control pupils. Thus at the outset of the data analysis, the suitability of the quadrupod grasp as an acceptable alternative to the tripod was considered. This was done by matching each of the control pupils with another control pupil who uses a tripod grip. Matching was done on year group, gender and set placement and wherever possible the same school. When these were compared very few differences were identified. The pupils using a quadrupod grip scored very slightly lower on the Raven's matrices test, but they did the test more quickly, this link having been also found across the research. They also wrote more quickly than those using a tripod grip. Statistical tests of significant difference were performed on this data using the Mann-Whitney U-Test using SPSS with no significant differences being detected.

The one difference between the tripod and quadrupod grips which was observed was a higher use of ballpoints in the pupils with a quadrupod grip. This result is not unexpected as the quadrupod grip like the lateral grips causes the pen to be elevated and thus the ink in a ballpoint pen to flow more smoothly. Where possible, the angles of elevation were measured on the photographs taken at the time of the pupils' assessments. There was a statistically significant difference between the averaged paired results, shown by testing with the Mann-Whitney U-Test, of 0.08. Namely, there is suggestive evidence (Arsham 1988, p 132) that for the pupils surveyed, those who use a quadrupod grip hold their pens at a steeper angle. This result accords with that found by other researchers (Sassoon et al 1986, p 94; Sassoon 1990a, p 34; Wann et al 1991, p 68) and furthermore, the choice of pen affects not only the way it is held but also the writing speed (p 60).

However, a causal link cannot be established. It may be that the use of a ballpoint pen causes a child to adopt a quadrupod grip in order to encourage the ink to flow smoothly. Alternatively, those children who have already assumed a quadrupod grip may then find a ballpoint pen less difficult to use than their peers who have a tripod grip. However, it is the transition from pencil to pen when the angle of elevation becomes important, as pens needs a higher degree of elevation than pencil (Burton and Dancisak 2000, p 12).

Some research has considered that the quadrupod is a grip which provides a greater surface area of contact between the fingers and the pencil and may be linked to less intrinsic hand movement during writing (Dennis and Swinth 2001, p 181). While this difference in the way that the written trace is produced may have consequences for writing speed or pain, these links were not found in this research with secondary school pupils. Thus, although those using a quadrupod grip hold their pen at a steeper angle, this was the only statistically significant result observed. Those using a quadrupod grip did not perform differently on the key research issues – Raven's matrices scores, the time taken to accomplish that task, handwriting speed and levels of pain experienced. It was thus concluded both that the quadrupod grip could be considered as an orthodox alternative to the tripod grip in this research and that it was not a grip that should be viewed with caution.

Lateral Tripod Grip

As with Tuckett's 2006 South Wales research (p 31) into 5 year-olds, this grip was perhaps the most frequently observed and could not now be considered particularly unusual and certainly not the most abnormal pattern as Ziviani and Elkins found in their 1987 research.

The lateral tripod has been reported since 1990 (Bergmann and also Schneck and Henderson) although the precise definition has changed. This was discussed fully in the previous chapter (p 154) but essentially since its first identification the lateral tripod has become more extreme. Initial definitions referred to a grip which allowed the thumb to control the writing trace because the pen lies distally to the thumb's distal interphalangeal joint, but such grips were categorised separately in school research's demographic study and excluded from this research. In this research the stricter contemporary definition was employed, requiring the pen to be in contact with the thumb between the distal and proximal interphalangeal thumb joints. There was, however, considerable variation in the precise way the pen was held by the twenty-six pupils identified as using a lateral tripod in this research, with a total of seven different variations being identified. This variation was discussed in detail in the previous chapter (pp 154-8).

The quantitative data for all lateral tripod grips and each of the subgroups were tested using the Mann-Whitney U-Test on SPSS. Only one significant difference emerged and this was for the number of adjustments for all pupils using a lateral tripod grip. There was moderate evidence of a significant difference at a level of 0.027 (Arsham 1988, p 132). However, these adjustments were not linked to pain as only three pupils reporting pain after six minutes of writing compared with five pupils in the control group.

Pupils who used a lateral tripod grip have more legible writing than those using a tripod grip. The statistical difference was suggestive of a difference when tested with the Mann Whitney U-Test, the difference being 0.078 (Arsham 1988, p 132). The mean legibility for the pupils with a lateral tripod grip was 2.00 while that for their peers was 2.42. The precise reasons for this is unclear but style did differ with the pupils using a lateral tripod having a more cursive style, as well as writing more fluently (quickly). Thus this grip seems to be an acceptable alternative to the tripod grip and the anxiety expressed by Tuckett (2006, p 33) concerning a possible societal trend towards this grip appears to be answered. The results of this research seem to contradict Erhardt (1994, p 14) who wrote that `certain variations of the tripod grip are often seen in older children and adults who may have fixated at an earlier level of prehension'.

Lateral Quadrupod Grip

The lateral quadrupod grip is similar to the lateral tripod, although with the index and second finger exerting equal pressure on the pen. As with the lateral tripod, the pen was held slightly differently by the twenty-eight pupils who were observed to use the lateral quadrupod. This was discussed in detail in the previous chapter (pp 158-64) with six patterns being identified. Unlike the lateral tripod grip which showed a pattern of higher set placements, only three of the pupils using a lateral quadrupod came from the higher set groupings and as described in Chapter 6, this indicates that there is a possible relationship between lower attainment and use of the lateral quadrupod grip. The issue of the suitability of the lateral quadrupod grip and its relationship to other grips was considered in the conclusion to the previous chapter (pp 194-5).

Although a relationship between the use of the lateral quadrupod and poorer attainment seems to exist, there is no suggestion of a casual link. It could be that the adoption of a lateral quadrupod grip happens more often by less able students, or the use of this grip makes it more difficult to achieve a place in the top set for all three subjects.

The quantitative data for all lateral quadrupod grips and each of the subgroups were tested using the Mann-Whitney U-Test on SPSS, although for the variations of the lateral quadrupod observed only once or twice statistical analysis is inconclusive. One significant difference emerged for the whole group and this was for the number of adjustments for all pupils using a lateral quadrupod grip, with this being highly significant at a level of 0.000, significant at the 0.001 level (Arsham 1988, p 132).

The most commonly observed variant occurs when the thumb is clasped over the index and middle finger. This grip was used by thirteen pupils in the sample and statistical analysis indicted that the number of adjustments made was higher than that observed in the control group. This was highly significant at a level of 0.001. Six for these pupils reported pain after only six minutes writing, compared to only four in the control group, while four of the pupils in this group reported that they had been early writers and three reported dyslexic tendencies.

A tight grip in the lateral quadrupod grip results in the pen lying in the webspace between the thumb and index finger. Four pupils used this grip, three boys and one girl. Two of these pupils experienced pain after six minutes of writing compared with only one of the controls who was dyslexic and was shortly to receive a laptop computer. Dennis and Swinth 2001 (p 181) considered that the lateral quadrapod, as well as some other grips, provides a greater surface area of contact between the fingers and the pencil and linked this greater surface area to an increase in pressure. Since this subgroup (lateral quadrupod with pen in web space) was observed only four times hindering firm statistical conclusions, it seems to be linked to pain caused by the very tight grip being exerted on the pen.

The two girls who had a high index finger in their lateral quadrupod grip experienced less pain than their controls. However, their writing speeds were 8 to 9% slower than their controls using a tripod grip. These two pupils also made far more adjustments than the control pupils with whom they were matched.

Another common variant of the lateral quadrupod grip was that in which the thumb did not make contract with the fingers. This was characterised by a thumb that would tremble during writing and was used by seven pupils. Interestingly, this grip was different to the other lateral variants in that these pupils wrote more slowly than their peers. This difference was statistically significant according to the Mann-Whitney U-Test at a significance level of 0.064, offering suggestive evidence against the null hypothesis that their writing speeds were the same (Arsham 1988, p 132). They also experienced pain after a shorter writing time with three of the seven pupils reporting pain after six minutes, of writing compared with only one in the control group. A consideration of how this grip is achieved explains both the slower writing speed and the pain. In a tripod grip, the thumb, index finger and middle finger each exerts pressure on the pen, although the pressures vary, the most common of the six combinations of pressure is for the thumb's pressure to be the highest (Herrick and Otto 1961, p 223). In the lateral quadrupod with free thumb, the thumb is not employed in forming the grip, which means that the fingers have to hold the pen very tightly in order to exert enough pressure to create the writing causing pain. Control of the pen in such a fisted grip is largely created by movements in the wrist and knuckle joints, rather than fine finger movements (Ziviani 1987, p 37) which could explain the slower writing speed observed by pupils using this most extreme form of the lateral quadrupod.

Some pupils commented on how `messy writing' had been linked to their lateral quadrupod grip. This relationship was neither borne out by analysis of the individual pupil's writing, nor statistical analysis, as pupils using a lateral quadrupod grip were found to have more legible writing than those using more orthodox grips. The reliability of this result was higher than that for the lateral tripod at 0.034, meaning that even greater reliance can be put on the result that pupils using the lateral quadrupod wrote more legibly that their peers. The mean legibility for the pupils with a lateral quadrupod grip was 2.00, while that for their peers was 2.57. The precise reasons for this are unclear, but users of a lateral quadrupod grip wrote more slowly as well as with a more cursive style, although neither difference was significant.

Although a large number of pupils were observed to use this grip, there remain some questions to be answered. Although the lateral tripod seemed to be an acceptable grip, the quadrupod form had some important differences. These centre on the under representation of higher achieving pupils which in isolation would not be considered significant, given the selection procedures involved in obtaining the sample. However, this under representation is concerning when compared with the over representation of high achievers using the lateral tripod grip who were selected in an identical way. Another difference is that pupils using the lateral quadrupod grip had slower handwriting speeds unlike the lateral tripod who wrote more quickly that their age and set matched controls. An efficient grip must allow for fluent writing, achievement and not be linked with undue pain or other discomfort and the lateral quadrupod, or at least some variants of it fail in a number of these qualities.

Four Finger Grip

This grip, like the index grip the description of which follows, has the tips of four digits controlling the pen and was illustrated with a drawing by Tseng (1998) and a photograph by Koziatek and Powell (2003). The tips of the index, second and ring finger are in opposition to the thumb with the hand balanced on the smallest finger.

Although this grip appears awkward, it does not provide its writers with excessive problems. Their thumbs were longer, a difference which was statistically significant (0.081), although the thumb is not positioned differently than in a tripod or quadrupod grip so the relationship remains unexplained. There was no difference in the pain described, although pain did seem to be focused on the base of the thumb and while one father had linked his daughter's grip to her bad handwriting, this was not found to be the case. Her writing was more legible than that of her match (2 compared with 3) and the legibility of the writing of all pupils using the four fingered grip was writing was identical to their control group. Thus Ziviani's (1987, pp 35-6) belief that grasps using three or four fingers to control the pen is immature and indicative that the child had had inadequate motor training before beginning to write, appears to be disproved.

Index Grip

The index grip has the forefinger being held high on the pen, opposition being created between the thumb and second and third fingers. The way the pen is held means that the writer cannot slide the hand across the page so that the forearm must be periodically moved. Since only one pupil was identified using this grip, it is impossible to make any statistical conclusions from the data collected. Although this grip appears uncomfortable, the pupil reported that he would only find writing painful after an hour and he made no adjustments during the timed writing exercise. His thumb was longer than the mean and the index grip could be an adaptation to the long thumb.

The pupil reported that he fell behind his classmates in Years 3 and 4 but subsequently recovered though his writing remains slower (22.6 words/min) than would be expected for his age and ability - 23.9 words/min (low and middle sets) while that for the higher sets was 25.3 words/min. However, given that there is only one pupil using the index grip statistical evidence is inconclusive. However, it does seem to be a grip that may affect performance, especially handwriting speed and a grip that should be avoided.

Quadrupod Index Grip

Two pupils used this grip, which is similar to the index grip, but used only two fingers rather than three above the pen. One of the two Year 8 boys in which this grip was observed really struggled to keep control of his pen while writing. There were few differences between these boys and their control matches, although a comparison of their behaviour ratings almost reached the level of suggestive evidence at 0.102. However, given the small sample size no conclusion should be attached to this result.

The interviews revealed that both pupils reported being able to write before they began school. The unusual grip of the research pupils was noticed by their infant school teachers and both pupils appeared to have made concerted efforts to use a tripod grip. One pupil also reported that his writing is not very neat and he does `good work but his presentation lets it down', an impression supported by the analysis of handwriting legibility as both boys had legibility scores of 4, compared to their classmates' assessments of 2 and 3. Although not statistically significant (0.102 again owing to the small sample size), it seems that this grip is linked to poor legibility. These pupils wrote more slowly than their controls and used a more cursive style. The pattern of the Ravens's times and scores also appears indicative of underperformance although with only two pupils in this group statistical support for this conclusion would be hard to achieve. Overall, the quadrupod index grip does appear to be linked to poorer school performance as well as poor behaviour and poor legibility, a finding that reinforces Sassoon's impression that this grip led to awkward writing (1986, p 45).

Quadrupod Grip with Middle Finger Dominance

This grip is similar to the quadrupod index grip, with opposition between the middle finger and thumb, although it differs because the index and middle finger are not spread out up the pen. The two pupils who use this grip came from the lowest set groupings and were early writers. There were few differences between the two pairs and their controls and with only two pupils using this grip statistical conclusions are difficult to make. There were differences in the pairs' handwriting speed with the research pupils writing about 5% slower than their controls. This difference was not statistically significant because of the small sample.

Quadrupod without Index Finger Opposition

This is a more extreme form of the previous grip with opposition created between the middle finger and the thumb with the index finger being curled or hooked over the pen. This grip was observed six times in the sample and was interesting in that it was only observed in girls. The girls came from a range of set groupings, although three came from the highest group, meaning that they were in the top set for mathematics, science and first language. Although there were differences between the research and control pairs in some quantitative variables, no statistical differences could be distinguished. Two of the six girls from each of the research and control groups seem to have been early writers. Although the levels of pain reported by the research group was less than that of the control group (mean of 1.5 compared with 1.83), none of the control group reported any emotional response to the pain they experienced. In contrast, three of those with using a quadrupod grip without index finger opposition reported adverse feeling to their pain. These feelings were quite strong and could indicate a discrepancy in the ways that the two groups perceive pain. However, there is no statistical evidence to suggest that this grip causes any educational disadvantage and half the pupils observed using it were placed in the highest sets, indicating that pupils using this grip are able to achieve. It would, however, be interesting to investigate whether any boys use this grip, as the indication of the purely female occurrence in this research is puzzling.

Index Finger Tucked Grip

In this grip pupils have their index finger bent up into the palm and the pen held between the middle finger and thumb with slight variations. The most noteworthy difference between these pairs of pupils is in their experiences of pain. Two of the four reported pain after only six minutes of writing which, when compared with their controls, was a significance level of 0.076, suggestive statistical difference (Arsham 1988, p 132). However, the pupil who described the pain as least severe made the most adjustments during the timed writing, possibly indicating that her continually shifting grip was easing her discomfort leading her to report less pain. Two of the four pupils using this grip reported writing before they went to school with one asking her mother to write so that she could copy it.

As a grip that occurs only infrequently, further research should be conducted into its appropriateness. However, Sassoon's assumption, unsupported by empirical evidence that this grip `looks strange but probably works' (1986, p 11) appears rather precipitate and until more substantive evidence is available this grip should be avoided owing to its association with pain.

Thumb Tucked Grip

This grip has the thumb folded over the pen and tucked under the index finger. Four boys in the study used this grip, three the tripod and one the quadrupod form, all four were in the top set for mathematics, science and first language.

The boys using the thumb tucked grip all experienced high levels of pain, two reporting pain after only six minutes the other two after half an hour. The level of pain was tested with the Mann-Whitney U-Test showing a moderate evidence of significance at 0.029 (Arsham 1988, p132). Similar although slightly less significant results (0.091) were shown when the number of adjustments made during writing were analysed, indicating that the grip not only appears awkward but is uncomfortable to maintain as well as resulting in a great deal of pain. A statistical difference (0.040) was detected for legibility as the boys using the thumb tucked grip had more legible writing. However, these boys wrote with a much more printed style (statistical significance 0.052) and wrote more slowly (23.8 compared with 26.6 words/minute although not statistically significant) and both these factors could have affected legibility. They also made more spelling mistakes (statistical significance 0.091).

Overall this grip seems to be adopted by the most able and does not prevent academic success, although it is associated with a number of difficulties particularly handwriting speed, pain and writing adjustments. The boys using this grip write more legibly, using a more printed style and make more spelling mistakes although these problems may be merely associated rather than causally linked. It may be the underlying difficulty that caused these boys to adopt the thumb tucked grip that may result some of these differences. Once again it is interesting that this grip was only observed in boys and further larger scale research would be required to determine whether the use of a thumb tucked grip is only associated with boys or whether this finding was a statistical anomaly in the current research. Sassoon disapproved of the left-handed version, believing that the `fingers cannot move freely' (1986, p 10) and that the right-handed version leads to little difference in height of letters, although this was not based on empirical evidence (p 44).

Interdigital Grip

Only one pupil in this study used this grip although the researcher observed it once in the demographic study and twice in sixth form pupils she has taught. Each of these used the interdigital grip with the pen projecting ulnarly between the ring and little fingers. Furthermore, one pupil who now used a tripod grip reported that she had used interdigital grip with the pen projecting between the middle and ring fingers. She reported that her reception teacher noticed that she was holding the pen incorrectly and she quickly changed it and used a tripod grip by Year 1.

With only one pupil using this grip it is not possible to make any significant statistical observations on the information collected about this grip. However, this grip does not seem to be causing this pupil any difficulty as she did not report any pain has been placed in the top set for all three subjects. The only anomaly was a longer than average thumb length (70 mm compared with her control - 55mm and the Year 9 female control mean of 62.3 mm).

Since this is such a different grip, the researcher has asked others who used it or their teachers for their impressions of its efficiency and any problems. It is variously linked to exceptionally high ability; poor motor control of pen causing an inability to draw causing feelings of serious inadequacy in the classroom and classroom disruption with possible underperformance. Thus, although the one pupil using an interdigital grip in this study did not cause it to be identified as a grip that raises concern, the use of this grip should be the subject of further research before any definitive judgements can be made.

Interdigital Grip with Middle Finger Control

This grip is interdigital with the fingers fisted into the palm with the pen projecting ulnarly between the middle and ring finger but with the middle finger flexed so that the tip rests on the pen exerting control. The grip was observed five times with slight variation with three pupils apparently having been early writers and most being aware of their atypical grip. Although there were no statistical differences in the analysis of the quantitative data, some results that indicated that some pupils were performing differently to their peers and three had slower handwriting speeds.

Tripod (Quadrupod) Grip without Web Space

In this grip the thumb is flexed so the ball of the thumb, although on the pen, lies almost underneath the fingers and does not provide opposition. This grip raises concern as Myers (1992, p 49) considered that an open index finger-thumb web space is needed to perform skilled activities This grip was observed eight times in this research sample, albeit with some variation. Three of the pupils using these grips seemed to have been early writers compared with only one from the control group.

The levels of pain reported by pupils using this grip were different than those reported by their controls. Five of the controls reported no pain while two pupils using this grip reported pain after only three minutes of writing and two others after six minutes of writing. This difference in pain perception was tested using the Mann-Whitney U-Test with a significance level of 0.066, offering suggestive evidence of a statistical difference between pupils using this grip and their peers in the control group. Although two pupils made a large number of adjustments (21 and 15) since the other pupils made very few overall, the level was not statistically significant. There were some severe reactions to the pain they experienced during writing, indicating that some pupils perceive that pain while is normal while others expressed anger because of their poor writing quality. This group had slightly more illegible writing (mean 1.88 compared with 1.50 for the controls) although the difference was not significant.

Mixed Feature Grip – Interdigital with Thumb Tucked

The one pupil using the interdigital grip with tucked thumb was male like the four boys who used a thumb tucked grip. Statistical analysis is obviously impossible on a single individual's quantitative data, although he did report pain after only six minutes of writing. This high achieving pupil seems to have been an early writer although he did not attend school until Year 2. Although he actually wrote more quickly than his match, he felt he wrote more slowly than he felt he needed to. He was stressed by his inability to write quickly as he felt he was always the last to finish and when asked what he did about the pain he experienced while writing he reported that he would felt obliged to carry on (see p 213 above). This pupil probably reported higher levels of stress than any other pupil in the research although this could be due to high expectations at the beginning of Year 11.

Mixed Feature Grip – Quadrupod Index Grip with Distal Interphalangeal Joint Control

This grip used the same digits as a tripod grip, namely the balls of the thumb and index finger and the distal interphalangeal joint of the middle finger. However, the index finger was held very high so that control of the pen was achieved by the thumb and middle finger. Thus it is similar to the quadrupod index grip although this grip uses the joint rather than the ball of the middle finger to control the pen.

This pupil experienced pain after only six minutes of writing and made six major changes to her grip, including putting the pen down and stretching and rubbing her hand on her trousers and subsequently reported that stretching her hand before carrying on was how she dealt with the pain she experienced. She described that she had used a quadrupod index grip when she first started primary school, holding her pen between the ball of the middle finger and her thumb. She found this difficult because her finger was too moist so she decided to hold it tighter between the thumb and the knuckle. Her grip was very tight and this could be causing the pain she experienced. Her writing speed was slower than her match or the control mean for her age and ability and she perceived that it was the pain that slowed her down.

CONCLUSIONS ABOUT GRIP

The research aim of obtaining information from several pupils using the same grip pattern was achieved, although the numbers of each grip varied meaning that the security of conclusions varied. However, it was possible to conclude that while some grips are acceptable others should be avoided. This information is summarised in the table on the next page:

Table 7:17 Table showing the acceptability of all the grips observed

	Grip	Sample size	Concerns
Acceptable grips	Quadrupod	17	Ballpoint pens used more
	Lateral tripod grip	26	Adjustments Increased legibility (more cursive style and faster handwriting) Possibly linked to female and higher ability pupils
	Four finger grip	4	Thumb length (longer)
	Quadrupod without index finger opposition	6	All female Pain perception
Undecided grips	Lateral quadrupod grip	28	Adjustments Increased legibility (more cursive style but slower handwriting) Linked to low ability Some variants writing speed and pain
	Index grip	1	Handwriting speed
	Quadrupod grip with middle finger dominance	2	Handwriting speed
	Interdigital grip	1	Long thumb (possibly linked to high ability/poor motor control/ performance/ behaviour)
	Interdigital grip with middle finger control	5	Slower handwriting performance
Unacceptable grips	Quadrupod index grip Mixed feature grip – quadrupod index grip with distal interphalangeal joint control	2 1	Behaviour Legibility Performance Pain
	Index finger tucked grip	4	Pain/adjustments
	Thumb tucked grip Mixed feature grip – interdigital with thumb tucked	4 1	All male Academic success Pain Adjustments More legible More printed style Slower handwriting More spelling errors
	Tripod (quadrupod) grip without web space	8	Pain

The process by which a child develops the fine motor control skills required to write was described in detail in Chapter 1. The new born child gradually gains the muscular control of their arms and hands initially learning to grasp objects with their whole hands by flexing all the fingers against the palm. This very primitive grip may be used by young children when first given a pen but it restricts fine motor control limiting control of any writing produced. It is only later that independent control of the thumb and then the index finger allows children to begin to grasp a pen between the tips of the fingers.

Even after children develop the finger positioning for a tripod grip, development continues as initially movement is controlled by the shoulder. As the child's development progresses, the lower joints of the arm and then the fingers become skilled at controlling the writing process. This control results in the fully developed dynamic tripod grip although Manoel and Connolly found that it was only by the age of four years four months to four years nine months that 80% of children can imitate the dynamic tripod grip (1998, pp 185-6). If it is only by this age that children gain sufficient maturity to correctly control their fingers, then the age that children should be beginning to write needs to be considered, this is the concept of writing readiness. Sassoon (1995, p 64) advises against pushing children into writing before they are mature enough and mentions the twin skills of hand-eye coordination and the ability to perceive and copy; furthermore (p 72) suggesting that five years is the age at which most children are writing ready.

In the demographic survey very high levels of unusual grips were observed in the youngest girls particularly those in Reception (Year 0) and Year 1 (see Table 4:14 and Graph 4:3 on pp 98-9). Although these would need to be confirmed by additional research, it appears that very young girls are particularly likely to use unusual grips. This may be as a result of them having adopted unorthodox grips before beginning school, although many may abandon them early in their school career (Pupil 143 described changing her grip by the time she was in Year 1 – see Photograph 6:17b) many more persevere despite the efforts of teachers to alter them (see pp 236-7). This explanation is premised on the supposition that girls write earlier and more willingly than their male counterparts.

The demographic survey further indicated that girls' unusual grips persist, with these grips being more often observed in girls and young women than in boys and young men. The disproving of the null hypothesis established that the genders are different with respect to the likelihood of adopting a non-tripod pengrip. Further analysis of the data indicated that although girls are more likely to use a quadrupod grip, a difference that was not statistically significant, it is their higher rates of unusual grip that results in their lower level of tripod grip (see p 102). Some interesting evidence comes from the selection of pupils for inclusion for the second phase of the research. This selection was not random. Quadrupod grips were only used as an alternative to a tripod grip if the tripod grip would have resulted in a poorer match, while lateral grips were avoided after sufficient had been included in the sample. It was impossible in the rush to complete the survey of, usually, four classes in a single lesson to keep accurate records, but the subjective impression was that it was the lateral grips of girls that were being avoided. This is supported by the fact that despite the demographic survey indicating a higher rate of unusual grips in girls, the secondary school sample initially identified 160 boys and 156 girls with unusual grips. The effects of these lateral grips has been considered earlier in this chapter (pp 219-23).

The premise that girls write earlier than boys is supported by Benbow (2006, p 319) who considered that `many (girls) begin to `write' as early as two and a half, often without proper adult attention or supervision' and that this may be a cause for their adoption of inefficient or even harmful grips. Myers (1992, p 49) is critical of the idea that children ages three and four years old should be `practising' writing believing that this early use of pencils and markers `may result in a poor pencil grasp' which may become fixed by repeated usage. She believes that children should be developing their hand skills in a variety of ways before they begin to write and reports (p 56) that she and her occupational therapist colleagues' clinical experience (working with children with mild to moderate special needs) is that some children who have an immature or incorrect pencil grasp may have used pencils or crayons at a age when they were unready for the activity. Tuckett (2006) added to this concern suggesting that society is `inadvertently pre-disposing children to develop lateral tripod and quadrupod grips by introducing writing tools before the child is developmentally ready' (p 33).

Schneck added a further factor to the concept of writing readiness (1991, pp 702-3) considering that less mature pencil grip patterns may become fixed if children's preferred hand is not sufficiently developed before they begin writing. Although mixed handedness is common amongst younger children, Annett considered that `the hand preferred for writing is usually fixed by the early school years' (1998, p 72). However, Schneck's 1991 research demonstrated that six year-olds with poor writing were statistically more likely to have mixed hand preference than those with good writing and that for such children the intervention should be concentrated on the development of a preferred hand rather than on remediation of their grip (pp 704-5).

The effect of mixed handedness was observed in the demographic study. The mother with an unusual right-handed grip explained that she had been forced to write with her right hand when at school but that she was naturally left-handed, as were her son and a grandson (see pp 75 and 89 above). Thus her unusual lateral tripod grip seemed to have been a result of being forced to use her right-hand. This compulsory change of writing hand often occurred in previous generations and this example indicates how writing with the less preferred hand may be linked to the formation of an unusual grip. One pupil observed in the study who used an idiosyncratic quadrupod grip, demonstrated mixed handedness. He was right handed, suggesting that he had made this choice because of copying his parents who both are right handed, demonstrating his ability to still write with his left hand. He used a dynamic tripod grip when writing with his left hand, which seems to indicate both that he could easily have been left-handed and that if he had made this choice he would almost certainly used a tripod grip.

The pattern of those using an unusual grip reporting having been able to write before they began school was frequently observed in this study, for example, three out of the five pupils using an interdigital grip with middle finger control compared with none of their controls; three of the eight pupils using a tripod or quadrupod grip without web space compared with only one control pupil; both the pupils using the quadrupod grip with middle finger dominance compared with only one of the controls and four of the thirteen using the thumb clasped variant of a lateral quadrupod grip compared with only one from the control group. These early memories should not be wholly relied on as memories cannot be relied on and is a danger of retrospective studies (Cohen et al 2007, pp 214-5). However, they do offer some suggestive evidence that children who were very early writers are more likely to use a less orthodox grip. Caution must be maintained, however, as these pupils' memories are at least ten years old and just because a child does not recall having been able to write before they went to school do not mean that they were not able to do so.

The developmental stages and the progression of grips employed by a child are essential to consider when reflecting on why it is some children use unconventional grips. Ziviani (1987, p 37) considered that it is the lack of fine finger movements that influence children into adopting a more fisted grip with the writing implement being held closer to the palm and movements created at the wrist and knuckle joints. The majority of the atypical grips observed both in this study and others such as the quadrapod, lateral tripod and lateral quadrapod use less intrinsic hand movements during writing (Dennis and Swinth 2001, p 181) although the classification of fine motor skills remains contentious (Pont, Wallen and Bundy 2009, p 14). Comparing the anecdotal evidence from the interviews the pupils' parents were sometimes forced not only to change their grip but even sometimes even their writing hand. The pupils themselves reported that even if their abnormal gip was detected efforts to effect a change were usually futile. Eleven pupils reported that at least one teacher, sometimes over a prolonged period, had tried to make them alter their grip without success. A few pupils did report a change in grip, for example, Pupil 143 who reported that she had used an interdigital grip but that her reception teacher noticed that she was holding the pen incorrectly and used a tripod grip by Year 1. Once again we are depending on a child's memories and changing grip is perhaps not one of the most memorable events of a child's life. However, the interviews were interesting for they reflected the laxity in the ways that children were permitted to write. This attitude is supported by the literature for it was previously believed that children should be allowed to write in a way that they find most efficient (Sassoon 1999, p 159) and that `there is not one correct way of holding a pen' (Bentley 1990, p 4). As a girl with one of the more extreme forms of the lateral quadrupod succinctly said, `as long as I could write they really didn't mind'.

Schneck (1991) considered that if `the optimal grip is not learned correctly, then perfection of this skill becomes more difficult' (p 701) so once a child has a grip that enables them to write they persevere with this grip unless there is an overwhelming impetus for change, and it does not seem for the evidence of the interviews that the displeasure of teachers is often a sufficient impetus. This is different to the situation that exists in other countries such as France where the teaching of handwriting is a major part of the curriculum for five or six years (Thomas 1998, p 44) and there appears to be greater uniformity in what is acceptable. One teacher in a research school explained that when living in France with two left-handed sons, attempts had been made (one successful) to alter their writing hand to the right, apparently on the basis that the world was right-handed.

While there is some, albeit, very limited indication from this research that a grip may be changed, care should be taken that any alteration is an improvement. A Year 3 teacher apparently changed Pupil 28's grip from a dynamic quadrupod grip to the pupil's current lateral version of a tripod grip. Both of these grips have been deemed acceptable by this research and it cannot be determined how often the attempt to move the middle finger results in a dynamic rather than a lateral tripod grip. The writing implement used at the time was not reported but this pupil currently uses a ballpoint. If a ballpoint were being used then, then the change to a lateral rather than a dynamic tripod is not unexpected as the increased elevation achieved by the lateral tripod and quadrupod grips is associated with ballpoint pens flowing more fluently. Teachers often have an aversion to a particular grip on a purely personal, instinctive and intuitive basis not based on statistical evidence. During the demographic study it was suggested to a reception teacher that a four finger grip be altered to quadrupod grip by moving the ring finger's position. However, subsequently empirical evidence in this study suggests that the four finger grip is acceptable. The boy using the four finger grip was four years old and the evidence is that were any alteration to be delayed practice allows grip to become so fixed by that by the age of five that change is impossible (Thomas 1997, p130). Ziviani (1987, pp 37-8) reiterates that that when problems with grip are detected it is important the intervention takes place as soon as possible given the difficulties in altering a grip once it has become established.

Of the 93 pupils using an unusual grip, 27 recalled at least one person commenting on their unusual grip. In addition to the eleven pupils reported that teachers had made efforts to correct their unusual grips, five others reported that it was a family member that tried to remediate it (2 fathers, 1 grandfather and 2 grandmothers). A similar number of pupils had had someone comment on their grip but not try to affect it. Five pupils reported it was one or both of their parents, three their peers and six their teachers. This included the Year 5/6 teacher of one of the pupils with a thumb tucked grip which has been linked to the most problems in this research: she apparently noticed the grip, commenting on it, but accepted it.

Having recognised how difficult it is to amend a grip once it has become established, what if anything can be done to prevent the adoption of undesirable grips? Summers in the conclusion of her 2001 article (p 139) considered that further research was needed to find out whether effective early training can lead to the development of a dynamic tripod grasp. When Yakimishyn and Magill-Evans (2002) assessed the grasp of 51 children aged 23-24 months according to Schneck and Henderson's 1990 developmental definitions of grip posture (p 895) they found that more mature grips were elicited with short crayons and vertical surfaces (p 571). Myers (1992, pp 48-52) suggested a wide range of activities that are appropriate for eliciting a tripod grip in preschool children, again emphasising the importance of vertical surfaces. Her suggestions include wall-mounted felt boards, rotating small balls of playdough between fingertips, tearing newspapers using index fingers and thumbs, stinging beads and other activities with shoe laces and finger puppets (index finger for heads, middle finger and thumb for arms).

The transitional stage of the demographic study to the higher incidence of non-tripod grip would have begun their education between the years 1980 and 1984. Sassoon writing in 1993 considered that the `teaching of handwriting was given a low priority. This action (or inaction) was fuelled by the 60s generation of teachers and theorists who believed such teaching to be repressive. As the years passed the situation was worsened by the retirement of the few stalwarts who resolutely maintained their belief in the teaching of the `three Rs'' (p 17). Research into other aspects of handwriting, have noted differences between children and adults and attributed the differences to the educational ethos in their early education with conformist pre 1960s and liberal 1990s (Thomas 1997, p 131).

In addition to increasingly liberal education policies it seems as if children were being introduced to writing much earlier than previously. This may have been due to increased usage of nursery or other day-care facilities. The increased use of childcare without one to one supervision of early writing experience may allow grip to be fixed by the time the child enters formal schooling. The number of places available for children in nursery and nursery schools has increased since the early 1980s with all three year-olds being now being entitled to 38 hours of care from April 2006 (DCSF 2006) although in 1980-81 there were only sufficient places for 25.8% of all three and four year-olds, which had risen to 28.4% by 1984-5 (Hansard, 1985).

The demographic survey indicated that the number of people using an unusual grip changed very sharply over a five year period. A much more detailed investigation into the pengrips of the adults aged 25 to 29 in 2005 would be needed to investigate exactly how this change was wrought, for although there was strong statistical evidence in support of this change around this time, only one hundred people in this age group were surveyed and only a portion used non-tripod grips. However, although the increase in non-tripod grips is a phenomenon reported throughout, at least the English speaking world and Taiwan (Tseng 1998), the evidence of this research indicates that the change in the area surveyed was abrupt. It was in 1983, exactly at the time that these young people were beginning school, that the 1981 Education Act based on the 1978 Warnock Report (Pumfrey and Reason 1991, p 23) was implemented. This Act introduced the concept of inclusion of children with both physical and learning difficulties in mainstream schooling. Although no definitive causal link can be established, enquiries among (young) infant teachers at that time indicated that they were imbued with a laissez faire attitude to grip reported above by Sassoon (1993, p 17), possibly augmented by having to teach children with learning difficulties, many of whom find writing difficult and use unusual grips, for the first time. This may be an area for future research, together with those described in the next section.

RESEARCH AIMS AND QUESTIONS

This section will examine how far the research aims and questions identified at the outset of the research have been answered.

It was a research aim to investigate the prevalence of unusual grips in both secondary school pupils and in the wider population. The preliminary research question concerning demographic handwriting grips was addressed in Phase One of the research (Chapters 3 and 4).

This demographic survey ascertained the grip pattern both in school children from Reception to Year 13 and was extended to include adults. The degree of reliance that can be placed on the sample was discussed in detail in Chapter 4. The results were more reliable for the school pupils than the adults, as a closed population was surveyed. This research although not entirely original in its intent, did unlike Bergmann's 1990 survey, not include a disproportionate proportion of high achieving students and was stratified for age. Thus despite the unavoidable problems with sampling an adult population a number of conclusions could be drawn from the data collected. Most significantly the older adults (over thirty) were much less likely to be using a non-tripod grip than writers under the age of twenty five.

The literature review identified a range of non-tripod grips already recognised. These were described in Table 1:1. This research described several novel grips: the quadrupod index grip, the quadrupod without index finger opposition, the index finger tucked grip, the thumb tucked grip, the interdigital grip with middle finger control as well as two idiosyncratic mixed feature grips.

The research was able to group varying numbers of writers using each of the previously identified and new grips. It was thus possible, as planned, to consider the way these unorthodox grips affect their users. As intended the research was not prescriptive but proactive and highlighted the problems with these users of non-tripod grips experienced. The results are summarised in Table 7:1 above.

For some grips it was deemed impossible to categorically determine their acceptability or otherwise. This was generally due to the small number of pupils using the grip. This group of grips included the index grip (a single user); the quadrupod grip with middle finger dominance (observed twice); the interdigital grip (a single user) and the interdigital grip with middle finger control (five users). Another grip for which it was impossible to determine acceptability is the lateral quadrupod grip. This grip was observed twenty eight times and unlike the very similar lateral tripod grip was statistically linked to placement in lower ability sets (see pp 158-64 and pp 220-1).

Using the same techniques some grips were determined not to disadvantage their users namely the quadrupod, the lateral tripod, the quadrupod without index figner opposition and the very awkward looking four finger grip in which the index, middle and ring finger oppose the thumb.

Certain grips were recognised as disadvantaging their users for a variety of reasons. These included the quadrupod index grip, the thumb tucked grip, the index tucked grip; the two variants (tripod and quadrupod) of a grip without webspace as well as the two idiosyncratic mixed feature grips which were each only observed once.

As anticipated a substantial proportion of secondary school pupils did not use a tripod grip and this research provides significant insight into the consequences of these choices. It was thus possible to fulfil the purpose of this research and indicate several ways in which these pupil’s experience of writing differs to that of those using the more orthodox tripod and quadrupod grips.

Although grip may be only one reason for poor writing skills, the consequences of unorthodox grips had not previously been established with recent research considering that the effects of pengrip are yet to be resolved (Rosenblum, Goldstand & Parush 2006). This is an important area of research as the effect of grip on handwriting performance is often considered as an afterthought to contemporary research into the factors affecting school performance (O`Mahony, Dempsey & Killeen 2008).

FUTURE RESEARCH

Although substantial numbers of pupils were identified as using some grips, many were observed so infrequently that substantive statistical conclusions could not be drawn from them. There is thus obviously the need to continue research into these and other grips for which only provisional conclusions could be drawn.

Many correlations between the variables studied emerged, although the establishment of a causal relationship is always difficult to ascertain with cross-sectional research (Cohen et al 2007, p 217). One example of these is the pattern of those using an unusual grip reporting having been able to write before they began school. This was often observed in this study and seems to indicate that children who were very early writers are more likely to use a less orthodox grip. The information the pupils are reporting, although significant to them, occurred several years ago, and for this reason must be considered with a degree of scepticism (Cohen et al 2007, pp 214-5). In order to improve the accuracy of these observations, research could involve the children's parents. A parental questionnaire could include questions about the pupils' earliest writing experiences and any steps employed by parents and teachers to remediate unusual grips. Parental inclusion was outside the scope of this research, as well as being impractical, especially in the light of trying to obtain a high level of parental consent to their child's involvement in the study. In addition, great care was taken never to suggest to the participants that their grip was inappropriate since to do so could cause unfounded concerns. The situation would be different with children at the outset of their education as if they were using inappropriate grips they would be able, with parental and teacher support, to alter their grip and thus to raise concerns would not be futile but potentially advantageous. Thus a study of children as their grip develops would avoid reliance on recalled events as well as proving to be more accurate indicator of causality, an acknowledged advantage of longitudinal research (Cohen et al 2007, p 217).

This research has demonstrated that some of the most common non-tripod grips, the quadrupod, and the lateral versions of the tripod and quadrupod raise the angle of elevation of the pen, although only one of these, the lateral quadrupod appears to be educationally disadvantageous. Ballpoint pens work more efficiently at higher angles of elevation (Burton and Dancisak 2000, p 12) with Ziviani (1987, pp 34-5) believing that an inappropriate choice of pen could encourage the use of non-tripod grips. Thus there is a need to investigate the transition from pencil to pen, as in previous generations this transition was made much later, owing, at least in part, to the poorer quality of paper available in schools. Enquiries into the local policies reveal that at least one of the primary schools included in the survey now give children a fountain pen with which to write as early as Year 3, but only after they are able to use cursive writing. Wider enquires suggest that this is not an infrequent policy, although the word used is often `pen' which could include not only fountain pens which require a low angle of elevation to work efficiently but also ballpoint pens.

During the research, staff in the schools visited suggested that the study be enlarged to include the use of knives and forks. One pupil, number 116 who used a quadrupod grip without web space, observed that her mother had told her that she held her knife in an unusual way. Tseng, in her Taiwanese study, observed higher (than US) rates of mature grips suggesting that this may be due to greater the children's use of chopsticks facilitating the acquisition of the mature dynamic tripod grip (1998, p 219). The whole area of the way implements other than pens are held, the declining use of knives and forks in the traditional manner amongst young children (Garner 2005) as well as relating the decline to a corresponding fall in the use of tripod pengrip are possible areas of research.

While it is generally believed that it is maturation that permits the development of an effective mature grip, there are dissenters. Newell and McDonald (1997 p 249) argued that the shift in grip is not an inevitable part of maturation but rather the result of the interaction of the child with its environment in which the scale of the writing implements in relation to the child's hand alters. Children learn to write with adult writing implements although frequently they are provided with very thick wax crayons or oversize pencils with which to begin writing (Carlson and Cunningham 1990, p 280; Tuckett 2006, p 34). The effects on the developing grip appear not to have been thought through for both the diameter and the weight could have an adverse effect on the formation of a tripod grip with a fully involved thumb (Burton and Dancisak 2000, p 16). Braswell, Rosengren and Pierroutsakos concurred with this opinion, suggesting that the greater friction of a large crayon could result in children adopting less mature grip with larger implements (2007, p 223). Research should be conducted into the appropriateness of pencils scaled to the preschool child's hand – such as the narrow diameter pencils found in diary spines.

In this research spelling was analysed on a relatively short writing task with poorer spelling correlated with a slower handwriting speed, poorer legibility and poorer behaviour. It would be interesting to research, not only any shared cause for these patterns of difficulties but expand the study into other aspects that affect could affect pupil performance. These might include the angle of the paper in relation to the writer, the angle of rotation of the wrist as well as tension and flexion of the different digits involved in an individual grip as well as punctuation, sentence and essay length. Such assessments would probably use longer standardised tests of writing speed allowing for comparison with published data. However, they would be difficult to administer individually and a group test would not permit the prolonged observation of the writing task which was one of the advantages of the research protocol adopted in this research. The analysis of style and legibility should continue to be included in any assessment although the scoring method could be improved by asking other teachers independently to score the writing with the mean scores aggregated providing increased reliability.

As demonstrated by the interviews very little time appeared to be devoted to the improvement of handwriting when those interviewed were learning to write. The National Literacy Strategy team produced Developing Early Writing in May 2001 advised that fifteen minutes a day in addition to the National Literacy hour is spend on handwriting (Allcock 2000, pp 42-3). It is to be expected that following the explicit instruction to infant teachers that young children `should be encouraged to hold the pencil between the thumb and forefinger with the pencil resting on the third finger' (DfEE 2001, p 161) fewer children will develop a non-tripod grip. These explicit instructions emphasising the tripod grip now extend into published manuals (Taylor 2001, p 49; Alston and Taylor 2000 p 14). This expectation of a fall in non-tripod grip should be investigated by research within primary schools or by ongoing research into the skills of Year 7 pupils upon entry to the secondary sector.

Certain grips were tentatively associated with either higher (lateral tripod and thumb tucked grips) or lower (lateral quadrupod grip) set placement. Given that a large proportion of the pupils surveyed were in Year 8 and 9 it is important to investigate whether these patterns are maintained into Year 11 and affect the external examinations taken. This is a particularly important aspect of future research, given the finding in the demographic study of different proportions of left-handed and non-tripod grips in students in the different post-16 settings investigated (the school's sixth form and further education college). For girls there appeared to be a higher left-handed rate and lower right-handed unusual grip rate in college than in the school, while no left-handed boys remained in school and very few boys had gone to the local further education college. This raises a number of concerns. Are left-handed 16 year-olds more likely to leave school, either to leave education or pursue it at a further education college instead of remaining in school? If they are more likely to leave school, what is the reason? Could it be poorer GCSE results or an unwillingness to conform to uniform and other discipline issues that are dealt with more flexibly in a college situation? If it is poorer results does the right-handed world make certain subjects of tasks more difficult? The optimum research method would be a longitudinal study of pupils relating their grip to set placements and examination performance continuing the study until the age of 18. Bergmann casually referred to a `hypothesis of a societal trend towards atypical grasps' (1990, p 739) but if a shift is occurring, then the potential consequences for individual children seem to have been poorly thought through.

Finally, although the majority of this research investigated the experience of right-handed pupils using different grips, this decision was taken for purely practical reasons owing to the difficulty in matching left-handed pupils. The demographic study indicated that left-handed pupils were slightly more likely to have an unusual grip and it is important to determine whether these pupils' experience of using mirrors that of their right-handed peers.

SUMMARY AND CONCLUSIONS

This research has established that there is a high frequency of non-tripod grip occurring among children that does not seem to have occurred in previous generations. The consequences for these children as they progress through secondary school were not foreseen when these grips were adopted when they first began to write.

Young children have poorer control over their extremities and in seeking to write before they have full motor control need to increase either tension or surface area in order to maintain a grip. A grip, once adopted, seems to become ingrained and is persisted with, despite injunctions from teachers or parents and unflattering observations from peers. The research amongst secondary school pupils reveals a number of consequences of different grips which can adversely affect performance and attitudes; these include high levels of pain after even very short writing periods, a high number of adjustments needed to maintain writing as well as different writing speeds, some of which appear to fall below generally accepted norms.

These findings have educational significance in a climate where under performance is a central educational concern. Pupil, especially male, underachievement at GCSE levels is currently a major concern. Although underperformance could not be established statistically for any group there is evidence that pupil grip is correlated with a number of aspects of their performance.

It was the intention of this research to obtain information from sufficient individuals using the same grip pattern to allow statistical analysis to be conducted on the data collected. This was achieved, although it was noticeable from the outset of the research that some unusual grips, especially the lateral tripod and lateral quadrupod were so frequently observed that they seemed to be commonplace.

Although there is the capacity for this study to be extended, this investigation did reach some conclusions. The lateral quadrupod grip which appears to be adopted very frequently is a grip which does not appear to correlate with high performance in secondary schools. In this it differs from similar variants, the quadrupod and lateral tripod, although all three are methods by which higher pen elevation is achieved, thereby allowing smoother writing with a ballpoint pen. Although other grips were observed which caused greater problems, the lateral quadrupod grip because it is so common, and possibly, because of its similarities to the other two grips is a grip which has not previously aroused anxiety. It comprised 17.4% of Dennis and Swinth's US sample of atypical grips (2001, p 179) but was not reported in Tuckett's 2006 South Wales study despite incidences of 58% and 12.5% of lateral tripod and quadrupod grips respectively.

The acceptability and concerns relating to other grips have been discussed in detail earlier in this chapter, although one other grip is of great interest. The thumb tucked grip is curious as it is linked to high performance despite it association with slower writing, high levels of pain, the need for frequent adjustment to the pen and more spelling mistakes.

Pupils who use grips linked to pain and slower writing speeds could be identified with a simple test upon their admission to secondary school and their progress monitored. Pupils identified as using grips associated with difficulties could then receive additional support, possibly including extra time in examinations for, if a pupil experiences pain after writing for only six or on some occasions three minutes, it seems unlikely they will demonstrate their full potential in the extended writing required of GCSE written examinations. This research also supports the principle that writing speeds should be included in the routine tests administered to pupils in secondary school, for a substantial number were identified whose writing speeds were slow enough to warrant anxiety yet had not previously identified as needing extra support.

This research also has implications for younger children. Yakimishyn and Magill-Evans (2002) who assessed the grips very young children, suggested that more mature grips were obtained with short crayons and vertical surfaces, indicating that the use of this combination could prevent the development of awkward grip in children (p 571). Other professionals, for example, occupational therapists such as Myers (1992) recommend that three and four year-olds should spend time developing their fine motor skills rather than using writing utensils, suggesting large numbers of activities which can be used to promote a tripod grip (pp 48-51). The informal discussions with infant teachers during the demographic study in this research indicated that many were concerned about the grips used by their pupils but were unclear about the strategies that could be used to alter these grips. Thus, early years teachers should not only be enjoined to promote a tripod grip (DfEE 2001, p 161) but provided with strategies to achieve this aim.

The recent changes to guidelines advising the use of a tripod grip would not have affected the pupils as they learnt to write ten to fifteen years ago. Nevertheless, handwriting remains the primary method by which children are assessed at the end of their education. This is almost an historic anachronism, as in no other field of life is handwriting given such prominence. Most assessment in employment, for example, will be by other methods, and much of subsequent written communication is likely to be word processed. However, this is the assessment process which exists and until assessment procedures alter, young people who are disadvantaged by their grip, should be helped to ameliorate this shortcoming.

BIBLIOGRAPHY

Allcock, P. *Handwriting speed and learning difficulties,* MA, Middlesex University, 2000.

Allcock, P. `The importance of handwriting skills in achievement at KS3 and GCSE examinations of more able pupils', *Educating Able Children* (May 2001a), pp. 23 – 26.

Allcock, P. `Testing handwriting speed', *Patoss Bulletin,* (November 2001b).

Alston, J. `A legibility index: can handwriting be measured`, *Educational Review,* 35, 3, (1983), pp. 237-242.

Alston, J. `The handwriting of seven to nine year olds', *British Journal of Special Education,* 12, 2, (1985), pp. 68-72.

Alston, J. `Writing output and writing speeds', *Dyslexia Review,* 6, 2, (1994), pp. 6-12.

Alston, J. & Taylor, J. *Handwriting: Theory, research and practice,* (London, Croom Helm, 1987).

Alston, J. & Taylor, J. *The Handwriting File,* 2nd ed., (Wisbech, LDA, 1988).

Alston, J. & Taylor, J. *Teaching Handwriting,* (Lichfield, Qed, 2000).

Annett, M. `The stability of handedness`, *The Psychobiology of the Hand*, Ed. K.J. Connolly (London, Mackeith Press, 1998), pp. 63-76.

Amandson, S.J. & Weil, M. `Prewriting and handwriting skills' *Occupational Therapy for Children* 5th ed., Ed. J. Case-Smith (St Louis, Mosby Year Book, 2005), pp. 587-610.

Arsham, H. `Kuiper's P-value as a measuring tool and decision procedure of the goodness-of-fit test', *Journal of Applied Statistics,* 15, 2, (1988), pp. 131-135.

Askov, E., Otto, W. & Askov, W. `A decade of research in handwriting: progress and prospect', *The Journal of Educational Research,* 64, 3, (1970), pp. 100-111.

Barnett, A.L. & Henderson, S.E. `Assessment of handwriting in children with Developmental Coordination Disorder', *Children with Developmental Coordination Disorder,* Eds. D.A. Sugden & M. E. Chambers (London, Whurr, 2005), pp. 168-188.

Benbow, M. `Principles and practices of teaching handwriting', *Hand Function in the Child*, Eds. A. Henderson & C. Pehoski (St Louis, Elsevier, 2006), pp. 321-342.

Bentley, D. *Creating a Handwriting Policy,* (Reading, University of Reading, 1990).

Bergmann, K.P. `Incidence of atypical pencil grasps among nondysfunctional adults', *The American Journal of Occupational Therapy,* 44, 8, (1990), pp. 736-740.

Berninger, V.W., Nielsen, K.H., Abbott, R.D., Carlisle, J., Nagy, W., Wijsman, E. & Raskind, W. `Writing problems in developmental dyslexia: under-recognised and untreated', *Journal of School Psychology,* 46, 1, (2008), pp. 1-21.

Bladon, E. *An investigation into the relationship between unusual penhold and school performance,* MA dissertation, Middlesex University, (2004).

Bowens, A.& Smith, I. *Childhood dyspraxia,* (Leeds, Nuffield Institute, 1999).

Bradley, N. `British survey of left-handedness', *The Graphologist,* 10, 4, Issue 37, (1992), pp. 176-182.

Braswell, G.S., Rosengren, K.S. & Pierroutsakos, S.L. `Task constraints on preschool children's grip configurations during drawing', *Developmental Psychobiology,* 49, (2007), pp. 216-225.

Brown, S. `Ability – a concept concealing disabling environments', *Support for Learning,* 18, 2, (2003), pp. 88-90.

Burton, A.W. & Dancisak, M.J. `Grip form and graphomotor control in preschool children', *The American Journal of Occupational Therapy,* 54, 1, (2000), pp. 9-17.

Butler-Por, N. *Underachievers in Schools: issues and intervention,* (Chichester, John Wiley & Sons, 1987).

Carlson, K. & Cunningham, J.L. `Effect of pencil diameter on graphomotor skill of preschoolers', *Early Childhood Research Quarterly,* 5, (1990), pp. 279-293.

Cohen, L. *Educational Research: Classrooms and Schools,* (London, Harper Row, 1976).

Cohen, L., Manion, L. & Morrison K., *Research methods in education,* 6th ed., (London, Routledge, 2007)

Cole, L. *Handwriting for Left-handed Children,* (Bobbs-Merrill Co., Indianapolis, 1955).

Connolly, V., Dockerell, J & Barnett, J. `The slow handwriting of undergraduate students constraints overall performance in exam essays', *Educational Psychology,* 25, 1, (2005), pp. 99-107.

Connolly, V., Campbell, S., MacLean, M. & Barnes, J. `Contribution of lower order skills to the written composition of college students with and without dyslexia', *Developmental Neuropsychology,* 29, 1, (2006), pp. 175-196.

Coren, S. *The Left-handed Syndrome: the causes and consequences of left-handedness,* (London, Murray, 1992).

Coren, S. & Halpern, D.F. `*Left-handedness- a marker of decreased survival fitness*', Psychological Bulletin, 109, (1991), pp. 90-106.

Cutkosky, M.R. & Howe, R.D. `Human grasp choice and robotic grasp analysis', *Dextrous Robotic Hands,* Eds. S.T. Ventkatarman & T. Iberall (New York, Springer Verlong, 1990), pp. 5-31.

Dennis, J.L. & Swinth,Y. `Pencil grasp and children's handwriting legibility during different-length writing tasks', *American Journal of Occupational Health,* 55, (2001), pp. 175-183.

Deuel, R.K. ` Developmental dysgraphia and motor skills disorders', *Journal of Child Neurology,* 10, (1995), pp. S6-S8.

Dewey, D. `What is developmental dyspraxia?', *Brain and Cognition,* 29, (1995), pp. 254-274.

Dewey, M.E. `Coefficients of agreement', *British Journal of Psychiatry*, 143, (1983), pp. 487-489.

DCSF, http://www.dcsf.gov.uk/everychildmatters/strategy/improvingquality/guidance/nurseryeducation/nurseryeducation.html (2006), (accessed 06 July 2009).

DfE *Code of Practice on Identification and Assessment of Special Educational Needs* (UK, Central Office for Information, 1994).

DfEE *The National Literacy Strategy – Developing Early Writing,* (London, DfEE Publications, 2001).

Dutton, K.P. `Writing under examination conditions: establishing a baseline', *Handwriting Review,* 6, (1992), pp. 80-101.

Education website, http://www.theeducationwebsite.co.uk/index.php?page=schools.html, (accessed 06 November 2007)

Eglinton, E. & Annett, M. `Left-handedness and dyslexia: a meta analysis', *Perceptual and Motor Skills,* 79, (1994), pp. 1611-1116.

Erhardt, R. *Developmental Hand Dysfunction – theory, assessment and treatment* 2nd ed. (Tucson, Therapy Skill Builders, 1994).

Elliot, J.M. & Connolly, K.J. `A classification of manipulative hand movements', *Developmental Medicine and Child Neurology,* 26, (1984), pp. 283-296.

Ellis, P.J., Marshall, E., Windridge, C., Jones, S. & Ellis S.J. `Longitudinal study of left-handedness and mortality', *The Lancet,* 351, (1998), p. 1634.

Enstrom, E.A. `The relative efficiency of the various approaches to writing with the left hand', *The Journal of Educational Research,* 55, (1962), pp. 573-577.

Ferriell, B.R., Fogo, J.L., McDaniell, S.A., Schillig, L.R., Shehorn, A.R., Stringfellow, J.K. & Varney, R.L. `Determining the effectiveness of pencil grips: an electromyographic analysis', *Occupational Therapy in Healthcare,* 12, 1, (1999), pp. 47-62.

Forssberg, H. `Neurophysiology of manual skill development`, *The Psychobiology of the Hand*, Ed. K.J. Connolly (London, Mackeith Press, 1998), pp. 177-98.

Freeman, F.N. *The Teaching of Handwriting* (London, Harap, 1922).

Garner, R. `Many children "do not know how to use a knife and fork" ' *The Independent,* 3 May 2005 http://www.independent.co.uk/news/education/education-news/many-children-do-not-know-how-to-hold-a-knife-and-fork-491498.html, (accessed 06 July 2009).

Geuze, R.H. `Longditudinal and cross-sectional approaches in experimental studies in motor development', *Motor Development in Early and Later Childhood Longitudinal Approaches,* Eds. A.F. Kalvenboer, B Hopkins & R. Geutze (Cambridge, CUP, 1993), pp. 307-316.

Graham, S., Weintraub, N. & Berninger, V. `The Relationship between handwriting style and speed and legibility', *The Journal of Educational Research,* 91, 5, (1998), pp. 290-297.

Gurney, P.W. *Self Esteem in Children with Special Educational Needs,* (London, Routledge, 1988).

Hamstra-Bletz, L. `Dysgraphic Handwriting Compared with Normal Handwriting', *Handwriting Review,* 6, (1994), pp. 121-127.

Hansard, http://www.hansard.millbanksystems.com/written.../dec/.../nursery-places.html, (1985), (accessed 06 July 2009)

Hatcher, J., Snowling, M.J. & Griffith, Y.M., `Cognitive assessment of dyslexic students in higher education', *British Journal of Educational Psychology,* 72, 1, (2002), pp. 119-133.

Henderson, S.E. `Motor development and minor handicap', *Motor Development in Early and Later Childhood Longitudinal Approaches),* Eds. A.F. Kalvenboer, B Hopkins & R. Geutze (Cambridge, CUP, 1993), pp. 286-306.

Henderson, S.E. & Barnett, A.L. `The classification of specific motor coordination disorders in children: some problems to be solved', *Human Movement Science,* 17, (1998), pp. 449-469.

Herrick, V.E. & Otto, W. `Pressure on point and barrel of a writing instrument', *Journal of Experimental Education,* 30, 2, (1961), pp. 215-230.

Hughes, W. & Dawson, R. `Memories of school: adult dyslexics recall their school days', *Support for learning,* 10, 4, (1995), pp. 181-189.

Jacobson, C. & Sperling, B.A. `Classification of the hand-grip', *Journal of Occupational Health,* 18 ,6, (1976), pp. 395-398.

Jarman, C. *The Development of Handwriting Skills,* 2nd ed., (G.B., Blackwell, 1993a)

Jarman, C. *The Parent's Guide to Handwriting, (*Sheffield, The Home School Council, 1993b)

Kirby, A. & Drew, S. *Guide to Dyspraxia and Developmental Coordination Disorders,* (London, Fulton, 2003)

Koziatek, S.M. & Powell, N.J. `Pencil grips, legibility and speed of fourth-grader's writing in cursive', *American Journal of Occupational Therapy,* 57, 3, (2003), pp. 284-8.

Levine, M.D., Brooks, R.& Shonkoff, J.P. *A Pediatric Approach to Learning Disorders,* (New York, John Wiley and Sons, 1980).

Lyth, A. `Handwriting speed: an aid to examination success', *Handwriting Today,* (2004), pp. 30-35.

Manoel, E.J. & Connolly K.J. `The development of manual dexterity in young children', *The Psychobiology of the Hand,* Ed. K.J. Connolly (London, MacKeith Press, 1998), pp. 177-198.

Mason, R. `Handwriting following transfer to secondary school - some interim research notes', *Handwriting Review,* 5 (1991), pp. 43-47.

Mason, R. `Handwriting following transfer to secondary school - further notes', *Handwriting Review,* 6 (1992), pp. 107-110.

Medway, J., Strand, S. and Wray, D. `What should we assess in primary handwriting', *Handwriting Today,* (2008) pp. 23-28.

Mojet, J.W. `Characteristics of the developing handwriting skill in elementary education', *Development of Graphic Skills,* Eds. J.P. Wann, A.M. Wing & N. Sovik (London, Academic Press, 1991), pp. 53-76.

Montgomery, D. *Gifted and talented children with special educational needs,* (London, Fulton, 2003).

Montgomery, D. `Cohort analysis of writing in year 7 following two, four and seven years of the National Literacy Strategy', *Support for Learning,* 23, 1, (2008), pp. 3-11.

Myers, C.A. `Theraputic fine-motor activities for preschoolers', *Development of Hand Skills in Children,* Eds. J. Case-Smith and C. Pehoski (Rockville, The American Occupational Therapy Association, 1992), pp. 47-61.

Napier, J.R. `The prehensile movements of the human hand', *Journal of Bone and Joint Surgery,* 38B, (1956) pp. 902-13.

Neave, H.R. *Elementary Statistics Tables* (London, Routledge, 1981)

Newell, K.M. & Cesari, P. `Bodyscale and the development of hand form and function in prehension`, *The Psychobiology of the Hand,* Ed. K.J. Connolly (London, Mackeith Press, 1998), pp. 162-175.

Newell, K.M. & McDonald, P.V. `The development of grip patterns in infancy' *Neurophysiology and Neuropsychology of Motor Development: Clinics in Developmental Medicine No 143/4 ,* Eds. K.J. Connolly & H. Forssberg (London, Mackeith Press, 1997).

Nicholson, R.I. & Fawcett, A.J. `Comparison of deficit in cognitive and motor skills among children with dyslexia', *Annals of dyslexia,* 44, (1994), pp. 147-164.

Nicholson, R.I., Fawcett, A.J., Berry, E.L. Jenkins, I.H., Dean, P. & Brooks, D.J. `Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults', *The Lancet,* 353, (1999), pp. 1662-1667.

O`Mahony, P., Dempsey, M. and Killeen, H `Handwriting speed: duration of testing period and relation to socio-economic disadvantage and handedness', *Occupational Therapy International*, 15, 3, (2008), pp. 165-177.

O`Regan, M. & Brown J.K. `Neurological disorder and abnormal hand function', *The Psychobiology of the Hand*, Ed. K.J. Connolly (London, MacKeith Press, 1998), pp. 241-262.

Pascoe, J., Gore, S., & McLellan, D.L. `Equipment to assist with pencil grasp', *Handwriting Review* 7 *(*1993) pp. 49-51.

Peters, J.M., Barnett, A.L. & Henderson, S.E. `Clumsiness, dyspraxia and developmental coordination disorder: how do health and educational professionals in the UK define the terms?', *Child: Care, Health and Development,* 27, 5, (2001), pp. 399-412.

Pind, J., Gunnarsdottir, E.K. & Johannesson H.S. `Raven's standard progressive matrices: new school age norms and a study of the test's validity', *Personality and Individual Differences,* 34, 3, (2003), pp. 375-386.

Pont, K., Wallen, M. & Bundy, A. `Conceptualising a modified system for classification of in-hand manipulation', *Australian Occupational Therapy Journal,* 56, (2009), pp. 2-15.

Portwood, M. *Developmental dyspraxia - identification and intervention,* (London, Fulton, 1999).

Poustie, J. et al *Solutions for Specific Learning Difficulties,* (Taunton, Next Generation, 1997).

Pumfrey, P.D. & Reason R. *Specific Learning Difficulties (Dyslexia),* (London, Routledge, 1991).

Raven, J.C. *The Raven's Progressive Matrices,* (London, Lewis, 1956).

Raven, J.C., Raven, J. & Court, J.H. *Raven Manual: Section 1 General Overview,* (Oxford, Oxford Psychologists Press, 1993).

Raven, J.C., Court, J.H. & Raven, J. *Raven Manual:Section 3 Standard Progressive Matrices,* (Oxford, Oxford Psychologists Press, 1996).

Ripley, K., Daines, B. & Barrett, J. *Dyspraxia, a guide for teachers and parents,* (London, Fulton, 1997).

Roaf, C. `Slow hand: a secondary school survey of handwriting speed and legibility', *Support for Learning,* 13, 1, (1998), pp. 39-42.

Rosenbloom, L. & Horton, M.E. `The maturation of fine prehension in young children', *Developmental Medicine and Child Neurology,* 13, (1971), pp. 3-8.

Rosenblum, S. `Characteristics and evaluation of developmental dysgraphia: research contribution to educational and clinical reasoning', *Handwriting Today*, (2008a), pp. 15-22.

Rosenblum, S. `Development, reliability, and validity of the Handwriting Proficiency Screening Questionnaire (HPSQ)', *American Journal of Occupational Therapy,* 62, 3, (2008b), pp. 298-307.

Rosenblum, S., Goldstand, S. & Parush, S. `Relationships among biomechanical ergonomic factors, handwriting product quality, handwriting efficiency and computerized process measures in children with and without handwriting difficulties', *American Journal of Occupational Therapy,* 60, 1, (2006), pp. 28-39.

Sanz, R. `Environmental influences and twice-exceptional students', *Educating Able Children,* 6, 1, (2002), pp. 26-34.

Sanz, R. `Factors influencing gifted students' academic achievement', *Educating Able Children,* 7, 2, (2003), pp. 24-31.

Sassoon, R. *Helping your Handwriting,* (Leeds, Arnold-Wheaton, 1986).

Sassoon, R. *Handwriting – the way to teach it,* (Cheltenham, Stanley Thornes, 1990a).

Sassoon, R. *Handwriting – a new perspective,* (Cheltenham, Stanley Thornes, 1990b).

Sassoon, R. *The Art and Science of Handwriting,* (Oxford, Intellect, 1993).

Sassoon, R. *The Practical Guide to Children's Handwriting,* (London, Hodder & Stoughton, 1995).

Sassoon, R. *Handwriting of the twentieth century,* (London, Routledge, 1999).

Sassoon, R., Nimmo-Smith, I. & Wing, A.M. `An analysis of children's penholds', *Graphonomics: Contemporary Research in Handwriting,* Eds. H.S.R. Kao, G.P. van Galen & R. Hoosain (North-Holland, Elsevier Science Publishers, 1986), pp. 93-106.

Sawyer, C.E. `Handwriting speed and special arrangements in GCSE', *Handwriting Review,* 7, (1993), pp. 7-9.

Sawyer, C.E., Francis, M.E. & Knight, E. `Handwriting speed, special learning difficulties and the GCSE', *Handwriting Review,* 7, (1993), pp. 10-14.

Schneck, C.M. `Comparison of pencil-grip patterns in first graders with good and poor writing skills', *The American Journal of Occupational Therapy,* 45, 8, (1991), pp. 701-706.

Schneck, C.M. & Henderson, A. `Descriptive analysis of the developmental progression of grip position for pencil control in nondysfunctional children', *The American Journal of Occupational Therapy,* 44, 10, (1990), pp. 893-900.

Scotland gov, http://www.scotland.gov.uk/library2/doc06/pppr-00.html, (accessed 06 November 2007).

Soloff, S. `The effect of non-content on the grading of essays', *Graduate Research in Education and Related Disciplines,* 6, (1993), pp. 44-54.

Sovik, N. `Development of children's writing performance: some educational implications', *Motor Development in Early and Later Childhood: Longditudinal Approaches,* Eds. A.F. Kalvenboer, B. Hopkins & R. Geutze (Cambridge, CUP, 1993), pp. 229-246.

Sovik, N., Arntzen, O. & Karlsdottir, R. `Relations between writing speed and some other parameters in handwriting', *Journal of Human Movement Studies,* 25, (1993), pp. 133-150.

Statistical solutions http://www.statisticssolutions.com/methods-chapter/statistical-tests/mann-whitney-u-test (accessed 22 December 2010)

Stott, D.H., Henderson, S.E. & Moyes, F.A. ` Diagnosis and remediation of handwriting problems', *Adapted and Physical Activity Quarterly,* 4, (1987), pp. 137-147.

Summers, J. `Joint laxity in the index finger and thumb and its relationship to pencil grasps used by children', *Australian Occupational Therapy Journal,* 48, (2001), pp. 132-141.

Summers, J. & Catarro, F. `Assessment of handwriting speed and factors influencing written output of university students in examinations', *Australian Occupational Therapy Journal,* 50, (2003), pp. 148-157.

Springer, S.P. & Deutsch G. *Left Brain Right Brain: perspectives from cognitive neuroscience,* 5th ed., (USA, Freeman Worth, 1999).

Taylor, J. *Handwriting, a teachers guide: multisensory approaches to assessing and improving handwriting skills,* (London, David Fulton, 2001).

Thomas, F. `Une question de writing: a comparative study', *Support for Learning,* 13, 1, (1998). pp. 43-5.

Thomas, S. `Near-point gripping in pencil hold as a possible disabling factor in children with SEN', *British Journal of Special Education*, 24, 3, (1997) pp. 129-132.

Thomson, M.E. *Developmental Dyslexia,* 3rd ed., (London, Whurr, 1990).

Tseng, M.H. `Development of pencil grip position in preschool children', *The Occupational Therapy Journal of Research,* 18, 4, (1998), pp. 207-224.

Tuckett, J. `An audit of typical pencil grasp in a nursery/reception class' *Handwriting Today,* (2006), pp. 27-34.

Tucha, L., Tucha, T., Walitza, S., Kaunzinger, I., & Lange, K.W. `Movement execution during Neat Handwriting', *Handwriting Today*, (2007), pp. 44-48.

Van Galen, G.P. `Handwriting a developmental perspective', *Motor Development in Early and Later Childhood: Longitudinal Approaches*, Eds. A.F. Kalvenboer, B. Hopkins & R. Geutze, (Cambridge, CUP, 1993), pp. 217-228.

Wann, J.P, Wing, A.M. & Sovik, N. *Development of Graphic Skills,* (London, Academic Press, 1991).

Yakimishyn, J. E. & Magill-Evans, J. `Comparisons among tools, surface orientation, and pencil grasp for children 23 months of age', *The American Journal of Occupational Health,* 56, (2002), pp. 564-572.

Yeo, D. *Dyslexia, Dyspaxia and Mathematics* (London, Whurr, 2003).

Ziviani, J. `Qualitative changes in the dynamic tripod grip between seven and fourteen years of age', *Developmental Medicine and Child Neurology,* 25, (1983), pp. 778-782.

Ziviani, J. `Pencil grasp and manipulation', *Handwriting: Theory, research and practice,* Eds. J. Alston & J. Taylor, (London, Croom Helm, 1987), pp. 24-39.

Ziviani, J.& Elkins, J. `Effect of pencil grip on handwriting speed and legibility', *Educational Review,* 38, 3, (1986), pp, 247-257.

Ziviani, J. & Wallen, M. `The development of grapho-motor skills', *Hand Function in the Child,* Eds. A. Henderson & C. Pehoski (St Louis, Elsevier, 2006), pp. 217-238.

Ziviani, J.& Watson-Will, A. `Writing speed and legibility of 7-14 year-old school students using modern cursive script', *Australian Occupational Therapy Journal,* 45, (1998), pp. 59-64.

Appendix A

containing

Preliminary information

Permission letter (bilingual)
Raven’s matrices score sheet

Parental permission

Mrs Bladon, a teacher in Aberaeron Comprehensive's Vocational Department is investigating a possible correlation between handwriting and performance.

This research is the final part of a PhD degree in Education with Middlesex University.

Your son/daughter ___________________has been chosen to participate in this research.

This is original research, undertaken with the County and school's approval. All information collected will be kept confidential, with averaged data being included in the final report. No pupil names will be used in this final report.

The investigation of each pupil will take place in school, following the half term holiday. It will take approximately one lesson and an individual appointment will be arranged with each pupil.

The research will include:

an oral test
a short interview about their early schooling, and any current writing problems
a test of handwriting speed
a photograph of the pupil's hands as they write (optional)

…………………………………………………………………………

I give permission/ do not give permission for my child ___________________ to participate in the research.

(signed)

____

Please return this form in the stamped, addressed envelope provided as soon as possible.

Caniatad Rhiant

Bwriedir Mrs Bladon, athrawes yn yr Adran Alwedigaethol Ysgol Gyfun Aberaeron cynnal ymchwil ar y cysylltiad posib rhwng llawysgrifen a phefformiad.

Cynhelir yr ymchwil fel rhen o radd PhD yn addysg gyda Prifysgol Middlesex.

Mae eich mab/merch ___________________wedi ei (d)dewis ar hap i gymryd rhan yn yr ymchwil.

Mae gan yr ymchwiliad yma, caniatad yr ysgol. Bydd yr holl wybodaeth a gasglwyd yn cael ei gadw yn hollol gyfrinachol, gyda data terfynnol yn cael ei gynnwys yn yr adroddiad. Ni fydd enw yr un disgybl yn cael ei defnyddio yn yr adroddiad terfynnol.

Bwriedir cynnal yr ymchwiliad yn yr ysgol ar ôl hanner tymor. Bydd y cyfweliad yn para tuag awr, gyda pob disgybl yn cael ei (g)chyfweld yn unigol.

Cynhwysir y canlynol yr y cyfweliad:

Prawf llafar
Cwestiynnau ynglyn ag addysg cynradd ac unrhyw problemau ysgrifennu presenol
Prawf cyflymder yn ysgrifennu
Llun o ddwylo'r disgyblion tra yn ysgrifennu (opsiynol)

………………………………………………………………………………

Rwyf yn rhoi/ ddim yn rhoi caniatad i'm mhlentyn ___________________ i gymryd rhan yn yr ymchwliad.

(arwyddwyd)

____

Dychwelir y ffurflen hon yn yr amlen priodol i swyddfa'r ysgol, cyn gynted a phosib.

Pupil number________

A	B	C
1 __	1__	1__
2 __	2__	2__
3 __	3__	3__
4 __	4__	4__
5 __	5__	5__
6 __	6__	6__
7 __	7__	7__
8 __	8__	8__
9 __	9__	9__
10 __	10__	10__
11 __	11__	11__
12 __	12__	12__
_____	_____	_____

D	E
1 __	1__
2 __	2__
3 __	3__
4 __	4__
5 __	5__
6 __	6__
7 __	7__
8 __	8__
9 __	9__
10 __	10__
11 __	11__
12 __	12__
_____	_____

Appendix B

containing

Additional information related to the demographic survey

Tables of raw data
Confidence limits
Statistical tests

Year 0	left tripod	left quadrupod	left thumb	left unusual	**Left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	5	2	0	1	**8**	20	14	2	6	**42**	50
female	4	2	0	0	**6**	13	16	5	10	**44**	50
total	**9**	**4**	**0**	**1**	**14**	**33**	**30**	**7**	**16**	**86**	100

Table B:1 Grips observed in pupils in Year 0

Year 1	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1	1	0	5	**7**	21	15	3	4	**43**	50
female	2	2	0	1	**5**	22	7	1	15	**45**	50
total	**3**	**3**	**0**	**6**	**12**	**26**	**22**	**4**	**19**	**88**	100

Table B:2 Grips observed in pupils in Year 1

Year 2	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	2	3	0	0	**5**	22	10	6	7	**45**	50
female	2	0	1	1	**4**	19	13	6	8	**46**	50
total	**4**	**3**	**1**	**1**	**9**	**41**	**23**	**12**	**15**	**91**	100

Table B:3 Grips observed in pupils in Year 2

Year 3	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	0	2	1	**6**	22	9	5	8	**44**	50
female	2	0	1	1	**4**	18	13	4	11	**46**	50
total	**5**	**0**	**3**	**2**	**10**	**40**	**22**	**9**	**19**	**90**	100

Table B:4 Grips observed in pupils in Year 3

Year 4	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	5	1	4	1	**11**	18	9	5	7	**39**	50
female	2	2	0	1	**5**	18	12	4	11	**45**	50
total	**7**	**3**	**4**	**2**	**16**	**36**	**21**	**9**	**18**	**86**	100

Table B:5 Grips observed in pupils in Year 4

Year 5	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	1	0	2	**6**	26	9	4	5	**44**	50
female	2	1	0	3	**6**	25	8	3	8	**44**	50
total	**5**	**2**	**0**	**5**	**12**	**51**	**17**	**7**	**13**	**88**	100

Table B:6 Grips observed in pupils in Year 5

Year 6	left tripod	left quadrupod	left thumb	left unusual	**Left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	6	1	2	2	**11**	20	9	6	4	**39**	50
female	1	1	0	0	**2**	9	14	11	14	**48**	50
total	**7**	**2**	**2**	**2**	**13**	**29**	**23**	**17**	**18**	**87**	100

Table B:7 Grips observed in pupils in Year 6

Year 7	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	2	2	1	1	**6**	24	4	7	9	**44**	50
female	2	1	1	1	**5**	20	8	4	13	**45**	50
total	**4**	**3**	**2**	**2**	**11**	**44**	**12**	**11**	**22**	**89**	100

Table B:8 Grips observed in pupils in Year 7

Year 8	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	5	1	0	1	**7**	16	14	5	8	**43**	50
female	2	0	1	2	**5**	15	17	6	7	**45**	50
total	**7**	**1**	**1**	**3**	**12**	**31**	**31**	**11**	**15**	**88**	100

Table B:9 Grips observed in pupils in Year 8

Year 9	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	2	1	0	3	**6**	26	6	8	4	**44**	50
female	0	1	1	0	**2**	26	6	5	11	**48**	50
total	**2**	**2**	**1**	**3**	**8**	**52**	**12**	**13**	**15**	**92**	100

Table B:10 Grips observed in pupils in Year 9

Year 10	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	4	3	1	0	**8**	24	8	3	7	**42**	50
female	1	1	0	0	**1**	23	16	3	7	**49**	50
total	**5**	**3**	**1**	**0**	**9**	**47**	**24**	**6**	**14**	**91**	100

Table B:11 Grips observed in pupils in Year 10

Year 11	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	1	0	1	**5**	31	2	4	8	**45**	50
female	3	1	0	2	**6**	25	9	2	8	**44**	50
total	**6**	**2**	**0**	**3**	**11**	**56**	**11**	**6**	**16**	**89**	100

Table B:12 Grips observed in pupils in Year 11

Year 12/age 17	left tripod	left quadrupod	left thumb	left unusual	**Left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	2	3	0	1	**6**	20	10	6	8	**44**	50
female	5	0	1	0	**6**	25	7	3	9	**44**	50
total	**7**	**3**	**1**	**1**	**12**	**45**	**17**	**9**	**17**	**88**	100

Table B:13 Grips observed in pupils in Year 12 or aged 17

Year 13/age 18	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1	1	0	1	**3**	25	6	2	2	**35**	38
	(1)	(1)		(1)	**(3)**	(32)	(8)	(3)	(3)	**(46)**	(50)
female	2	0	0	3	**5**	18	13	4	11	**46**	50
total	**3**	**1**	**0**	**4**	**8**	**50**	**21**	**7**	**14**	**92**	100

Table B:14 Grips observed in pupils in Year 13 or aged 18 (including %)

Age 19	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1	0	0	0	**1**	20	5	2	3	**30**	31
	(2)				**(2)**	(32)	(8)	(3)	(5)	**(48)**	(50)
female	3	0	0	0	**3**	20	7	0	11	**38**	41
	(4)				**(4)**	(24)	(9)		(13)	**(46)**	(50)
total	**6**	**0**	**0**	**0**	**6**	**56**	**17**	**3**	**18**	**94**	100

Table B:15 Grips observed in adults age 19 (including %)

Age 20-24	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	1	0	1	**5**	28	7	2	8	**45**	50
female	1	1	1	1	**4**	33	5	2	6	**46**	50
total	**4**	**2**	**1**	**2**	**9**	**61**	**12**	**4**	**14**	**91**	100

Table B:16 Grips observed in adults aged 20-24

Age 25-29	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	0	0	3	**6**	29	9	1	5	**44**	50
female	2	0	0	0	**2**	34	10	1	3	**48**	50
total	**5**	**0**	**0**	**3**	**8**	**63**	**19**	**2**	**8**	**92**	100

Table B:17 Grips observed in adults aged 25-29

Age 30-34	left tripod	left quadrupod	left thumb	left unusual	**Left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	4	1	0	0	**5**	36	7	0	2	**45**	50
female	2	1	0	0	**3**	43	2	2	0	**47**	50
total	**6**	**2**	**0**	**0**	**8**	**79**	**9**	**2**	**2**	**92**	100

Table B:18 Grips observed in adults aged 30-34

Age 35-39	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	6	1	0	1	**8**	33	5	1	3	**42**	50
female	4	0	0	0	**4**	43	3	0	0	**46**	50
total	**10**	**1**	**0**	**1**	**12**	**76**	**8**	**1**	**3**	**88**	100

Table B:19 Grips observed in adults aged 35-39

Age 40-44	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	6	2	0	0	**8**	36	4	1	1	**42**	50
female	2	0	0	0	**2**	42	4	2	0	**48**	50
total	**8**	**2**	**0**	**0**	**10**	**78**	**8**	**3**	**1**	**90**	100

Table B:20 Grips observed in adults aged 40-44

Age 45-49	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	3	0	0	0	**3**	43	1	2	1	**47**	50
female	4	0	0	0	**4**	40	4	1	1	**46**	50
total	**7**	**0**	**0**	**0**	**7**	**83**	**5**	**3**	**2**	**93**	100

Table B:21 Grips observed in adults aged 45-49

Age 50-54	left tripod	left quadrupod	left thumb	left unusual	**Left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1 (1)	0	0	0	**1 (1)**	34 (49)	0	0	0	**34**	35 (50)
female	3 (4)	0	1 (1)	0	**4 (5)**	38 (42)	2 (2)	0	1 (1)	**41 (42)**	45 (50)
total	**5**	**0**	**1**	**0**	**6**	**91**	**2**	**0**	**1**	**94**	100

Table B:22 Grips observed in adults aged 50-54

Age 55-59	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1 (2)	0	0	0	**1 (2)**	27 (43)	3 (5)	0	0	**30 (48)**	31 (50)
female	2 (3)	0	0	0	**2 (3)**	33 (47)	0	0	0	**33 (47)**	35 (50)
total	**5**	**0**	**0**	**0**	**5**	**90**	**5**	**0**	**0**	**95**	100

Table B:23 Grips observed in adults aged 55-59

Age 60-64	left tripod	left quadrupod	left thumb	left unusual	**left total**	right tripod	right quadrupod	right thumb	right unusual	**right total**	total
male	1 (1)	0	0	0	**1 (1)**	40 (49)	0	0	0	**40 (49)**	41 (50)
female	2 (3)	0	0	0	**2 (3)**	40 (46)	1 (1)	0	0	**41 (47)**	43 (50)
total	**4**	**0**	**0**	**0**	**4**	**95**	**1**	**0**	**0**	**0**	100

Table B:24 Grips observed in adults aged 60-64

	No. left-handed /sample size = % *	95% confidence limits to 1dp
Year 0	14/100 = 14%	7.8 – 22.4 %
Year 1	12/100 = 12%	6.3 – 20.1 %
Year 2	9/100 = 9%	4.1 – 16.4 %
Year 3	10/100 = 10%	4.9 – 17.7 %
Year 4	16/100 = 16%	9.4 – 24.7 %
Year 5	12/100 = 12%	6.3 – 20.1 %
Year 6	13/100 = 13%	7.1 – 21.3 %
Year 7	11/100 = 11%	5.6 – 18.9 %
Year 8	12/100 = 12%	6.3 – 20.1 %
Year 9	8/100 = 8%	3.5 – 15.2 %
Year 10	9/100 = 9%	4.1 – 16.4 %
Year 11	11/100 = 11%	5.6 – 18.9 %
Year 12	12/100 = 12%	6.3 – 20.1 %
Year 13	8/88 = 11%	4.0 – 17.2 %
Age 19	4/72 = 5.6%	1.5 – 13.7 %
Age 20-4	9/100 = 9%	4.1 – 16.4 %
Age 25-9	8/100 = 8%	3.5 – 15.2 %
Age 30-4	8/100 = 8%	3.5 – 15.2 %
Age 35-9	12/100 = 12%	6.3 – 20.1 %
Age 40-4	10/100 = 10%	4.9 – 17.7 %
Age 45-9	7/100 = 7%	2.8 –13.9 %
Age 50-4	5/70 = 7.1%	2.3 – 15.9 %
Age 55-9	3/66= 4.5%	0.9 – 12.8 %
Age 60-4	3/84 = 3.6%	0.7 – 10.1 %

Table B:25 Confidence limits for left-handed %, all male and female c.v. mean 10.0%
* The percentages do not match those on tables B 1-24 as this table does not adjust the results to take account of the different numbers men and women in the sample and their different rates of left-handedness

	Male left-handed /sample size = %	Male 95% conf. limits to 1dp	Female left-handed /sample size = %	Female 95% conf limits to 1dp
Year 0	8/50 = 16%	7.1 – 29.2 %	6/50 = 12%	4.5 – 24.3 %
Year 1	7/50 = 14%	5.8 – 26.8 %	5/50 = 10%	3.3 – 21.9 %
Year 2	5/50 = 10%	3.3 – 21.9 %	4/50 = 8%	2.2 – 19.3 %
Year 3	6/50 = 12%	4.5 – 24.3 %	4/50 = 8%	2.2 – 19.3 %
Year 4	11/50 = 22%	11.5 – 36.0 %	5/50 = 10%	3.3 – 21.9 %
Year 5	6/50 = 12%	4.5 – 24.3 %	6/50 = 12%	4.5 – 24.3 %
Year 6	11/50 = 22%	11.5 – 36.0 %	2/50 = 4%	0.5 – 13.8 %
Year 7	6/50 = 12%	4.5 – 24.3 %	5/50 = 10%	3.3 – 21.9 %
Year 8	5/50 = 10%	3.3 – 21.9 %	5/50 = 10%	3.3 – 21.9 %
Year 9	6/50 = 12%	4.5 – 24.3 %	2/50 = 4%	0.5 – 13.8 %
Year10	8/50 = 16%	7.1 – 29.2 %	1/50 = 2%	0.1 – 10.7 %
Year11	5/50 = 10%	3.3 – 21.9 %	6/50 = 12%	4.5 – 24.3 %
Year12	6/50 = 12%	4.5 – 24.3 %	6/50 = 12%	4.5 – 24.3 %
Year13	3/38 = 7.9%	1.6 – 21.4 %	5/50 = 10%	3.3 – 21.9 %
Age 19	1/31 = 3.2%	0.1 – 16.8 %	3/41 = 7.3%	1.5 – 20.0 %
20-4	5/50 = 6.5%	3.3 – 21.9 %	4/50 = 8%	2.2 – 19.3 %
25-9	6/50 = 12%	4.5 – 24.3 %	2/50 = 4%	0.5 – 13.8 %
30-4	5/50 = 10%	3.3 – 21.9 %	3/50 = 6%	1.2 –16.6 %
35-9	8/50 = 16%	7.1 – 29.2 %	4/50 = 8%	2.2 – 19.3 %
40-4	8/50 = 16%	7.1 – 29.2 %	2/50 = 4%	0.5 – 13.8 %
45-9	3/50 = 6%	1.2 –16.6 %	4/50 = 8%	2.2 – 19.3 %
50-4	1/35 = 2.9%	0.1 – 15.0 %	4/45 = 8.9%	2.4 – 21.3 %
55-9	1/31= 3.2%	0.1 – 16.8 %	2/35= 5.7%	7.0 – 19.2 %
60-4	1/41 = 2.4%	0.1 – 12.9 %	2/43 = 4.6%	5.7 – 15.9 %

Table B:26 Confidence limits for male and female left-handed %,
c.v. means of 12.0% (male) and 8.0% (female)

Statistical test 1
Test and Confidence Interval for the Proportions of left-handed males and females in the whole sample

Sample	X	N	Sample p
1	135	1126	0.119893
2	93	1164	0.079897

Estimate for p(1) - p(2): 0.0399965
95% CI for p(1) - p(2): (0.0154486, 0.0645444)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 3.19 P-Value = 0.001

	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11
r. tripod	38.4	48.9	45.1	44.4	42.9	58.0	33.3	49.4	35.2	56.5	51.6	62.9
r. quadrupod	34.9	25.0	25.3	24.4	25.0	19.3	26.4	13.5	35.2	13.0	26.4	12.4
r. thumb	8.1	4.5	13.2	10.0	10.7	8.0	19.5	12.4	12.5	14.1	6.6	6.7
r. unusual	18.6	21.6	16.5	21.1	21.4	14.8	20.7	24.7	17.0	16.3	15.4	18.0
all right grips	86	88	91	90	84	88	87	89	88	92	91	89

	Yr 12	Yr 13	age 19	age 20-4	age 25-9	age 30-4	age 35-9	age 40-4	age 45-9	age 50-5	age 55-9	age 60-4
r. tripod	51.1	54.3	59.6	67.0	68.5	85.9	86.4	86.7	89.2	96.8	94.7	99.0
r. quadrupod	19.3	22.8	18.1	13.2	20.6	9.8	9.1	8.9	5.4	2.1	5.3	1.0
r. thumb	10.2	7.6	3.2	4.4	2.2	2.2	1.1	3.3	3.2	0	0	0
r. unusual	19.3	15.2	19.1	15.4	8.7	2.2	3.4	1.1	2.2	1.1	0	0
all right grips	88	92	94	91	92	92	88	90	93	94	95	96

Table B:27 Percentages of right-handed grips (to one decimal place)

Statistical test 2

Test and Confidence Interval comparing the Proportions of unusual right-handed grips in those under 25 and those 30 and over (using gender adjusted raw data)

Sample	X	N	Sample p
1	263	1428	0.184174
2	9	648	0.013889

Estimate for p(1) - p(2): 0.170285
95% CI for p(1) - p(2): (0.148253, 0.192316)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 15.15 P-Value = 0.000

Statistical test 3

Test and Confidence Interval comparing the Proportions of unusual right-handed grips in 20-4 and those 30-4

Sample	X	N	Sample p
1	14	91	0.153846
2	2	92	0.021739

Estimate for p(1) - p(2): 0.132107
95% CI for p(1) - p(2): (0.0522116, 0.212002)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 3.24 P-Value = 0.001

Statistical test 4
Test and Confidence Interval comparing the Proportions of unusual and thumb right-handed grips in those under 25 and those 30 and over (using gender adjusted raw data)

Sample	X	N	Sample p
1	374	1428	0.261905
2	18	648	0.027778

Estimate for p(1) - p(2): 0.234127
95% CI for p(1) - p(2): (0.208048, 0.260206)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 17.60 P-Value = 0.000

Statistical test 5
Test and Confidence Interval comparing the Proportions of all non-tripod right-handed grips in those under 25 and those 30 and over (using gender adjusted raw data)

Sample	X	N	Sample p
1	989	1428	0.692577
2	56	648	0.086420

Estimate for p(1) - p(2): 0.606157
95% CI for p(1) - p(2): (0.573896, 0.638419)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 36.83 P-Value = 0.000

Statistical test 6
Test and Confidence Interval for Two Proportions comparing right-handed unusual grips in 25-29 and those 30-34 years old

Sample	X	N	Sample p
1	8	92	0.086957
2	2	92	0.021739

Estimate for p(1) - p(2): 0.0652174
95% CI for p(1) - p(2): (0.000385880, 0.130049)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 1.97 P-Value = 0.065

Statistical test 7
Test and Confidence Interval for Two Proportions comparing right-handed unusual grips in 20-24 and 25-29 year olds

Sample	X	N	Sample p
1	14	91	0.153846
2	8	92	0.086957

Estimate for p(1) - p(2): 0.0668896

95% CI for p(1) - p(2): (-0.0269743, 0.160754)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 1.40 P-Value = 0.162

Statistical test 8
Test and Confidence Interval for Two Proportions comparing right-handed unusual and thumb grips in 20-24 and 25-29 year olds

Sample	X	N	Sample p
1	18	91	0.197802
2	10	92	0.108696

Estimate for p(1) - p(2): 0.0891065
95% CI for p(1) - p(2): (-0.0145448, 0.192758)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 1.68 P-Value = 0.09

Statistical test 9
Test and Confidence Interval for Two Proportions comparing right-handed unusual and thumb grips in 25-29 and 30-34 year olds

Sample	X	N	Sample p
1	10	92	0.108696
2	4	92	0.043478

Estimate for p(1) - p(2): 0.0652174
95% CI for p(1) - p(2): (-0.0108205, 0.141255)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 1.68 P-Value = 0.093

Statistical test 10
Test and Confidence Interval for Two Proportions comparing right-handed unusual and thumb grips in 20-24 and 30-34 year olds

Sample	X	N	Sample p
1	18	92	0.195652
2	4	92	0.043478

Estimate for p(1) - p(2): 0.152174
95% CI for p(1) - p(2): (0.0610280, 0.243320)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 3.27 P-Value = 0.001

Statistical test 11
Test and Confidence Interval for Two Proportions comparing all non-tripod grips in 20-24 and 25-29 year olds

Sample	X	N	Sample p
1	30	91	0.329670
2	29	92	0.315217

Estimate for p(1) - p(2): 0.0144529
95% CI for p(1) - p(2): (-0.120979, 0.149885)

Test for p(1) - p(2) = 0 (vs not = 0): Z = 0.21 P-Value = 0.834

Statistical test 12
Test and Confidence Interval for Two Proportions comparing all non-tripod grips in 24-29 and 30-34 year olds

Sample	X	N	Sample p
1	29	92	0.315217
2	13	92	0.141304

Estimate for p(1) - p(2): 0.173913
95% CI for p(1) - p(2): (0.0552561, 0.292570)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 2.87 P-Value = 0.004

Statistical test 13
Test and Confidence Interval for Two Proportions comparing all non-tripod grips in 24-29 and 30-34 year olds

Sample	X	N	Sample p
1	30	91	0.329670
2	13	92	0.141304

Estimate for p(1) - p(2): 0.188366
95% CI for p(1) - p(2): (0.0683860, 0.308346)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 3.08 P-Value = 0.002

Statistical test 14
Test and Confidence Interval for Two Proportions comparing the unusual pengrip rates for right-handed males and females under the age of 25

Sample	X	N	Sample p
1	98	668	0.146707
2	160	723	0.221300

Estimate for p(1) - p(2): -0.0745936
95% CI for p(1) - p(2): (-0.115035, -0.0341522)
Test for p(1) - p(2) = 0 (vs not = 0): Z = -3.62 P-Value = 0.000

Statistical test 15
Test and Confidence Interval for Two Proportions comparing the unusual pengrip rates for right-handed males and females from years 0 to 12 inclusive

Sample	X	N	Sample p
1	85	558	0.152330
2	132	593	0.222597

Estimate for p(1) - p(2): -0.0702672

95% CI for p(1) - p(2): (-0.115100, -0.0254348)
Test for p(1) - p(2) = 0 (vs not = 0): Z = -3.07 P-Value = 0.002

Statistical test 16
Test and Confidence Interval for Two Proportions comparing all non-tripod grips for right-handed males and females under the age of 25

Sample	X	N	Sample p
1	303	668	0.453593
2	394	723	0.544952

Estimate for p(1) - p(2): -0.0913588
95% CI for p(1) - p(2): (-0.143731, -0.0389865)
Test for p(1) - p(2) = 0 (vs not = 0): Z = -3.42 P-Value = 0.001

Statistical test 17
Test and Confidence Interval for Two Proportions comparing all non-tripod grips for right-handed males and females from years 0 to 12 inclusive

Sample	X	N	Sample p
1	278	558	0.498208
2	335	593	0.564924

Estimate for p(1) - p(2): -0.0667162
95% CI for p(1) - p(2): (-0.124277, -0.00915532)
Test for p(1) - p(2) = 0 (vs not = 0): Z = -2.27 P-Value = 0.023

Statistical test 18 Test and Confidence Interval for unusual grips rates in left and right-handed people under the age of 25

Sample	X	N	Sample p
1	37	172	0.215116
2	263	1430	0.183916

Estimate for p(1) - p(2): 0.0312002
95% CI for p(1) - p(2): (-0.0334071, 0.0958075)
Test for p(1) - p(2) = 0 (vs not = 0): Z = 0.95 P-Value = 0.344

Inter-rater reliability tests (Cohen's kappa)

Rater A

	tripod	quadrupod	unusual	total
tripod	52	3	1	56
quadrupod	0	11	0	11
unusual	2	0	31	33
total	54	14	32	100

Po = 0.94
Pe = 0.4234

$\kappa = \frac{Po - Pe}{1 - Pe} = 0.896$

Rater B

	tripod	quadrupod	unusual	total
tripod	52	2	2	56
quadrupod	0	11	0	11
unusual	0	0	33	33
total	52	13	35	100

Po = 0.96
Pe = 0.4210

$\kappa = \frac{Po - Pe}{1 - Pe} = 0.931$

Rater C

	tripod	quadrupod	unusual	total
tripod	47	7	2	56
quadrupod	1	9	1	11
unusual	1	3	29	33
total	49	19	34	100

Po = 0.85
Pe = 0.4075

$\kappa = \frac{Po - Pe}{1 - Pe} = 0.747$

Appendix C

containing

Additional information related to the investigation into the effects of unusual pengrip on secondary school performance

Tables of raw data

Inter-rater reliability calculations

χ^2 statistical tests

Pupil number	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
2	female	11	middle	14.27	29.4	8	biro	.	1	2	u
1	female	11	middle	14.68	37.0	10	biro	.	1	1	q
3	female	9	middle	16.25	28.5	3	fountain	78	2	2	u
4	female	9	middle	7.75	29.7	0	biro	64	1	3	t
5	female	9	low	8.25	24.5	5	gel	71	1	3	u
7	female	9	low	15.17	25.6	2	biro	75	7	3	t
14	male	8	low	7.10	20.1	0	gel	68	1	0	u
6	male	8	low	9.02	18.5	0	biro	.	4	1	q
8	male	8	low	15.42	14.2	8	fountain	61	2	1	u
11	male	8	low	23.35	21.3	1	biro	66	8	2	t
10	male	10	low	10.20	29.2	5	biro	76	5	3	u
9	male	10	low	9.12	25.6	0	biro	84	2	3	t
13	male	10	middle	17.83	24.7	3	biro	88	1	0	u
12	male	10	middle	15.37	21.9	0	biro	76	1	0	t
22	female	8	middle	10.25	26.3	2	gel	72	1	2	u
21	female	8	middle	6.57	27.2	3	biro	74	1	0	t
15	male	8	high	12.12	21.2	0	gel	61	1	1	u
16	male	8	high	9.50	29.6	0	fountain	64	2	0	t
17	male	9	high	14.12	16.3	24	biro	71	1	3	u
18	male	9	high	15.87	13.7	1	biro	69	1	2	q
19	male	9	middle	8.28	23.9	5	biro	62	1	1	u
20	male	9	middle	13.97	28.9	0	biro	65	3	0	t
25	female	9	high	7.02	29.8	3	biro	65	1	1	u
23	female	9	high	10.55	36.3	2	biro	63	1	1	q
26	female	10	high	10.28	20.1	3	biro	70	1	1	u

Table C:1a Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
27	female	10	high	10.40	34.7	1	biro	73	1	3	q
28	female	9	middle	10.98	24.4	6	biro	70	4	3	u
38	female	9	middle	17.98	20.4	3	fountain	58	1	0	t
29	male	8	low	11.90	20.2	6	biro	70	5	3	u
35	male	8	low	9.34	19.8	4	fountain	58	5	0	t
33	female	8	middle	8.53	20.8	0	biro	62	3	0	u
32	female	8	middle	15.87	23.0	8	biro	71	3	0	t
39	male	10	middle	14.03	23.9	10	fountain	72	1	0	u
34	male	10	middle	12.95	23.2	1	biro	77	8	3	t
37	female	8	high	13.55	19.4	2	fountain	64	1	3	u
36	female	8	high	21.08	22.0	0	fountain	73	1	1	t
40	female	8	middle	16.53	19.6	0	gel	66	2	1	u
43	female	8	middle	12.28	24.6	1	fountain	66	2	0	q
42	female	9	high	12.63	28.2	1	biro	61	1	1	u
44	female	9	high	16.12	28.2	4	biro	68	1	0	t
41	male	9	high	11.60	18.2	1	female	67	1	2	u
45	male	9	high	12.27	19.9	1	gel	70	6	2	t
50	female	9	middle	6.73	27.1	4	biro	77	1	1	u
46	female	9	middle	8.32	23.8	5	biro	64	2	3	t
48	male	10	middle	10.25	21.8	10	biro	78	1	0	u
47	male	10	middle	19.75	21.9	8	biro	67	4	3	t
49	male	8	low	19.60	19.8	2	female	58	6	3	u
51	male	8	low	11.80	20.7	1	gel	72	6	3	q
53	female	8	low	7.35	24.3	5	biro	60	1	3	u
58	female	8	low	11.85	22.3	0	biro	64	1	3	q
54	male	9	low	14.82	30.5	1	biro	63	1	3	u

Table C:1b Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
60	male	9	low	20.18	18.5	0	biro	74	1	3	t
55	female	9	low	13.00	23.8	8	biro	67	3	2	u
59	female	9	low	6.10	26.2	0	biro	61	8	3	t
61	male	8	middle	9.88	22.4	23	gel	61	1	3	u
57	male	8	middle	13.68	23.5	1	fountain	56	2	1	t
76	female	10	middle	11.47	30.2	1	biro	75	2	0	u
56	female	10	middle	14.50	20.4	0	biro	62	4	0	q
62	male	8	middle	14.50	29.0	7	biro	70	1	1	u
67	male	8	middle	10.00	21.5	3	biro	59	1	0	t
63	male	9	middle	12.12	19.2	7	biro	74	1	3	u
68	male	9	middle	10.42	25.6	5	gel	67	4	1	t
64	female	9	high	11.07	37.1	5	biro	64	1	1	u
71	female	9	high	7.45	32.2	0	biro	60	1	1	t
66	female	8	high	16.95	29.0	1	biro	74	1	0	u
65	female	8	high	12.05	23.9	0	fountain	71	1	2	t
70	female	10	low	12.62	24.7	2	biro	70	8	2	u
69	female	10	low	5.45	27.1	0	fountain	69	2	0	t
73	female	8	high	7.07	27.2	14	biro	60	1	0	u
78	female	8	high	10.30	26.1	2	fountain	63	1	1	q
75	female	9	high	20.73	24.7	0	fountain	70	2	0	u
77	female	9	high	11.95	26.5	6	biro	55	1	0	q
79	female	9	high	9.13	33.2	5	biro	59	1	2	u
74	female	9	high	11.55	24.4	0	biro	51	1	2	t
80	male	8	middle	7.27	20.3	5	biro	72	2	0	u
91	male	8	middle	7.02	21.6	0	fountain	70	1	0	t
81	male	8	low	12.20	24.9	2	biro	70	1	0	u

Table C:1c Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
90	male	8	low	9.87	18.9	0	biro	60	1	2	t
82	female	8	low	15.73	22.8	6	fountain	60	1	1	u
83	female	8	low	13.45	24.7	1	biro	71	1	3	t
84	female	8	low	13.30	16.0	12	biro	59	1	3	u
85	female	8	low	6.75	18.8	0	fountain	59	1	0	t
86	male	8	middle	13.32	12.5	6	biro	65	1	0	u
89	male	8	middle	7.52	16.9	0	fountain	71	1	0	t
87	female	8	low	10.45	14.4	9	fountain	64	1	3	u
93	female	8	low	18.80	23.2	0	fountain	80	1	1	t
88	female	8	high	8.98	22.8	8	biro	63	1	0	u
93	female	8	high	8.70	27.8	0	biro	74	1	2	t
97	male	10	high	15.52	25.8	3	gel	60	3	2	u
94	male	10	high	9.08	30.8	0	fountain	83	1	0	t
95	male	11	low	11.92	17.6	0	gel	69	4	0	u
96	male	11	low	18.63	18.6	0	biro	84	3	1	t
99	female	11	high	12.53	30.4	1	biro	56	4	2	u
109	female	11	high	15.02	20.2	2	biro	62	1	3	t
100	female	8	low	16.43	10.4	3	biro	71	1	1	u
104	female	8	low	6.42	10.7	1	gel	63	1	0	t
102	female	10	low	11.58	21.4	3	biro	75	1	0	u
123	female	10	low	8.40	15.2	3	biro	77	4	0	q
103	male	11	high	15.88	21.2	6	gel	74	5	3	u
110	male	11	high	10.05	19.3	2	fountain	68	1	0	t
106	female	8	high	15.97	21.7	4	biro	57	1	0	u
105	female	8	high	13.70	17.0	5	biro	58	1	0	t
111	male	9	low	6.42	15.8	2	fountain	60	7	3	u

Table C:1d Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
153	male	9	low	14.90	19.8	1	gel	66	3	2	t
112	female	8	low	38.15	14.1	0	gel	59	2	0	u
114	female	8	low	10.13	26.5	3	biro	64	3	3	q
122	male	9	low	20.65	21.8	1	gel	58	1	3	u
113	male	9	low	9.58	19.9	0	biro	74	2	1	t
116	female	11	high	12.48	27.4	4	fountain	56	1	3	u
115	female	11	high	13.83	27.9	2	gel	70	2	0	t
124	female	9	low	6.57	25.4	4	biro	69	1	1	u
125	female	9	low	9.03	22.3	4	biro	61	2	3	t
126	female	8	middle	14.57	13.0	1	biro	68	1	0	u
152	female	8	middle	7.35	17.5	0	gel	61	2	0	t
117	male	10	high	11.30	19.7	2	biro	63	1	2	u
120	male	10	high	15.52	25.4	0	biro	76	1	0	t
119	male	8	low	19.17	17.0	13	biro	60	1	3	u
118	male	8	low	9.28	21.3	0	fountain	61	1	1	t
121	female	8	middle	12.98	19.0	2	fountain	63	1	0	u
129	female	8	middle	6.20	23.6	2	fountain	58	1	3	t
127	male	8	low	12.33	13.4	8	biro	75	3	2	u
128	male	8	low	17.65	20.2	5	biro	54	1	0	q
130	female	8	high	9.36	28.3	0	biro	77	1	2	u
132	female	8	high	8.60	19.2	6	biro	62	1	0	t
134	female	8	low	10.88	19.0	1	gel	66	1	1	u
131	female	8	low	9.10	16.1	3	biro	61	1	2	t
133	female	8	middle	9.05	25.5	15	biro	61	1	3	u
136	female	8	middle	6.17	30.5	0	fountain	53	1	0	t
135	female	9	high	10.82	26.7	5	biro	54	1	3	u

Table C:1e Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
148	female	9	high	9.85	25.3	1	biro	57	1	2	t
138	male	11	middle	7.70	23.5	4	biro	50	1	3	u
137	male	11	middle	6.05	26.5	0	biro	58	6	0	t
140	female	8	middle	6.97	22.0	6	biro	66	1	3	u
139	female	8	middle	8.08	29.6	0	fountain	52	1	3	t
141	female	9	middle	9.90	27.3	2	biro	58	1	3	u
142	female	9	middle	8.22	18.1	0	fountain	61	1	0	t
145	male	8	low	25.58	15.0	4	biro	62	2	1	u
151	male	8	low	13.30	22.0	0	gel	62	1	2	q
150	male	8	low	6.67	23.5	2	biro	70	7	3	u
144	male	8	low	7.67	23.5	0	gel	71	1	3	t
149	female	9	low	9.55	21.1	0	biro	62	1	3	u
146	female	9	low	8.25	21.0	0	biro	56	2	0	t
147	male	9	middle	16.20	28.4	7	biro	71	2	2	u
154	male	9	middle	8.17	20.1	8	biro	64	1	1	t
162	male	9	low	11.70	20.6	1	biro	78	4	1	u
148	male	9	low	9.73	17.3	0	biro	51	5	2	t
155	female	8	high	11.82	25.6	3	biro	69	2	2	u
171	female	8	high	7.93	26.7	5	biro	60	3	2	t
156	female	9	high	13.17	31.8	13	biro	60	2	1	u
165	female	9	high	8.55	20.3	0	biro	73	1	0	t
163	female	8	high	6.00	21.4	2	biro	66	1	3	u
158	female	8	high	5.17	16.2	0	gel	59	1	3	t
157	male	8	low	11.72	11.6	4	biro	64	3	2	u
164	male	8	low	8.32	17.6	10	gel	57	3	2	t
161	male	9	high	16.27	23.8	4	biro	66	1	3	u

Table C:1f Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
160	male	9	high	13.20	28.5	0	biro	70	1	2	t
167	female	9	middle	8.05	17.7	2	biro	62	2	0	u
166	female	9	middle	4.63	21.2	0	fountain	67	1	2	t
170	female	10	middle	12.28	19.4	1	biro	62	1	1	u
168	female	10	middle	9.88	21.4	0	biro	65	1	2	q
169	male	10	high	9.65	27.3	0	biro	69	1	3	u
173	male	10	high	9.85	26.7	0	fountain	68	1	0	t
175	male	10	middle	12.72	22.6	0	biro	82	1	1	u
172	male	10	middle	15.20	20.1	0	fountain	74	1	0	t
174	female	10	low	6.95	27.9	0	biro	62	5	3	u
176	female	10	low	10.63	24.0	0	biro	70	4	0	t
177	female	10	middle	8.90	27.6	1	gel	64	4	3	u
178	female	10	middle	6.73	18.6	0	biro	72	1	1	t
184	female	9	middle	13.95	24.2	0	biro	71	1	0	u
179	female	9	middle	13.95	27.7	2	biro	58	1	2	t
181	male	9	middle	11.02	23.1	1	biro	77	1	2	u
182	male	9	middle	18.42	26.1	0	fountain	68	5	3	t
183	female	10	high	10.08	24.5	0	fountain	63	1	1	u
180	female	10	high	9.88	22.8	3	biro	64	1	0	t
185	female	10	middle	8.32	26.8	0	biro	75	1	2	u
186	female	10	middle	8.05	25.8	0	gel	66	1	0	t
187	male	8	low	10.97	15.2	2	fountain	60	2	0	u
188	male	8	low	21.27	18.0	0	fountain	75	1	3	t
190	male	8	middle	12.20	21.1	0	biro	71	1	0	u
192	male	8	middle	10.80	15.8	3	biro	78	1	1	q
189	female	8	high	11.92	16.5	4	fountain	51	1	2	u

Table C:1g Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

	Gender	Year Group	Set	Raven's time (min)	Handwriting Speed (word/min)	Adjust	Pen	Thumb length (mm)	Behaviour	Pain	Grip
191	female	8	high	8.13	22.9	0	fountain	61	1	0	t
196	female	10	low	6.75	29.6	0	biro	62	1	3	u
194	female	10	low	6.30	31.2	0	biro	60	1	3	t
193	male	9	middle	11.88	18.2	1	biro	66	1	2	u
195	male	9	middle	10.97	22.3	0	gel	65	1	0	t

Table C:1 h Raw results (birth month and Raven's score omitted) (grip **t** tripod, **q** quadruped, **u** unusual)

Time	Frequency	Cumulative Percent
5	3	1.6
6	8	5.9
7	17	15.1
8	18	24.7
9	16	33.9
10	24	46.2
11	12	52.7
12	23	65.1
13	13	72.0
14	10	77.4
15	11	83.3
16	12	89.8
17	2	90.9
18	4	93.0
19	3	94.6
20	3	96.2
21	4	98.4
23	1	98.9
26	1	99.5
38	1	100.0
Total	186	

Table 6:2 Summary of time for Raven's matrices (to the nearest minute)

Quadrupod pupil number	Angle of elevation (°) researcher	Angle of elevation (°) colleague	Angle of elevation (°) mean	Tripod pupil number	Angle of elevation (°) researcher	Angle of elevation (°) colleague	Angle of elevation (°) mean
1	**80**	**79**	**79.5**	**109**	**70**	**64**	**67**
6	---	---	---	11	---	---	---
18	---	---	---	45 (gel)	74	---	---
23	---	---	---	44	71	---	---
27	---	---	---	180	66	---	---
43 (fountain)	62	---	---	32	---	---	---
51	92	---	---	35 (fountain)	---	---	---
58	---	---	---	93 (fountain)	53	---	---
56	62	---	---	186 (fountain)	---	---	---
78 (fountain)	**77**	**81**	**79**	**65 (fountain)**	**48**	**49**	**48.5**
77	**73**	**74**	**73.5**	**71**	**62**	**73**	**67.5**
123	**90**	**88**	**89**	**176**	**79**	**77**	**78**
114	**97**	**95**	**96**	**83**	**58**	**60**	**59**
128	**76**	**79**	**77.5**	**118 (fountain)**	**58**	**54**	**56**
151 (gel)	**82**	**82**	**82**	**146**	**58**	**80**	**81**
168	**70**	**70**	**70**	**178**	**70**	**75**	**72.5**
192	**76**	**75**	**75.5**	**89 (fountain)**	**65**	**64**	**64.5**

Table C:3 Quadrupod and tripod pairings and angle of pen elevation. Bold indicates pairs used in statistical analysis. Pen ballpoint unless otherwise stated.

Ranks

grip	number	Mean rank	Sum of ranks
angle quadrupod	9	12.75	115.00
angle tripod	9	6.22	56.00
total	18		

Test statistics

	angle
Mann-Whitney U	11.000
WilcoxonW	56.000
Z	-2.606
Exact Significance	0.008

Tables C:4 & 5 Significance of quadrupod tripod pairing angle of pen elevation

	Researcher word count	Colleague word count	Inter-rater reliability (lower/higher)
4 (Welsh)	179	177	0.9888
14	126	129	0.9767
21	172	171	0.9942
26 (Welsh)	122	122	1.0000
38	128	130	0.9846
94 (Welsh)	189	191	0.9895
96 (Welsh)	111	112	0.9911
99	186	186	1.0000
117	129	129	1.0000
130 (Welsh)	174	175	0.9943
131	100	100	1.0000
140 (Welsh)	138	139	0.9928
141	174	174	1.0000
152 (Welsh)	107	107	1.0000
191 (Welsh)	138	140	0.9857
196	182	183	0.9945
Mean			0.993

Table C:6 Comparison of word counts

Pupil number	Words with 1 letter	Words with 2 letters	Words with 3 letters	Words with 4 letters	Words with 5 letters	Words with 6 letters	Words with 7 letters	Words with 8 letters	Words with 9 letters	Words with 10 letters	Words with 11 letters	Words with 12 letters	Uncount-able words	Mean
4	12	15	22	20	15	10	3	1	1	0	0	0	1	3.647
26	8	20	16	23	13	5	6	6	1	1	0	1	0	4.040
94	13	24	9	23	13	7	5	6	1	0	0	0	0	3.790
96	11	15	19	15	8	10	15	5	2	0	0	0	0	4.210
130	13	22	22	13	9	8	4	6	2	1	0	0	0	3.720
140	4	28	19	17	10	6	9	4	2	1	0	0	0	3.940
152	13	19	19	16	6	15	8	2	0	0	1	1	0	4.070
191	13	14	9	26	15	11	5	4	2	0	0	1	0	4.100
14	14	11	22	19	8	6	8	3	6	2	0	0	0	4.120
21	3	24	30	11	14	3	6	5	3	1	0	0	0	3.920
38	8	23	14	24	6	14	6	4	1	0	0	0	0	3.950
99	5	24	24	17	12	9	7	2	0	1	0	0	0	3.750
117	6	20	14	17	17	6	6	3	1	2	2	4	2	4.510
131	7	19	19	15	14	8	5	4	1	3	2	0	3	4.206
141	15	21	22	9	15	8	5	0	0	0	0	0	0	3.570
196	13	18	23	14	12	8	4	5	3	0	0	0	2	3.847

Table C:7 Detail of word letter counts

Pupil number	Language	Mean letters/word	Hand-writing Speed (w/min)	Letters /min (mean letters x speed	Gender	Year group	Set	Grip
4	Welsh	3.647	29.7	108.4	female	9	mid	tripod
141	English	3.570	27.3	97.5	female	9	mid	unusual
130	Welsh	3.720	28.3	105.3	female	8	high	unusual
99	English	3.750	30.4	114.0	female	11	high	unusual
94	Welsh	3.792	30.8	116.7	male	10	high	tripod
196	English	3.847	29.6	114.0	female	10	low	unusual
21	English	3.920	20.4	80.0	female	8	mid	tripod
140	Welsh	3.940	22.0	86.7	female	8	mid	unusual
38	English	3.950	27.2	107.4	female	9	mid	tripod
26	Welsh	4.040	20.1	81.2	female	10	high	unusual
152	Welsh	4.070	17.5	71.2	female	8	mid	tripod
191	Welsh	4.100	22.9	93.9	female	9	mid	unusual
14	English	4.120	20.1	82.8	male	8	low	unusual
131	English	4.206	16.1	67.7	female	8	low	tripod
96	Welsh	4.210	18.6	78.3	male	11	low	tripod
117	English	4.510	19.7	88.9	male	10	high	unusual

Table C:8 Word letter counts in relation to other characteristics

Grip	Mean	N	Std. Deviation
Tripod	1.41	76	2.316
Quadrupod	2.24	17	2.682
All control	1.56	93	2.393
All unusual	4.18	93	4.618
Total	2.87	186	3.897

Table C:9 Mean and standard deviation for the number of adjustments observed during writing

Pupil number	Researcher style	Colleague style	Researcher legibility	Colleague legibility	Spelling errors/100 words
2	1	1	1	1	.54
1	4	-	2	-	.00
3	4	-	3	-	1.72
4	4	-	3	-	2.23
5	3	-	2	-	.00
7	**3**	**4**	3	3	.00
14	2	-	2	-	2.38
6	2	-	3	-	1.71
8	1	-	2	-	9.78
11	1	-	3	-	10.61
10	1	1	2	2	.00
9	1	-	2	-	3.68
13	1	-	1	-	.67
12	4	-	2	-	1.44
22	2	-	1	-	3.14
21	2	-	2	-	2.91
15	4	4	2	2	1.50
16	3	-	3	-	.00
17	1	-	2	-	.71
18	1	-	3	-	3.44
19	4	-	4	-	.00
20	4	-	4	-	.56
25	1	1	1	1	1.06
23	1	-	2	-	.00
26	3	-	1	-	.82
27	2	-	3	-	.94
28	2	-	2	-	.67
38	3	-	1	-	2.34
29	4	4	2	2	2.50
35	4	-	4	-	4.20
33	2	-	1	-	1.40
32	1	-	1	-	2.24
39	2	-	1	-	2.03
34	2	-	4	-	1.37
37	1	1	2	2	2.40
36	4	-	2	-	.00
40	1	-	2	-	4.24
43	2	-	3	-	27.63
42	1	-	2	-	1.75
44	1	-	3	-	.57
41	1	1	3	3	4.24
45	2	-	4	-	1.64

Table C:10a Pupil style, legibility and spelling (disagreements bold)

Pupil number	Researcher style	Colleague style	Researcher legibility	Colleague legibility	Spelling errors/100 words
50	1	-	1	-	1.82
46	1	-	2	-	.00
48	2	-	1	-	4.31
47	1	-	3	-	1.42
49	2	2	**4**	**3**	10.66
51	1	-	3	-	10.45
53	1	-	2	-	1.99
58	1	-	2	-	.00
54	1	-	1	-	.64
60	1	-	4	-	3.39
55	1	1	1	1	1.92
59	1	-	1	-	1.19
61	2	-	3	-	2.76
57	4	-	4	-	1.39
76	2	-	2	-	.00
56	2	-	2	-	.78
62	3	3	**3**	**2**	.00
67	4	-	4	-	.00
63	4	-	4	-	2.60
68	2	-	2	-	1.19
64	3	-	4	-	1.26
71	2	-	2	-	.00
66	1	1	2	2	4.42
65	1	-	3	-	2.63
70	2	-	1	-	.00
69	2	-	3	-	2.23
73	1	-	3	-	1.20
78	3	-	2	-	.61
75	**3**	**4**	1	1	.00
77	2	-	3	-	.60
79	2	-	3	-	.00
74	2	-	2	-	.00
80	4	-	4	-	3.17
91	1	-	2	-	.72
81	4	4	3	3	.00
90	4	-	4	-	9.09
82	4	-	2	-	4.29
83	1	-	2	-	2.60
84	1	-	2	-	2.00
85	4	-	2	-	.81

Table C:10b Pupil style, legibility and spelling (disagreements bold)

Pupil number	Researcher style	Colleague style	Researcher legibility	Colleague legibility	Spelling errors/100 words
86	**3**	**4**	3	3	8.75
89	1	-	1	-	1.10
87	1	-	3	-	7.69
93	1	-	2	-	.00
88	1	-	2	-	.00
93	2	-	2	-	1.15
97	1	1	3	3	2.99
94	4	-	4	-	.00
95	1	-	1	-	6.09
96	1	-	1	-	6.30
99	2	-	1	-	.00
109	2	-	2	-	1.64
100	2	2	**4**	**3**	2.86
104	4	-	3	-	7.69
102	2	-	1	-	.00
123	1	-	2	-	5.38
103	2	-	3	-	.00
110	1	-	2	-	1.60
106	**2**	**1**	2	2	.00
105	1	-	1	-	3.70
111	4	-	3	-	8.42
153	1	-	3	-	6.15
112	3	-	3	-	10.47
114	3	-	2	-	3.75
122	1	1	1	1	.76
113	2	-	3	-	8.87
116	1	-	2	-	5.33
115	1	-	2	-	1.16
124	2	-	1	-	.00
125	3	-	3	-	.00
126	4	4	4	4	8.73
152	3	-	3	-	10.28
117	1	-	3	-	1.55
120	2	-	3	-	.00
119	2	-	2	-	.94
118	3	-	2	-	.76
121	4	4	1	1	.86
129	2	-	1	-	.00
127	2	-	2	-	7.31
128	1	-	2	-	.00

Table C:10c Pupil style, legibility and spelling (disagreements bold)

Pupil number	Researcher style	Colleague style	Researcher legibility	Colleague legibility	Spelling errors/100 words
130	1	-	1	-	.57
132	3	-	3	-	5.73
134	**3**	**4**	1	1	6.09
131	3	-	1	-	2.00
133	1	-	3	-	1.29
136	1	-	1	-	.00
135	2	-	1	-	1.19
148	4	-	2	-	1.27
138	1	1	2	2	2.11
137	2	-	4	-	3.77
140	2	-	3	-	2.17
139	2	-	1	-	1.10
141	1	-	1	-	.57
142	1	-	2	-	4.03
145	4	4	3	3	3.70
151	1	-	4	-	3.01
150	2	-	4	-	2.00
144	2	-	3	-	4.17
149	1	-	1	-	.00
146	1	-	1	-	.77
147	3	3	2	2	.00
154	4	-	4	-	2.42
162	1	-	1	-	.00
148	1	-	2	-	2.86
155	2	-	1	-	.63
171	1	-	3	-	1.85
156	3	3	1	1	.52
165	4	-	1	-	.00
163	1	-	2	-	.77
158	1	-	1	-	.00
157	4	-	2	-	4.23
164	2	-	2	-	1.79
161	4	4	3	3	.69
160	2	-	3	-	.00
167	1	-	1	-	1.83
166	1	-	1	-	.00
170	1	-	1	-	1.68
168	2	-	2	-	2.33
169	3	3	3	3	.00
173	4	-	4	-	.00

Table C:10d Pupil style, legibility and spelling (disagreements bold)

Pupil number	Researcher style	Colleague style	Researcher legibility	Colleague legibility	Spelling errors/100 words
175	4	-	3	-	1.40
172	4	-	3	-	3.23
174	2	-	4	-	1.16
176	1	-	2	-	2.07
177	4	4	2	2	.00
178	1	-	1	-	.68
184	3	-	2	-	2.68
179	2	-	2	-	.00
181	1	-	2	-	.00
182	1	-	3	-	1.23
183	1	1	1	1	.00
180	2	-	1	-	.69
185	2	-	2	-	1.18
186	1	-	2	-	.63
187	4	-	3	-	7.45
188	1	-	3	-	4.39
190	4	4	**3**	**2**	.00
192	1	-	3	-	1.04
189	4	-	1	-	1.96
191	3	-	2	-	2.90
196	2	-	3	-	7.69
194	3	-	3	-	2.65
193	1	1	1	1	.84
195	3	-	2	-	.74

Table C:10e Pupil style, legibility and spelling (disagreements bold)

χ^2 statistical tests comparing set groupings of lateral tripod, lateral quadrupod and other unusual grips (see Table 6:15)

a Other unusual with whole sample

observed	expected	$(o-e)^2/e$	
15	11.74	0.905	
14	13.42	0.025	
10	13.84	1.065	
39	39.01	χ^2=1.995	Ho accepted populations equivalent

b Lateral tripod with whole sample

observed	expected	$(o-e)^2/e$	
10	7.83	0.601	
8	8.95	0.101	
8	9.25	0.164	
26	26.01	χ^2=0.866	Ho accepted populations equivalent

c Lateral quadrupod with whole sample

Observed	expected	$(o-e)^2/e$	
3	8.43	3.498	
10	9.63	0.014	
15	9.94	2.576	
28	28.00	χ^2=6.088	Ho rejected $p< 0.05$

d Lateral quadrupod with lateral tripod

Observed	expected	$(o-e)^2/e$	
3	10.77	5.606	
10	8.62	0.221	
15	8.62	4.722	
28	28.01	χ^2=10.550	Ho rejected $p< 0.01$

χ^2 tables Neave (1981), p 21