Ann-Sofie Selin

Pencil Grip

A Descriptive Model and Four Empirical Studies

Ann-Sofie Selin (formerly Lyytinen-Lund) has a Master's degree (1996) in special education from Åbo Akademi University. She is the special education teacher at Cygnæus School in Åbo, and currently a member of the Board of Directors of the International Reading Association, Newark, DE, USA.

Cover by Tove Ahlbäck (layout) and Axel Lund (artwork)

Åbo Akademi University Press
Tavastgatan 30 C, FIN-20700 Åbo, Finland
Tel. +358-2-215 32 92, fax +358-2-215 44 90
e-mail forlaget@abo.fi; http://www.abo.fi/stiftelsen/forlag

Distribution
Oy Tibo-Trading Ab, Pb 33,
FIN-20601 Pargas, Finland
Tel. +358-2-454 92 00, fax +358-2-454 92 20
e-mail tibo@tibo.net

PENCIL GRIP

Pencil Grip

A Descriptive Model and Four Empirical Studies

Ann-Sofie Selin

ÅBO 2003

ÅBO AKADEMIS FÖRLAG – ÅBO AKADEMI UNIVERSITY PRESS

CIP Cataloguing in Publication

Selin, Ann-Sofie
Pencil grip : a descriptive model and four empirical studies / Ann-Sofie Selin. -
Åbo : Åbo Akademi University Press, 2003.
Diss.: Åbo Akademi University.
ISBN 951-765-130-9

ISBN 951-765-130-9
ISBN 951-765-131-7 (digital)
Painosalama Oy
Åbo 2003

ABSTRACT

Previous studies on pencil grip have typically dealt with the developmental aspects in young children while handwriting research is mainly concerned with speed and legibility. Studies linking these areas are few. Evaluation of the existing pencil grip studies is hampered by methodological inconsistencies. The operational definitions of pencil grip are rational but tend to be oversimplified while detailed descriptors tend to be impractical due to their multiplicity.

The present study introduces a descriptive two-dimensional model for the categorisation of pencil grip suitable for research applications in a classroom setting. The model is used in four empirical studies of children during the first six years of writing instruction. Study 1 describes the pencil grips observed in a large group of pupils in Finland (*n* = 504). The results indicate that in Finland the majority of grips resemble the traditional dynamic tripod grip. Significant gender-related differences in pencil grip were observed. Study 2 is a longitudinal exploration of grip stability *vs.* change (*n* = 117). Both expected and unexpected changes were observed in about 25 per cent of the children's grips over four years. A new finding emerged using the present model for categorisation: whereas pencil grips would change, either in terms of ease of grip manipulation or grip configuration, no instances were found where a grip would have changed concurrently on both dimensions. Study 3 is a cross-cultural comparison of grips observed in Finland and the USA (*n* = 793). The distribution of the pencil grips observed in the American pupils was significantly different from those found in Finland. The cross-cultural disparity is most likely related to the differences in the onset of writing instruction. The differences between the boys' and girls' grips in the American group were non-significant. An implication of Studies 2 and 3 is that the initial pencil grip is of foremost importance since pencil grips are largely stable over time. Study 4 connects the pencil grips to assessment of the mechanics of writing (*n* = 61). It seems that certain previously not recommended pencil grips might nevertheless be included among those accepted since they did not appear to hamper either fluency or legibility.

Key words: pencil grip, categorisation, development, handwriting, mechanics of writing, speed, fluency, legibility.

CONTENTS

ACKNOWLEDGEMENTS

My expressions of appreciation go to my supervisor, Professor of Psychology at Turku University, Dr. Pekka Niemi for believing in a schoolteacher's dream, to the chair of the department, Professor of Psychology at Åbo Akademi University, Dr. Matti Laine for inviting me to be part of Academia and for his brilliance of interpretation, and to Professor Emeritus, Dr. Ralf Lindman for an intensive four-month-working period, without which I would still wish for a star. I would also like to thank the staff members of the Department of Psychology and others within Åbo Akademi University and the Centre for Learning Research at Turku University who have offered their support. My thanks also go to my mentor, Rector Emeritus of Cygnæus School in Åbo, Pehr-Olof Rönnholm for expecting nothing less than professionalism and to my colleagues, staff members, and pupils at Cygnæus. Thank you for all the writing hands.

To my hosts during my six-month stay in the USA and your friends and families I express my gratitude and joy for friendship. Thank you reading specialist Ms. Sharon P. Eshler and staff members at Cold Harbor Elementary School, Richmond, VA, for your sincerity. Thank you Dr. Susan M. Glazer, Director of the Center for Reading and Writing at Rider University, Lawrenceville, NJ, for supervising me and showing me how, and Phyllis Fantauzzo and Gail Turner at Rider for your unconditional support. Thank you Dr. Linda B. Gambrell, formerly Assistant Dean of the University of Maryland, Faculty of Education, MD, for introducing me to the research and the library of College Park. Thank you to my colleagues within the International Reading Association worldwide for your mental and concrete support. For professional guidance and friendship, I am humbly grateful.

Thank you Dr. Steve Graham, Professor and Distinguished Scholar-Teacher at the University of Maryland, MD, for your research, which opened up the field of handwriting and for the consequent insight that pencil grips may play a part, and Dr. Greg Brooks, Professorial Research Fellow at the University of Sheffield, UK, for showing what it means to be literate. I could not have wished for more knowledgeable expert readers. I am also honoured that Dr. Graham has agreed to act as opponent at the public examination.

I am wholeheartedly thankful to my parents, mother, Ebba, and my late father, Olavi Lyytinen, and to my children, Sofia and Axel, for your never-ending love and support. To my old and new dear ones, family and friends, thank you all for standing by me.

This work has been financially supported by the Research Institute of the Åbo Akademi University Foundation, the Rector of Åbo Akademi University, the Ella and Georg Ehrnrooth Foundation, the Foundation for Swedish Culture in Finland and by the City of Turku (Åbo) school administration by granting leave of absence.

INTRODUCTION

It is customary to believe in the existence of a normal or correct pencil grip. We are well aware of the appearance and functions of the hand, and anything that comes across as abnormal is perceived as disturbing. At any moment over the years when I have presented my research question, there are members in the audience who stop writing, or move the note pad to their lap, or make remarks expressing concern that their child's or friend's pencil grip may not be "normal". Professional observations and authentic informal interviews confirm anecdotal beliefs in the correct pencil grip. Teachers asked by the present author to systematically observe their pupils when writing were asked if their awareness of which grips their pupils used in their classes had increased as a result of the task. The teachers confirmed that they were aware of struggling pupils with awkward grips beforehand, but that they had no idea that in their classes there were many well performing pupils with equally odd grips. Teachers are subject to confirmation bias when observing awkward pencil grips in pupils with untidy handwriting, or with problems in writing, with the effect that they observe an unusual grip mostly in pupils encountering learning difficulties in school. In other words, the fact that teachers expect to see awkward grips only in children with untidy handwriting or other writing problems predisposes them not to see awkward grips in children without such problems. This failure to respond to baseline frequency is likely to lead to an illusory correlation between grip and learning difficulties (*cf.* Ziviani 1982, 307). With a background of 15 years as a practising occupational therapist, before entering the teaching profession, I also pictured in my mind, how a normal functional hand would be gripping the pencil. When teaching third grade pupils in my first class, I was confused as I observed pupils representing extremes in academic performance, different gender and social ability, in fact being different in most respects, but still displaying similar, most unusual pencil grips I had ever seen. The question I then posed myself was and still is whether or not the pencil grip matters?

Writing is an issue throughout the school years and further on in life. The mechanics of handwriting have an impact on both the writer and the reader. Writing fluency is most important from the perspective of the writer. How fast can I write down my thoughts? Is the process tedious, do I get tired and perhaps choose not to write, lose interest in the skill? Legibility affects the reader. Is the writing accessible, easy or difficult to decipher? Does it invite one to read or to turn away? What makes forms of handwriting different? The ergonomics, the writing instrument, the skilfulness of the writer and surely the pencil grip have an impact on handwriting, and perhaps motivation and academic achievement also play a role.

Writing hands have been pictured as long as humans have communicated in written signs and symbols. Although showing some variation, the hand holding the writing tool has most often been portrayed holding the shaft in a relaxed, yet precise position (see the drawing by Mercator, 1540 in *e.g.* Jean, 1992, and in Sassoon 1993, and the poem *How to hold a pen* by Bales, 1590 in Jarman 1979). This widely recommended pencil grip, which depicts the writing tool between the thumb and the index finger with the shaft resting on the third finger, was first named the dynamic tripod by Wynn-Parry (1966).

The question is whether teachers should struggle to have their pupils duplicate this traditional grip, or should they accept a degree of freedom for the writer to adopt some other grip?

Research views the writing hand and the pencil grip from different perspectives (Wann, Wing and Søvik, 1991). Pencil grip is depicted in medicine, graphonomics, psychology, occupational therapy, and education. Medicine describes the anatomy and the function of the human hand. Graphonomics analyses the product of the detailed hand movements. Psychology studies the development of the writing hand as part of cognitive processes. Occupational therapists and educators build on this research. The basis for occupational therapy is in medicine and psychology and in the analyses of the functional writing hand. Education takes an interest in the ergonomics of writing, and in the process and the product of writing based on both psychological studies and the art of writing.

In the present study, the aim is to describe the diversity of pencil grips in school age children. The structure of the thesis is as follows: First, earlier research on pencil grips and handwriting relevant for the present studies is reviewed. Second, a new model for categorising pencil grip is put forth. Third, this model is applied in four separate studies, which address the distribution, development and cross-cultural aspects of pencil grip in schoolchildren, as well as its relationships to mechanical writing.

PENCIL GRIP AND HANDWRITING

One particular pencil grip is frequently seen and typically recommended (Figures 1 and 4). It has come to be known as the 'dynamic tripod' (Wynn-Parry, 1966). The term refers to the use of the thumb, index and middle fingers so that they function together and perform well co-ordinated movements (Ziviani, 1983, 778). Rosenbloom and Horton (1971, 3) have described the dynamic tripod as the posture in which shoulder, elbow, and wrist stabilisation allow the interphalangeal joints to perform very fine and intricate movements. Further, the flexed ring and little fingers provide stability by resting on the surface, forming an arch. The tripod opposition of thumb and two fingers is precise and at the distal end of the pencil (Erhardt, 1994, 14). The dynamic tripod grip is considered by many teachers and therapists to be ideal (Benbow, 1997; Bergmann, 1990; Erhardt, 1994; Holle, 1983; Hyldgaard, 1982; Jarman, 1979; Rosenbloom and Horton, 1971; Sassoon, Nimmo-Smith and Wing, 1986; Schneck and Henderson, 1990). However, the basis for recommending the dynamic tripod pencil grip and for excluding other grips is subjective and lacks scientific underpinning. For example, little is known about the possible detrimental effects on writing caused by deviation from this recommended grip.

PENCIL GRIP RESEARCH

The following review deals with the questions of what constitutes a functional grip of the hand, as well as the development of the pencil grip through the life span. For a description and details of the hand, see Figure 1.

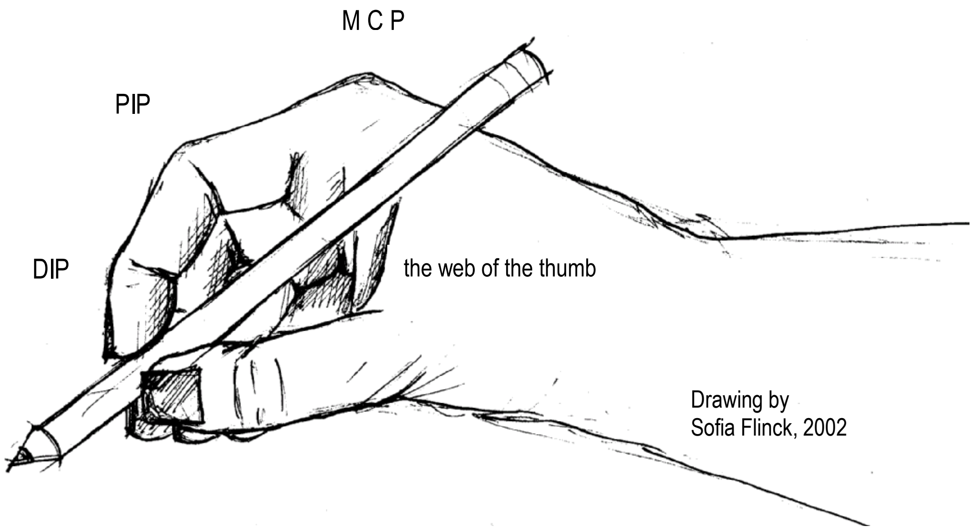
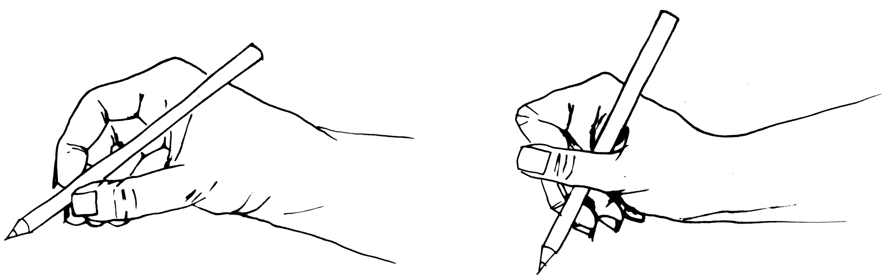


Figure 1. A hand holding a pencil in a dynamic tripod position. Terminology relevant for the present study included: DPI, distal interphalangeal joint; PIP, proximal interphalangeal joint; MCP, metacarpophalangeal joint.

The grips of the hand, their stability and function

Stability, which in the normal hand can be achieved by a precision grip or a power grip, is a pre-requisite for all refinements of hand function (Napier 1956, 902). In the precision grip the object, *e.g.* the pencil, is pinched between the flexor aspects of the finger and the opposition of the thumb (Figure 2). In the power grip the fingers and the palm, and the thumb lying more or less in the plain of the palm, hold the pencil (Figure 2). Napier's method of classifying prehensile movements is based on the anatomical and functional distinction between these two discrete patterns. Landsmeer (1962) added to Napier's classification a distinction between gripping and handling objects. The power grip immobilises the object and thus the verb gripping is accurate. However, Landsmeer considered the term precision handling to be more accurate than Napier's precision grip as the fingers and the opposed thumb hold and handle the object, the pencil.



Drawings by Sofia Flinck, 2002

Figure 2. Examples of a precision grip (to the left) and a power grip (to the right).

Elliott and Connolly (1984, 283) agree with Landsmeer, but argue that there is a strong case for anatomical and functional descriptions to be regarded as separate, so that the functional distinction between digital prehensile patterns and palmar grips is brought forth. They also offer a classification of the patterns of hand movement and object manipulation, suggesting that an object such as the pencil may be held in either a power grip or in a precision grip with equal security. The immobility of the power grip gives fewer degrees of freedom of movement, but adds to stability and power. The facility of movement gained by precision grip, or precision handling, allows for a variety of movement, convenience and economy of action rather than merely precision or delicacy.

Complex hand activity involves stereognostic and tactile feedback, muscle, joint, and visual input, and the co-ordination of some 40 muscles (Hyldgaard, 1982). Motor control of the hand must begin with sensory input and optimal muscle tension (Erhardt, 1994). The movements of the fingers require further refinement and must be differentiated from the movements of the wrist and arm while the body learns to keep still in order to facilitate complex distal movements (de Ajuriaguerra and Auzias, 1980, 68). The role of the thumb in both gripping and in prehensile movements is indisputable (Elliott and Connolly, 1984; Napier, 1956); the thumb provides stability to the grip. The thumb also enhances the utilisation of the tactile cells of the fingertips. Hyldgaard (1982, 31) claims that when the opposition of the thumb against the finger(s) is absent, the hand function is impaired, and thus for example a cross thumb grip (Figure 2 to the right) can reflect tactile impairment of the hand. On the other hand, Hyldgaard (1982, 32) admits that a functional pencil grip does not have to look like the dynamic tripod. It is enough for it not to hinder the fine motor movements of the writing hand. Functional use of the hand is more dependent on joint stability than on joint mobility (Benbow, 1995, 267).

Stability is the prerequisite for prehensile handling of a writing tool. Not even normal sensory acuity can compensate for lack of stability (Napier, 1956).

The development of pencil grip up to seven years of age

Among children who adopt the dynamic tripod grip, a precision grip, this has been found to evolve between four and six years of age (Erhardt, 1994; Rosenbloom and Horton, 1971; Schneck and Henderson, 1990). Rosenbloom and Horton (1971) described the development of the dynamic tripod in 128 children aged from one-and-a-half years up to their seventh year. They found that once the crayon is secured between the thumb and the index, resting on the third digit with the fourth and fifth digit forming a stability-increasing arch, the progression towards refinement takes place. This development from the age of two-and-a-half years gradually unfolds until intrinsic movements within the hand appear between the ages of four and six. The fourth and fifth digit reinforce the middle finger, and thus the tripod, providing sufficient stability for the localised movement consisting of flexion and extension of the interphalangeal joints of the tripod (Rosenbloom and Horton, 1971, 6). The same progression towards grip maturation was seen in Japanese children aged three-and-a-half years (Saida and Miyashita, 1979) and in four-year-old British children (Rosenbloom and Horton, 1971).

Schneck and Henderson (1990) investigated the developmental progression in pencil and crayon grip in 320 non-dysfunctional children aged 3 years to 6 years 11 months. Their cross-sectional study gives a guideline for understanding the normal fine motor development in children. The developmental progression was shown by the increasing percentage of children at each age level using both the dynamic and the lateral tripod grips, which are considered mature grips (Figure 5). The percentages of children using such grips ranged from an initial level of 48 per cent of the youngest three-year-olds to 90 per cent of the oldest children aged seven years. Schneck and Henderson (1990) divided the observed pencil grips into primitive, transitional and mature grips (see Figures 3 to 5). By the age of four-and-a-half years, children can be expected to use transitional or mature grips and children at six-and-a-half years of age and older typically use mature grips, either the lateral tripod or the dynamic tripod grasp. The researchers observed the lateral tripod, defined as a power grip, in approximately one fourth of the children demonstrating mature grips, and they posed the question as to why children use a power grip such as the lateral tripod grasp to perform a precision task (Schneck and Henderson, 1990, 899). This relevant question still remains unanswered.

Rosenbloom and Horton (1971) observed both the hand posture and the movements of 128 children from one-and-a-half to seven years of age while the children were drawing. The study described both the finger postures of the dynamic tripod pencil grip and also the intrinsic movements that make the grip dynamic instead of static. There is a variation in the development of the pencil grip both in the order of appearance of grips and in whether they appear at all (Schneck and Henderson, 1990).

Blöte (1988) studied one- to seven-year-old children's ability to handle pencils. Age-related sequences of four different clusters of behavioural features were identified. The first two clusters included a non-tripod-like grip. A tripod or tripod-like grip was first observed in the third cluster, which also included the features of the arm resting on the surface and an upright body posture. The fourth cluster included a resting arm, a forward leaning body posture, and a tripod grip. In a subsequent study by Blöte and Dijkstra (1989) the task effects of four-year-old children's writing performance was studied. They found a phenomenon of alternating behaviour in the writing development in that children would sometimes return to grip patterns belonging to earlier clusters, and then switch back again (Blöte and Dijkstra, 1989, 517). There appeared to be extended periods of mixed behaviour, which could partly explain why some writers have got stuck with a seemingly primitive pencil grip. The study by Blöte (1988) included a one-year follow-up of 55 children of mean age 6 years 4 months. The design of the study did not allow for interpretation of changes over time but, since writing instruction was initiated during the time-period, the author suggests that this may be a factor of influence (Blöte, 1988).

An example of alternative pencil grips is the *combined pencil grip* named and discussed in Callewaert (1963), and referred to as the *modified grip* in Otto, Rarick, Armstrong and Koepke (1966), and as the *adapted tripod* in Benbow (1997) (see Figure 6). This alternative pencil grip is rarely adopted spontaneously (Sassoon *et al.*, 1986, 103). The grip is, however, a recurrently recommended non-modal grip as it decreases tension without the grip losing stability.

An explanation for the existence of non-normative pencil grips, which differ from the observed developmental patterns, could be that the hand is seeking the stability, which is lacking as a result of premature writing. When the hand is not mature enough to adopt the dynamic tripod grip, it spontaneously deals with the situation by finding other functional grips. As the hand seeks stability, positions like instability in the metacarpophalangeal joint of the thumb and a collapsed web in an immature hand will cause the hand to seek spontaneous adaptations such as a thumb wrap or thumb tuck grip (see Figure 6) (Benbow 1995, 267). Another adaptation described in Benbow (1995) is a narrowed space between the index and the third finger, which also increases the stability of the grip. These interpretations support the conclusions that stability is a prerequisite for the functional pencil grip and that stability can be gained either by positioning the fingers in different pencil grip configurations, or by force.

Operational definitions of pencil grips

Operational definitions of numerous pencil grips have been presented in research reports and handbooks. Schneck and Henderson (1990) offer a developmental scale of pencil and crayon grips on the basis of a literature review and a cross-sectional study of 320 children from three to seven years of age. They divided the ten pencil grips they observed into five primitive, three transitional, and two mature grip postures. Descriptions presented by other researchers collate with those by Schneck and Henderson. Therefore their definition will serve as a base for the present analysis. Drawings of pencil grips [a–j] arranged by the Schneck and Henderson (1990) scale are presented in Figures 3 to 5, and some additional grips in 6 [k–p]. The terminology is derived from original articles.

Primitive grips. The first group of grips in the Schneck and Henderson (1990) scale, the primitive grips, were observed from three years to 5 years 5 months of age. In two of the five grips the pencil is grasped across the palm of the hand. In the first *radial cross palmar grip* (Morrison, 1987), the pencil tip is in the web of the thumb side of the hand. In the second *palmar supinate grasp* (Erhardt, 1994; named *transpalmar* in Benbow, 1997), the pencil tip is by the fifth digit. In the next two primitive grip postures the pencil shaft is placed along or in the palm of the hand and in line with the arm, which takes no support from the table. In the *digital pronate grasp* (Morrison, 1987), the index is extended along the shaft, and in the *brush grasp* (Schneck and Henderson, 1990; named *top tongue grip* in Blöte, 1988), all the fingers are gathered along the shaft with the eraser end against the palm. The fifth primitive grip, the *grasp with extended fingers* (Schneck and Henderson, 1990), is the first tripod-like grip in the Schneck and Henderson scale. However, it is still without the stability and refinement of the mature grip.

The grips did not always appear in chronological order in the age groups. Schneck and Henderson (1990) observed *e.g.* the brush grip in two boys in the age group of three to three-and-a-half years old and in one boy in the group of five to five-and-a-half years old. These observations are similar to those by Blöte and Dijkstra (1989, 519) who found a phenomenon of alternating patterns in children's writing development. Children would part of the time fall into patterns belonging to earlier clusters and then back again.

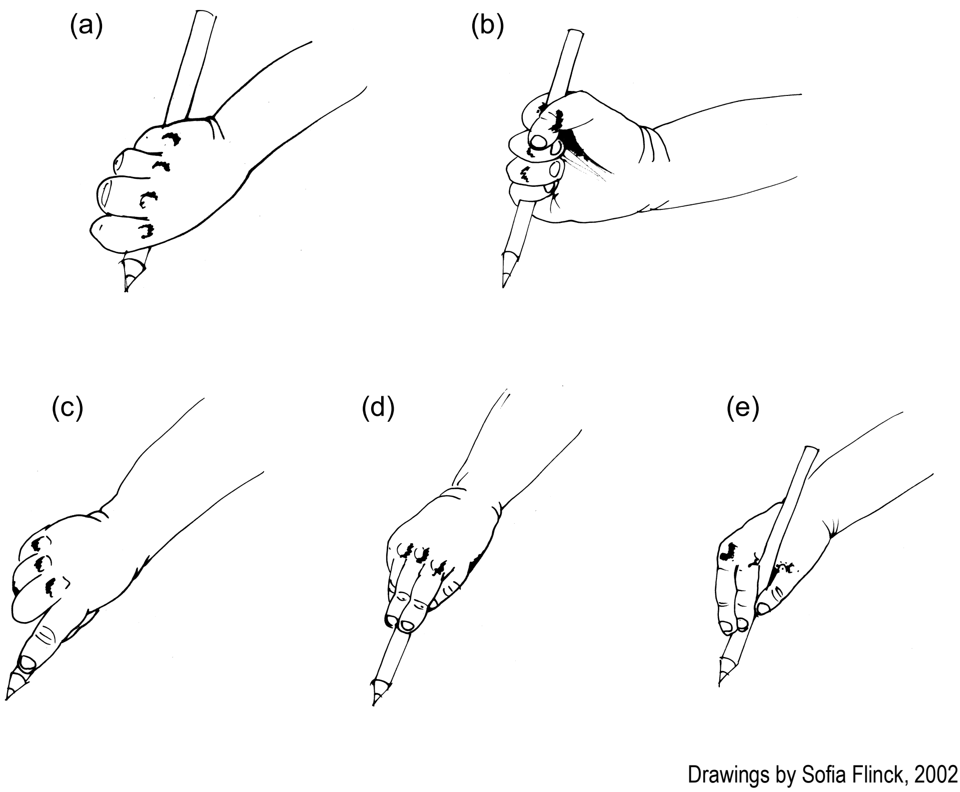


Figure 3. Primitive grips in the Schneck and Henderson (1990) scale: (a) the radial cross palmar grip (Morrison, 1987), (b) the palmar supinate grasp (Erhardt, 1994; named transpalmar by Benbow, 1997), (c) the digital pronate grasp (Morrison, 1987), (d) the brush grasp (Schneck and Henderson, 1990; named top tongue grip by Blöte, 1988), and (e) the grasp with extended fingers (Schneck and Henderson, 1990).

Transitional grips. The second group of grip postures in the Schneck and Henderson developmental scale consists of the transitional grips, including three operational definitions of grip posture. In all of them, the forearm is resting on the table and the pencil is held between the thumb and fingers. In the *cross thumb grasp* (Gesell, 1940, as cited in Schneck and Henderson, 1990; Bergmann, 1990; named *thumb right over* in Sassoon *et al.,* 1986), the fingers are loosely fisted and the thumb crossing over the pencil is held against the side of the index. Levine (1987) associates such a grip with wrist movement and finger agnosia. The second transitional grip, the *static tripod grasp* (Rosenbloom and Horton, 1971), looks bewilderingly similar to the dynamic tripod. The difference lies in the lack of stability in the static tripod, which in the dynamic tripod is offered by fourth and fifth digit, and in the intrinsic movements of the hand. In the third transitional grip, the *four finger grasp* (Schneck and Henderson, 1990; named *quadrupod* in Benbow, 1997), the pencil is held with the thumb in opposition to three fingers.

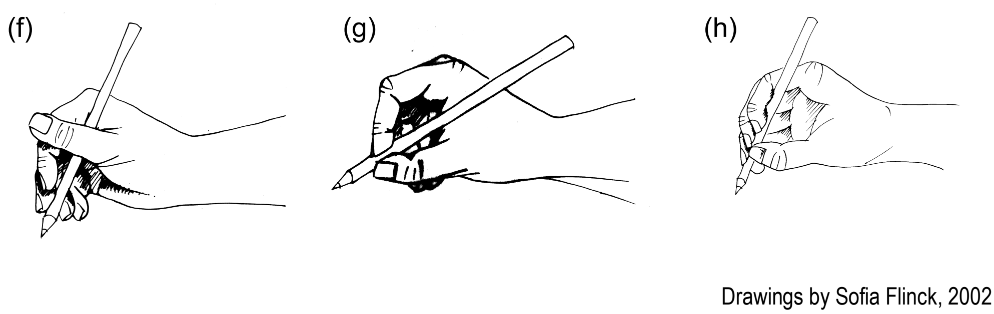


Figure 4. Transitional grips in the Schneck and Henderson (1990) scale: [f] the cross thumb grasp (Gesell, 1940, as cited in Schneck and Henderson, 1990; Bergmann, 1990, named thumb right over in Sassoon *et al.*, 1986), [g] the static tripod grasp (Rosenbloom and Horton, 1971), and [h] the four finger grasp (Schneck and Henderson, 1990; named quodrupod in Benbow, 1997).

Mature grips. The third group in the Schneck and Henderson scale includes two grips classified as mature pencil grips. In the *lateral tripod grasp* (Schneck, 1987, as cited in Schneck and Henderson 1990), the shaft is stabilised along the third digit, steered by the index and held by the thumb crossing half over the pencil. The second mature grip is the *dynamic tripod* (Rosenbloom and Horton, 1971; Wynn-Parry, 1966). Schneck and Henderson (1990) observed both transitional and mature grips in all age groups included in their study.

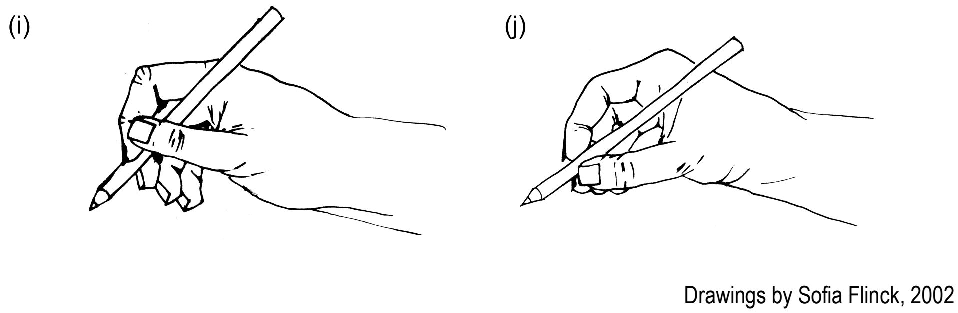
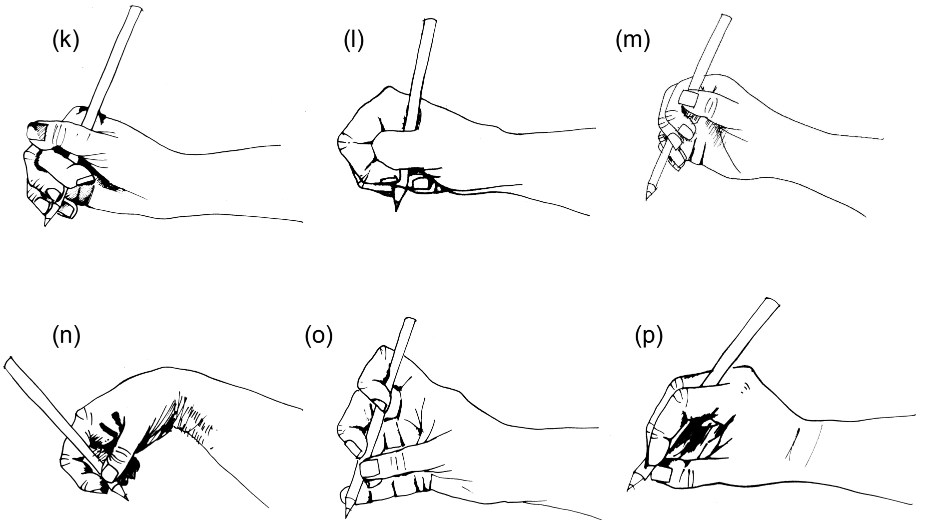


Figure 5. Mature grips in the Schneck and Henderson (1990) scale: [i] the lateral tripod grasp (Schneck, 1987, as cited in Schneck and Henderson, 1990), and [j] the dynamic tripod grip (Rosenbloom and Horton, 1971; Wynn-Parry, 1966).

Additional inefficient and efficient grips. A number of grips observed in schoolchildren and adults are missing in the classification of Schneck and Henderson (1990) although it includes a variety of pencil and crayon grips seen in children up to seven years. Benbow (1997) includes some of the grips in her operational definitions, which comprise six inefficient and three efficient pencil grips. **The inefficient grips.** In the *thumb wrap* the thumb and the index cross over the pencil, and in the *thumb tuck* the thumb is tucked in under the index finger over the shaft (Figure 6). Benbow's *transpalmar* grip is the primitive grip *palmar supinate grasp* (Figure 3, [b]) of the Schneck and Henderson classification. The *transpalmar interdigital brace* (Figure 6, [m]) with the pencil pointing out between the third and the fourth digit observed by Bergmann (1990) in her study of adults was also considered by Schneck and Henderson (1990) but left out as none of the observed 320 children demonstrated the grip. The *supinate grip* (Figure 6, [n]) is in Sassoon *et al.* (1986, 96) presented as an example of a digit position with thumb and index on both sides of shaft. In this grip both the wrist and the fingers are in a hooked position with the pencil lying on the hooked fingertips held in position by the thumb. The sixth inefficient grip described in Benbow is the *index grip* (named *high index grip* in Lyytinen-Lund, 1998; *index finger curled up* in Sassoon *et al.,*1986). In the *index grip* (Figure 6, [o]) the thumb and the third and fourth fingers hold the pencil against the fifth finger while the index finger is hooked high up on the shaft. **The efficient pencil grips.** According to Benbow (1997), these grips include the *tripod grip* (Figure 5, [j]), the *quadrupod* (Figure 4, [h]; named the transitional *four finger grasp* in Schneck and Henderson, 1990), and the *adapted tripod* (Figure 6, [p]), in which the pencil is placed between the index and the third digit. The grip was introduced as the *combined pencil grip* in Callewaert (1963) and referred to as the *modified grip* in Otto *et al.* (1966).



Drawings by Sofia Flinck, 2002

Figure 6. Additional inefficient and efficient grips by Benbow (1997). The inefficient grips are [k] the thumb wrap (Benbow, 1997), [l] the thumb tuck (Benbow, 1997), [m] the transpalmar interdigital brace (Benbow, 1997; Bergmann, 1990), [n] the supinate grip (Benbow, 1997; named thumb and index on both sides of shaft in Sassoon *et al.*, 1986), and [o] the index grip (Benbow, 1997; named high index grip in Lyytinen-Lund, 1998; named index finger curled up in Sassoon *et al.,* 1986). The additional efficient grip is [p] the adapted tripod (Benbow, 1997; introduced as the combined pencil grip in Callewaert, 1963; named the modified grip in Otto *et al.,* 1966).

These operational definitions have been shortened for the purposes of this presentation and the reader is referred to the original articles for more detail. Operational definitions depict the hand holding the pencil, thus assimilating the details or descriptors into the big picture of the operational definition. The grips included in each operational definition often vary in level of detail. If every observed deviation from a model led to the definition of a new grip, the field would be even more confusing than it is now, and the definitions would still not offer a method for categorising any observed pencil grip in an economical way, suitable for research purposes. Efficient standard grips are needed as models for functional pencil grips at different developmental levels. Such grips could, however, not be expected to cover the observed pencil grips. Therefore, standard grips would not suffice for research purposes when the aim is to understand which details in the grip matter and what their possible effects are for the writer and for the handwriting.

Pencil grips as classified by descriptors

Pencil grip can be defined via detailed descriptions of the variables constituting the grip as suggested by Jacobson and Sperling (1976). Their method was intended as an aid to data collection and includes detailed descriptions of individual deviations in handgrips. The method presents a coding system suitable for computerised handling of variables constituting handgrips (Jacobson and Sperling, 1976).

Blöte (1988) included 27 descriptors with two to four categories in each in a study of writing movements and posture of five- to seven-year-olds. Subsequently, Blöte and Dijkstra (1989) included nine descriptors with two categories in each in a study of task effects on four-year-old children's performance in manipulating a pencil.

Callewaert (1963) used detailed descriptions of the index finger to classify grips resulting in skilful or defective handwriting (see Figure 7). The index finger plays a crucial role in skilful writing by being dependent on the coordination and the movements of the hand. The index finger has the same position in both *the usual type* (the dynamic tripod grip) and in *the combined type* (named *adapted grip* in Benbow, 1997; named *combined grip* in Otto *et al.* 1966) in which the pencil is placed between the index and third fingers. Of these two pencil grips Callewaert recommends *the combined type* since the thumb in it is less prone than in *the usual type* to hinder the full movement of the index. Callewaert's second category consists of grips prone to result in defective handwriting. It includes three types of index finger positions: the *solidary (sic), broken* and *fixed types*, all characterised by the functional exclusion of the distal phalanx of the index finger. In the *solidary type* the distal interphalangeal joint of the index finger is straight and placed as a prop against the pencil (named *index finger ext;ext* in Sassoon *et al.*, 1986). In the *broken type* the distal interphalangeal joint is in hyperextension (named *index finger* *hyperext;flex* in Sassoon *et al*., 1986), and in the *fixed type* the distal interphalangeal is fixed straight with the tip of the finger locked against the shaft (named *index finger ext;flex* in Sassoon *et al*., 1986). None of these three index finger positions described in Callewaert allows for movement of the index finger.

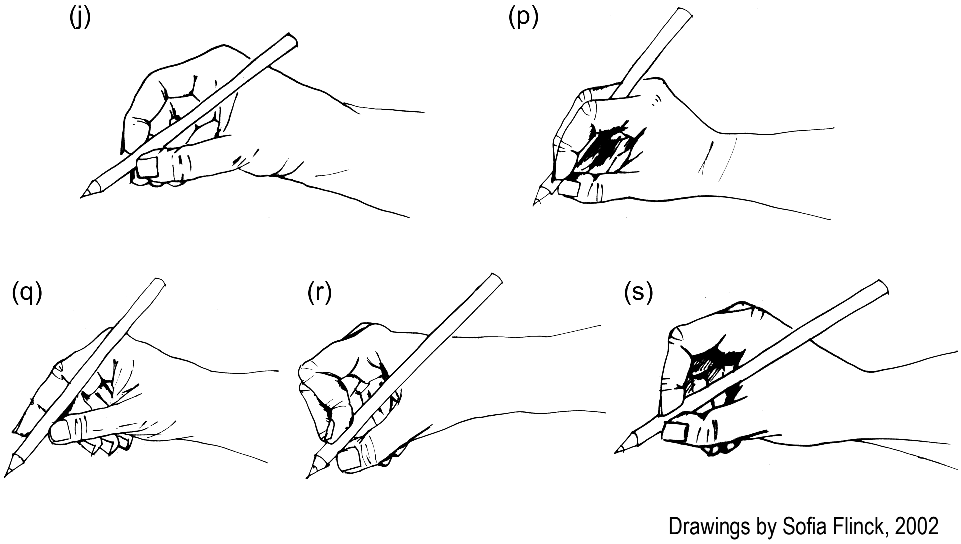


Figure 7. Index finger postures described in Callewaert (1963): [j] the usual type (the dynamic tripod in *e.g.* Rosenbloom and Horton, 1971), [p] the combined type (named adapted grip in Benbow, 1997; named modified grip in Otto *et al.,* 1966) [q] the solidary (*sic)* type (named index finger ext;ext in Sassoon *et al.,* 1986), [r] the broken type (named index finger hyperext;flex in Sassoon *et al.,* 1986), and [s] the fixed type (named index finger ext;flex in Sassoon *et al.,* 1986).

Combinations of operational definitions and detailed descriptions of certain variables have been presented by Ziviani (1982; 1983), Sassoon *et al.,* (1986), and the present author (formerly Lyytinen-Lund, 1998). These studies depict pencil grips actually used by schoolchildren between the ages of seven and sixteen.

Classification by four descriptors. Ziviani has published two studies on pencil grip and its development in pupils (Ziviani, 1982; n = 56, age 7 years 4 months to 13 years 1 month; Ziviani, 1983; n = 287, age 6 years 8 months to 14 years). Four descriptors were used to analyse pencil grips. Each descriptor was given score 1 when the observed descriptor differed from the expected dynamic tripod grip posture, and score 2 for the expected posture. The first descriptor was grip tension, which was scored 1 when the flexion in the proximal interphalangeal joint was >90º with or without hyperextension in the distal interphalangeal joint as a result. A score of 2 was given when the observed index finger flexion was <90º. (See Figure 1 for terminology.) Ziviani's (1982; 1983) second descriptor was the number of fingers on the shaft in a non-dynamic or dynamic tripod finger posture. The third descriptor was fingers either in or not in pad-to-pad opposition. The fourth descriptor was scored 1 when the forearm was in a pronated position, and given score 2 when a supinated pincer grip position over 45º was observed. The writing hands were photographed and analysed. For descriptors [1] and [4] a graphed overlay was used on the photographs to define angles.

Ziviani's descriptors can be used for classification of pencil grips. Such a classification of *e.g.* the dynamic tripod grip would, however, be complex. With Ziviani's four descriptors a dynamic tripod grip would be given a score of 2 on each of the four descriptors, thus describing a relaxed [descriptor 1, score 2], stabile [descriptor 2, score 2], prehensile [descriptor 3, score 2] grip in a functional position [descriptor 4, score 2].

A dynamic tripod grip includes traditionally a description of thumb and index finger opposition (see page 4). However, Ziviani's (1982) conclusion in the first study seems to indicate that opposition is not a prerequisite for a dynamic tripod grip. A dynamic tripod was shown by 91 per cent of the pupils, while only 68 per cent demonstrated a pad-to-pad opposition.

Classification by eight descriptors. Sassoon *et al.* (1986) described pencil grips in even more detail than Ziviani (1982; 1983). They refined Jacobson and Sperling's (1976) approach to classifying handgrips used in holding a variety of objects (Sassoon *et al.,* 1986, 95). The study included 294 pupils who were 7 years 2 months to 16 years 1 month of age. Sassoon *et al.* included eight descriptors with two to six values in each to classify a pencil grip. The descriptors comprised four groups. Group one included four descriptors of digits: [1] contact with pen; [2] position on pen; [3] proximity to pen tip; [4] shape of digit: distal *vs.* proximal. The second group described [5] hand rotation, the third [6] upper body posture, and the fourth [7] paper orientation *vs.* shoulder line, and [8] paper position *vs.* body midline.

The Sassoon *et al.* (1986) system for classification offers the possibility to describe numerous variations in pencil grips. Some of the variations are presented below in more detail. The first descriptor of the fingers (contact with pen) is checked for each of the five digits. Provided that the digit is touching the pen, the following three descriptors are scored. The second descriptor (position on pen) makes a distinction between the extent to which the thumb stabilising the pencil is crossing over the shaft with the thumb half over or thumb right over. The fourth descriptor (shape of digit: distal *vs.* proximal) refers to the angle of the interphalangeal joints. Also, a variety of digit shapes, or joint angles, are described for the thumb and the index finger holding the pencil. The alternatives include flexion, extension, and hyperextension in both thumb and index finger in five different combinations. The sixth digit shape is index finger curled up, similar to Benbow's index grip (1997; see Figures 4 to 6).

Classification by ten descriptors. In an earlier study the present author attempted to develop a comprehensive coding system for pencil grip and associated features in school-age children (Lyytinen-Lund, 1998). The study included 503 pupils who were 7 years 5 months to 12 years 9 months of age. They were observed one to three times each with a minimum of one year between the observations, resulting in a total of 697 pencil grip observations. The checklist of descriptors was developed through an iterative trial and revision process (Appendix A). The reliability of the descriptors in the checklist was tested by determining consistency over time, inter-rater reliability in classroom situations, and inter-rater reliability when scoring was based on photographs (Appendix B). All observations were noted on the checklists. After the initial stage of the research, photographs were taken of 285 pupils' writing hands. Although the coding system worked, it proved overly detailed for classroom use. The process of developing and testing this system for describing pencil grips is documented in Lyytinen-Lund (1998). The method has been further developed for the purpose of the present research (Appendix C and Figure 10).

Comparison of the three earlier studies employing a descriptor coding system. The descriptors used in the above three studies (Lyytinen-Lund, 1998; Sassoon *et al.,* 1986; Ziviani, 1983) are summarised in Table 1. All three studies have considered the descriptors in isolation and also attempted to relate features to operational definitions. For example Sassoon *et al.* (1986) applied Ziviani's (1983) modified tripod. Both studies were utilised in Lyytinen-Lund's checklist for descriptors and in her attempt to offer a variety of operational definitions for pencil grips (Lyytinen-Lund, 1998). In all three studies, pupils' on-task writing performance was observed and photographed. The participating pupils were of roughly the same age range (from 6–7 to 14–16 years of age). The sample sizes were comparable (n = 287 in Ziviani 1983; n = 294 in Sassoon *et al.,* 1986; n = 503 of which 285 were photographed in Lyytinen-Lund, 1998). These methodological similarities allow for some comparison. However, differences in the procedure exist as well. Sassoon *et al.*, and presumably also Ziviani, photographed the hand at an early stage of the writing assignment while Lyytinen-Lund took the

Table 1. *Descriptors used for classification of pencil grip and posture in school-age pupils by Ziviani (1982, 1983), Sassoon, Nimmo-Smith and Wing (1986), and Selin, formerly Lyytinen-Lund (1998).*

handwriting grip (Ziviani); **penhold** (Sassoon *et al* .); **pencil grip** (Lyytinen-Lund)	# of categories per descriptor	Ziviani	Sassoon *et al.*	Lyytinen-Lund
proximity to pen tip	4		X	
finger closest to pen tip (+ any combination of fingers)	4+			X
functional distance from pen tip	3			X
degree of index finger flexion	2	X		
shape of digit [index and thumb joints]	5		X	
angle of distal joint of index	3			X
angle of distal joint of thumb	3			X
fingers used	2	X		
number of digits touching the barrel	2		X	[X]
[number of fingers on shaft; omitted during revision, included in operational definitions]				
opposition of thumb and index	2	X		
position [of thumb and index] on pen [included in operational definitions of 7 pencil grips]	4		X	[X]
operational definitions (+ group of miscellaneous)	7+			X
sum of pencil grip descriptors		3	4	5
pencil grip posture (Ziviani); **postural descriptions** (Sassoon *et al.*); **the student's working posture and movements** (Lyytinen-Lund)	# of categories per descriptor	Ziviani	Sassoon *et al* .	Lyytinen-Lund
upper body posture	6		X	
writing posture	4			X
non-writing hand	4			X
paper position	3		X	
paper orientation	3		X	
[writing] arm on the table	2			X
writing movements	3			X
forearm supination	2	X		
wrist angle, rotation	2		X	
wrist angle	2			X
sum of posture descriptors		1	4	5

photo after 10 minutes of copying, thus allowing for the hand to take the posture normally assumed. Sassoon herself performed the classification on the basis of the photos. Ziviani used two raters and Lyytinen-Lund mixed both methods in addition to filling out the checklists during the pupils' writing. Sassoon and Ziviani worked with pupils individually, and Lyytinen-Lund observed groups of pupils. Although all three studies were thorough, they fail in describing pencil grips in an economical way, which would make data collection and analysis easier.

The pencil grip during the school years and beyond

There is ample research on pencil grip development up to seven years. However, much less research has been conducted on what happens to the pencil grip once the child becomes a writer. A basis for such research can be found in the cross-sectional studies by Ziviani (1983) and Sassoon *et al.* (1986), describing pencil grips in seven to 15-year-olds. Bergmann (1990) depicts some variation in adult pencil grips, and Otto *et al.* (1966) present an experimental approach by introducing an alternative pencil grip to a group of non-dysfunctional adult writers.

In Australia, two studies were conducted to identify components of handwriting grip and its development (Ziviani, 1982), and to investigate eventual changes in the selected four descriptors in non-dysfunctional children of different ages (Ziviani, 1983). The first pilot study included 56 pupils aged of 7 years 4 months to 13 years 1 month. The second study included 287 boys and girls in two age groups, 6 years 8 months to 9 years 9 months and 10 years to 14 years, respectively. The four descriptors examined were [1] degree of flexion of the index finger, [2] fingers used, [3] opposition, and [4] degree of forearm supination/pronation (Table 1). Significant variation over age was observed in two of these descriptors, *i.e.* [1] and [4].

The results suggest an age-related decrease in the occurrence of hyperextension in the index finger joints over age with the older girls demonstrating significantly less hyperextension of the distal interphalangeal joint of the index finger than both the younger girls and all boys. The results suggest a refinement of the dynamic tripod grip with age. However, this research was conducted cross-sectionally, thus making it inconclusive concerning individual development in these children. Ziviani (1982) also analysed the index finger posture and defined the angle of the proximal interphalangeal joint, PIP, as the prime point of interest, whereas the angle of the distal interphalangeal joint, DIP, was of secondary interest (see Figure 1 for terminology). One can argue, however, that the hyperextension of the DIP causes the PIP to flex over 90° and thus the angle of the DIP joint should be the prime interest instead of the PIP joint. In the second study by Ziviani (1983), the hyperextension of the distal interphalangeal joint, DIP, was targeted and its relationship to handwriting studied. The results suggested that the observed hyperextension of the DIP is related to pressure as manifested by uninterrupted handwriting lines on paper.

The other significant difference between the two age groups in Ziviani's study was an increased supination of the forearm in the older pupils. A forearm supinated more than 45º is closer to bringing the hand to a precision grip position than to a power grip position as described by Napier (1956, 911). In the precision grip the hand is held midway between radial and ulnar deviation and the wrist is quite markedly dorsiflexed. In the power grip the hand is deviated towards the ulnar (fifth digit) side and the wrist is held in the neutral position between full extension and full flexion. This result, too, would suggest a refinement of the dynamic tripod grip with age.

Ziviani's two remaining descriptors, [2] number of fingers on shaft and [3] on pad-to-pad opposition, appeared to be randomly distributed among the participants and unrelated to age.

In the United Kingdom, Sassoon *et al.* (1986) attempted to identify various components of handwriting grip and its development. The sample included 294 non-dysfunctional boys and girls seven to 16 years of age. The pupils were divided into three groups. One group consisted of 91 third-year pupils (average age 7 years 6 months), a second group of 100 fifth-year pupils (average age 9 years 6 months), and a third group of 103 pupils who were in their ninth year of school (average age 15 years 8 months). Eight descriptors were used, divided into postural descriptions and penhold (Table 1). The results were presented in terms of mutually exclusive modal categories. The modal value for each descriptor turned out to be constant across age (Sassoon, 1986, 99), an outcome that suggests little change in pencil grip over time. Two features were observed that were different from the widely recommended dynamic tripod pencil grip. First the thumb, rather than the index finger, was observed to be closest to the pencil tip. Second hyperextension was present in the distal joint of the index fingers.

Both Sassoon *et al.* (1986) and Ziviani (1983) describe how to gather information on details of pencil grip but do not give comprehensive descriptions of pencil grips. Their cross-sectional design makes the analysis of individual development impossible.

In the USA, Bergmann (1990) observed three groups of non-dysfunctional right-handed adults in natural writing situations with the aim of finding atypical pencil grips. Fifty-five occupational therapy students and 285 voters were observed signing their names, and 107 medical students were observed taking a written examination. Thus 340 persons signed their name while 107 were engaged in writing. Bergmann (1990) sorted the writing hands into six categories according to operational definitions of pencil grips. Of the 107 writers, 83 per cent used the dynamic tripod grip and 15 per cent the lateral tripod grip. Furthermore, one transpalmar interdigital grip and one cross-thumb grip (2 per cent) were observed in the writers. Of the 340 adult participants signing their names, 86 per cent used the dynamic tripod grip and nine per cent the lateral tripod grip. The remaining five per cent consisted of seven transpalmar interdigital grips, three cross-thumb grips, six dynamic bipods, and one static tripod grip.

The study by Bergmann (1990) depicts briefly observed pencil grips, and shows that to some extent the diversity of grips is similar in both outlined circumstances. However, the value of the classification of 340 persons merely signing their name can be questioned. The ergonomics of the situation varies to a great extent when the task is only to sign. The time it takes to sign is also too short to reflect normal writing behaviour.

Finally in an intervention study, Otto *et al.* (1966) introduced Callewaert's (1963) *combined pencil grip*, which they named the *modified pencil grip* (Figure 6), to 20 right-handed female college pupils in order to judge its functionality in comparison with the traditional grip. The results suggest that the alternative grip functioned well. There was little difference in the writing products and virtually no fatigue effect after 30 minutes of writing with the two grips. However, the participants strongly favoured the traditional grip. This modified pencil grip has been both recommended and tried out by writers and described in a number of sources (Benbow, 1997; Callewaert, 1963; Repo, 2002; Sassoon *et al.,* 1986).

The pencil grip in relation to gender, handedness and culture

Gender. Rosenbloom and Horton (1971) found no significant differences between boys and girls in the maturation of fine prehension in 128 young children from 1 year 6 months up to their seventh year. Saida and Miyashita (1979) compared their results to those by Rosenbloom and Horton's (1971) and found girls of 3 years 6 months and boys of four years of age to be at the same pencil grip maturation level. Schneck and Henderson (1990) studied the developmental progression of grip position and the grips used for pencil and crayon control in 320 boys and girls. The results suggest that boys and girls have different developmental progression although general developmental trends are similar.

Girls, especially the three- and four-year-olds, more frequently showed lateral tripod and dynamic tripod grips defined as mature by Schneck and Henderson (Figure 5). In the older groups, beyond 4 years 6 months, more boys than girls used the dynamic tripod (Schneck and Henderson, 1990, 897). Consequently more girls than boys appeared to use a power grip and not a precision grip as defined by Napier (1956). Levine (1987), on the other hand, pointed out that boys' grip strength increases generally more than that of girls during the school years. Schneck (1991) compared the grips of 60 six-year-old boys and girls with and without handwriting difficulties. No differences between the boys and girls were reported.

In a study of 84 three-year-olds, Blöte and Dijkstra (1989) found boys' skills in proximo-distal pencil manipulation to lag behind those of girls. In an earlier study of body and grip postures, as well as transport movements, in writing behaviour in 120 children who were 4 years to 5 years 5 months of age, Blöte (1988) observed girls to show more frequent tripod postures than boys. Blöte (1988) also studied children who were 1 year to 6 years 5 months of age and found boys' writing behaviour to lag behind that of girls in all age groups, with one exception. In the oldest group, children aged 5 years 5 months to 6 years 5 months, the girls were not observed to be ahead of boys, a result consistent with the findings of Schneck and Henderson (1990). Blöte suggests that the differences between boys and girls are primarily of a developmental nature but also secondarily gender-related reflecting the effort put into writing as a result of instruction (Blöte, 1988, 72 and 92).

Ziviani (1983) studied the variations in the dynamic tripod grip in 287 pupils 6 years 8 months to 14 years of age. Her findings suggest that boys use less pressure than girls when writing. This suggestion derives from girls demonstrating more hyperextension of distal joint of index finger than boys at 6 years 8 months to 9 years 9 months of age, and younger boys being more likely than girls to show greater forearm supination. Blöte (1988) found the same difference as Ziviani in boys' and girls' index finger flexion. Sassoon *et al.* (1986) also observed hyperextension at the distal interphalangeal joint of the index finger, a feature that goes against the typical images of an ideal pencil grip. Their study included 294 boys and girls 7 years 4 months to 16 years 1 month of age, of whom 64 per cent demonstrated a hyperextended index finger joint. However, no statistically significant effect of gender on the proportion of pupils using the modal pencil grip feature was observed. In a study of 485 adults, Bergmann (1990) observed two types of non-tripod pencil grip in a total of 14 individuals, the transpalmar interdigital and the dynamic dipod grips. Bergmann offers a gender-related explanation to the transpalmar grip adopted predominantly by women with long fingernails.

Handedness. Saida and Miyashita (1979), Sassoon *et al.* (1986) and Schneck (1991) have singled out right- and left-handed writers for research purposes. Saida and Miyashita (1979) reported no significant differences between right- or left-handed or ambidextral groups in the developmental stages of pencil grip in two- to six-year-olds. Schneck (1991) observed unclear hand preference in children with poor handwriting, but no association between good handwriting and handedness. Sassoon *et al.* (1986) included paper orientation and other postural features in their study. They observed that right-handed pupils tilt their paper counterclockwise to the left and left-handed pupils accordingly clockwise to the right. However, no statistically significant effect of the preferred hand on the proportion using the modal features of the pencil grip was observed.

Part of the pencil grip research has dealt with right-handed writers (Bergmann, 1990; Blöte, 1988; Otto *et al.*, 1966), while many reports do not mention the handedness of the observed writer at all. Textbooks and articles on handwriting include statements on the correct or awkward left hand, often based on beliefs and anecdotal observations (Clark, 1974; Gray, 1956; Holle, 1980; Salminen, 1982). One of the handwriting postures often thought to be associated with left-handedness is the “hooked wrist” in which the hand is flexed forward against the palm as opposed to the normal wrist position which is straight (extended), or slightly flexed to the dorsal side of the hand.

Cultural issues. The pencil grip research reviewed here has been conducted in Australia, Belgium, Finland, Japan, United Kingdom, and in the USA. The Japanese writing system and tools differ from the Western cultures. Finland has the oldest children introduced to formal writing instruction. Some cultural differences might thus emerge but variability in the measures, set-ups and materials used in existing studies precludes drawing conclusions on cultural effects. The issue of pencil grip is approached in ways varying from one classroom to another, not to mention the countries. In the Japanese study (Saida and Miyashita, 1979), a comparison was made with an earlier British study by Rosenbloom and Horton (1971). Saida and Miyashita reported that in comparison to the British sample, three-year-old Japanese children are approximately six months ahead in the development of pencil manipulation. However, none of the reviewed studies introduced cross-cultural research settings.

Limitations of existing research on pencil grip

Earlier research reviewed above has paved the way to detailed analyses of pencil grips, suggested developmental trends in the evolvement of children's pencil grips over age, and provided data on gender-related differences. However, variability in operational definitions of pencil grips, study design, and subject groups makes it difficult to draw definite conclusions on the distribution and development of pencil grips in pupils. Descriptor-based classification systems are also too complex for classroom use, which seriously limits their applicability. Follow-up studies are lacking (with the single exception of a one-year study reported in Blöte, 1988, 41) even though these would be crucial in establishing developmental patterns of pencil grips in pupils. Finally, the issues of handedness effects and cultural effects on pencil grips still await further systematic studies.

HANDWRITING RESEARCH

As one of the aims of the present study is to examine the relationships between pencil grip and the mechanics of writing, a review of relevant handwriting research is presented.

Good and poor handwriting

Beautiful and legible handwriting is a courtesy to the reader. Illegible handwriting has aptly been called the greatest time-thief in schools today (Enstrom, 1967). Apart from making reading tedious, untidy penmanship has been shown to influence the grading of pupils' writing. Thus, Briggs (1970) found handwriting to have a highly significant influence on teachers' marking of essays so that poor handwriting predicted low grades. Sweedler-Brown (1992) attempted to minimise this type of assessment bias by training graders to ignore handwriting quality when marking essays. The training, however, had no significant effect; untidy handwriting still remained a handicap working against the writer. It has been speculated that pupils may use poor handwriting in an attempt to attract attention, or to mask poor spelling and inadequate answers, or even to convey negative attitudes (de Ajuriaguerra and Auzias, 1980; Otto and Smith, 1980).

In the 1960's, calligraphy was still a school subject in Finland. By the turn of the century, however, a growing number of primary school teachers lacked both the experience of calligraphy as a school subject and specific training in handwriting. Certain script and cursive alphabets are still recommended. There is, however, no national testing in handwriting (or in any other subject) in the Finnish public school system in grades 1 to 9. Schools and teachers have individual freedom in choosing teaching methods within the national framework curriculum. Consequently, the teaching and evaluation of penmanship is more dependent on the individual teacher than upon national convention.

A literature review shows that in the USA handwriting styles as well as the teaching and grading of handwriting have been both discussed and studied (Barbe, Milone and Wasylyk, 1983; Graham, 1992; Gray, 1956; Tinker, 1955). The distinction between manuscript and cursive handwriting has led researchers to explore the effects of handwriting style on fluency and legibility, and thus the functionality of the writing process, as in Graham, Weintraub and Berninger (1998b). In their study on the relationships between handwriting style and speed and legibility, pupils who used a combination of manuscript and cursive letters proved to be more fluent writers than those who used either manuscript or cursive script exclusively.

Handwriting assessment

The appearance of handwriting is conventionally evaluated against normative scales. This is appropriate when normative letter-forms are mandated but less expedient when none are mandated, as in Finland.

Graham (1986a) has extensively studied handwriting measures from various points of view. Four handwriting scales were initially evaluated. They all met the criteria for ease of administration and instructional applicability for various groups of writers (Graham, 1986a). Next, three rating methods were compared. Two methods were labelled "holistic", one with and the other without a model for comparison. In a third method, scores were based on representational accuracy which was checked by text correspondence with transparent overlays and verbal directives (Graham, 1986b). The outcome of the comparison was inconclusive: none of the rating methods could be shown to be significantly superior to the others. In a later study based on learning disabled children's writing, Graham, Boyer-Shick and Tippets (1989) investigated the handwriting scores obtained from a specific test of general legibility (Test Of Legible Handwriting, TOLH, Larsen and Hammill, 1989). The study provided evidence that the TOLH scale is a valid measure of the legibility of learning disabled pupils' handwriting and also that learning disabled children have handwriting difficulties associated with generally poor legibility (Graham *et al.*, 1989).

In a review of handwriting scales published in 1942–1988 Bruinsma and Nieuwenhuis (1991) presented 17 scales, each consisting of three to 25 evaluative aspects. Another review of handwriting tests administered by occupational therapists was presented in Reisman (1991). She also discussed the criteria by which children are referred to school occupational therapists because of handwriting problems and the remediation available in the USA. In regular schools in Finland occupational therapists (Finnish: toimintaterapeutti, Swedish: ergoterapeut) are not readily available for these types of referral.

As an alternative method to teacher intervention, Furner (1969) has suggested handwriting instruction based on student-centred learning and self-assessment. Similarly, in an attempt to induce the writers to take responsibility for their own handwriting, Bruinsma and Nieuwenhuis (1991) constructed and tested a subjective method for handwriting evaluation on college students. The aim was to improve handwriting quality by self-evaluation. Based on the results the researchers suggest that self-evaluation be introduced for development of proficiency. They also considered the possibility of initiating self-evaluation of handwriting as early as the pre-writing stage. The handwriting criteria need, however, to be carefully reconsidered before further application.

Handwriting tools

Studies and reports on handwriting occasionally refer to the correct tools for handwriting. The discussion concerning the correct paper is often about whether lined or unlined paper should be used. In a study involving 56 seven-year-old pupils 75 per cent of the essays written on lined paper were rated as more legible than the essays by the same children when written on unlined paper (Burnhill, Hartley and Davies, 1980). The beneficial effect of the lined paper lies in organising the writing (Burnhill *et al.,* 1980; Krzesni, 1971). Also, wide-lined paper may be especially useful when young children initially practise a newly introduced letterform (Graham, 1992). Whether lined paper hinders creativity or not is unclear (Burnhill *et al.*, 1980).

With regard to the writing tools, large-sized lead pencils have been recommended for the beginning writer (Gray, 1956). Over-sized pencils, pencils with triangular cross-sections and pencils with grippers are all still used and recommended, despite lack of empirical evidence in their support (Judd, 2000; Larsen and Hammill, 1989). On the other hand, Ziviani (1981) has pointed out the risk that young children may adopt immature pencil grip postures as a result of using thicker pencils or pencils equipped with grippers. Still, Carlson and Cunningham (1990) found no differences in pencil management and performance related to pencil diameters. Two studies have compared the effects of three different writing tools (pencil, ballpoint pen, felt tip or the fountain pen). Krzesni (1971) studied the effect of these writing tools on children's writing performance and Kao (1976) studied user preference. In both studies the ballpoint pen emerged as the most favoured tool. In Finland there is a variety of writing tools for the child to choose from. Also the quality of the pens and pencils has improved since the time of leaking and smudging pens. The school can suggest and recommend writing tools for classroom use. However, instead of requiring one type of pencil to be used, a variety of writing tools could be available for children to try out (Coles and Goodman, 1980; Graham, 1992).

The mechanics of writing

Handwriting is a compound cognitive and motor skill, which has been examined and analysed in a variety of studies. The present review takes up some studies of handwriting, handwriting assessment and the role of the mechanics of writing relevant for placing the present study in perspective. A bulk of studies which are beyond the scope of the present thesis may only be mentioned in passing or left out.

One of the main areas of research on writing is the focus on the composing process (Scardamalia and Bereiter, 1986). A description of this process is provided in the theoretical model of Hayes and Flower (1980) that is derived through protocol analysis of competent adult writers' writing processes. The structure of the model includes the writer's long-term memory module (knowledge and plans) and the task environment module (problem and produced text), which interact with writing processes (planning, translating, reviewing, and monitoring) (Hayes and Flower, 1980; Scardamalia and Bereiter, 1986). Good process instruction must be built on both a sound understanding of the writing process and competent diagnoses of developing writers' problems and needs (Hayes and Flower, 1986). The model does not, however, include low level processes such as creating letter representations in memory, retrieving these representations, motor planning, and motor production (Berninger, Vaughan, Abbott, Abbott, Rogan, Brooks, Reed and Graham, 1997). The Hayes and Flower model has been challenged by *e.g.* Berninger *et al.* (1997) who believe that it needs re-thinking to be applicable at the beginning writer's stage. Learning to write is a process of creating a functional system that draws on both low and high level processes (Berninger *et al.*, 1997). An augmented schematic of the Hayes and Flower writing process model was suggested by Butterfield (1994, 206) in a synthesis of research reports (*cf.* Butterfield and Carlson, 1994). The suggested additions are knowledge of language in the module of long-term memory, and control as well as monitoring of working memory in the processing part of the model. Furthermore, the original translation process is split into separate expression and transcription processes (Butterfield, 1994). For further discussion on the modification of the model, see *e.g.* Berninger, Fuller and Whitaker (1996).

Graham (1992) has provided a summary of those aspects of the writing processes which are influenced by the mechanics of writing. Poor mechanics can interrupt higher order processes resulting in lost ideas, less attention allocated to the planning process and less time for precise expression (*cf.* Martlew, 1983). What is more, writers may not be able to keep up with their thoughts (*cf.* Graham, 1990). Persistence, motivation and the sense of efficacy may be impeded by difficulties in the mechanics of writing (*cf.* Harris and Rarick, 1963).

Allocating attention to the mechanics may particularly distract inexperienced and immature writers (Scardamalia and Bereiter, 1986). Improved text generation was found with letter production automatisation in first-graders at risk for handwriting problems (Berninger *et al.,* 1997; Jones and Christensen, 1999). However, writing mechanics should be considered with at-risk children of any age. In a study of grade 4 and 6 learning disabled children's writing, both the quality and the quantity of composition were improved when the children were freed from the mechanics of writing (Graham, 1990). The best results were achieved when the child dictated the story to the examiner for scribing. The second best method as compared to the baseline (writing) was dictation to a tape recorder. The outcome suggests that learning disabled pupils' writing problems may be due in part to the mechanics of writing (Graham, 1990). On the other hand, Graham, Berninger, Abbott, Abbott and Whitaker (1997) reported that individual differences in handwriting were predictive of individual differences in compositional fluency and quality. Results by Graham *et al.* (1997) suggested that handwriting difficulties might constrain the attainment of composing competence, including handwriting and spelling, among children in grades 1 to 6. A recent study indicated that explicit handwriting instruction is an important element in preventing writing difficulties in the primary grades (Graham, Harris and Fink, 2000).

Fluency and legibility

Fluency of handwriting is usually understood as writing speed and measured by letters written per minute. Legibility is often apprehended as readability or quality of writing. Legibility of handwriting is not a unitary construct but a composite of simpler elements including letter formation, slant, size, spacing, alignment, and line quality (Weintraub and Graham, 2000, 134).

Handwriting patterns are affected by writing conditions. For this reason, Harris and Rarick (1963) have suggested that studies investigating handwriting should include multiple texts, to be presented with different instructions, and preferably with variable durations of writing time (up to 10 minutes) which would bring out any fatigue effects.

Various data collection procedures have been used for speed and legibility analysis. Graham, Berninger, Weintraub and Schafer (1998a) administered one copy task and two samples of free writing. All three writing samples were scored for legibility against a handwriting scale (Larsen and Hammill, 1989), and the copy task was analysed for speed by counting letters per minute (Graham *et al.,* 1998a). Abbott and Berninger (1993) used two writing tasks, a copy task and the letters of the alphabet, and compiled a score of accuracy of representation and of speed from both writings. Ziviani and Elkins (1984) developed an assessment method that evaluates both speed and legibility. Comparing performance to existing scales assessed speed. The method for validating legibility components of the test was to compare results with teacher ratings for the same characteristics (Ziviani and Elkins, 1984, 258). Factor analysis of the scores obtained by their procedures yielded four factors (handwriting formation, word and letter size, symbol and sentence spacing and range of spacing, symbol and sentence alignment) that accounted for 70 per cent of the total variance in legibility.

Alston (1983) studied the reliability of teachers' scoring of 100 handwriting samples based on overall legibility on a seven-point scale. The results were compared to the same samples scored using a checklist type scale with 20 items. Examination of rate-rerate correlation indicated that teachers are reliable in their subjective ratings of writing samples (Pearson's r .77 to .90 on the 7-point scale, and .64 to .98 on the 20-point scale).

Computerised laboratory settings for data collection and analysis in combination with evaluation by raters provide more accurate data. Wann and Jones (1986) asked children with good or poor handwriting to copy letters and words on a digitiser tablet using a sensory pen. The grouping of handwriters was by legibility of the letters and words according to the Rubin and Henderson criteria (1982). A significantly greater degree of correspondence with the model letters was found in the good writers' letterforms over time than in the poor writers' letterforms. Also the variability in writing time differentiated clearly between the two groups, favouring the good writers. Søvik, Arntzen and Thygesen (1987) separated dysfunctional children in two groups as they compared legibility and speed of the handwriting of non-dysfunctional, dyslexic and dysgraphic pupils. The tests included analyses of legibility and speed. In addition to the technical parameters measuring the absolute velocity curve as a function of time, the writings were also scored for accuracy by raters using a seven-point scale. Søvik *et al.* (1987) found dysgraphic writers to be inferior to the dyslexics in all performances except for writing time. The use of laboratory equipment also makes it possible to obtain data on the writer's affective state, muscle tension and fine motor control by measures of skin conductance and muscle activity (Harris and Rarick, 1963).

Other factors contributing to handwriting

In his review of elementary psychomotor findings and theoretical issues related to the handwriting skill, van Galen (1991) made the assumption that stroke generation and letter formation should be seen as results of biophysical processes, cognitive variables, and contextual factors. Accordingly, he suggested a model designed to give a description of the generation of script. Feedback is not included in the model, which is a missing aspect van Galen himself points out. The model includes processing modules (from activation of intentions to muscular adjustment), processing units (from ideas to strokes), and mediating memory stores (from episodic memory to motor output buffer) for the production of handwriting (van Galen, 1991, 183).

Based on a literature review by Tseng and Cermak (1993), tactile-kinesthetic, visuo-motor, and motor planning factors appeared to be more closely related to handwriting than visual perception. Weil and Cunningham Amundson (1994) also found a significant relationship between kindergarten children's visuo-motor and handwriting skills. Weintraub and Graham (2000) reported similar results in fifth grade pupils. Visuo-motor integration and eye-hand coordination contributed most to legibility of handwriting in 143 Chinese schoolchildren in grades three to five (Tseng and Murray, 1994). However, within this group visual perception contributed the most to good handwriters' legibility, whereas motor planning contributed the most to poor handwriters' legibility. Jones and Christensen (1999) found orthographic-motor skills involved in handwriting to have a significant effect on first-graders' ability to generate written text. Berninger, Abbott, Rogan, Reed, Abbott, Brooks, Vaughan and Graham (1998) also reported different weights of contributing processes in children with different handwriting. Their results indicate that children with poor handwriting receive qualitatively different orthographic feedback than children with good handwriting.

Handwriting appears to play a part in learning to spell both prior to and in response to spelling lessons (Berninger *et al.,* 1998). On the other hand, orthographic processes did not make a significant or unique contribution to handwriting status in a recent study by Weintraub and Graham (2000) while visual-motor and finger functioning showed predictive value.

Exner and Henderson (1995) describe how perceptual and motor processing difficulties not only affect motor performance but can also affect the child's ability to learn reading and writing. They conclude that it is hand function and not gross motor function that seems critical in supporting cognitive development in the child (Exner and Henderson, 1995, 108).

In a study on space-time invariance in handwriting, Wann and Jones (1986) observed that in the early stages of writing acquisition there were no differences between good and poor (by the criteria of Rubin and Henderson, 1982) writers' letter and word writing speed. No significant differences were observed in word writing tasks either. Letter writing tasks, however, were effective in highlighting differences between poor and good writers' legibility and might be considered a meaningful measure for assessment at early stages of writing (Wann and Jones, 1986). Consequently, handwriting instruction that helps children write letters accurately and quickly can increase the probability that they will become skilled writers (Graham *et al.,* 2000).

An additional intriguing issue is the possible connection between handwriting and motivation for and attitudes towards writing. The tests on writing motivation which have been reviewed do not address the mechanics of writing (Codling and Gambrell, 1997; Kear, Coffman, McKenna and Ambrosio, 2000; Larsen and Hammill, 1989). However, discussion on writers' self-efficacy and its possible connections to the writing process, including aspects of the mechanics of writing, has recently been initiated (Graham and Harris, 1997: Graham *et al.*, 2000; Graham, Schwartz and MacArthur, 1993; Knudson, 1995).

Pencil grips and handwriting

”Pencil grip” as a search key does not attract references from databases. Computerised searches were conducted in the Educational Resources Information Center (ERIC), PsycLIT, Medline and Open Access Catalogues; also a hand-search through the archives of The University of Maryland at College Park Library. Two comprehensive reviews of contemporary handwriting research support the scarcity of search results (Berninger and Graham, 1998; Graham and Weintraub, 1996). Nevertheless, a few reports on the connections between pencil grip and the writing process were found. Some of the reports convey the beliefs and practices in teaching while others attempt to tap the relationship. Most of the studies including the pencil grip, however, suffer from various methodological weaknesses or of not being compatible.

A variety of grip criteria. Some reported studies present an overwhelming set of criteria to compare to handwriting (Bailey, 1984), while others give an unspecified, oversimplified description of pencil grips like the good grip *vs.* tense or wrong grips, and the correct *vs.* incorrect or tight grips (Tseng, 1998).

Same grip – different handwriting criteria. Callewaert (1963) and Otto *et al.* (1966) studied the same combined modified pencil grip (Figure 6) and its relation to handwriting. Based on analysis in laboratory settings, Callewaert (1963) suggested that the consequences of holding a pencil improperly, defined by faulty index finger profiles (Figure 7), are poor formation of letters and failure to join letters together to form words. As a remediation of the unwarranted grips Callewaert presented the combined modified grip, which would result in superior calligraphy. Otto *et al.* (1966) introduced the modified grip to 20 college students and studied their handwriting production and legibility relative to a control group, which used a traditional dynamic tripod grip. The results showed no difference in the writing speed. Both writing samples were readable although the samples written with the traditional grips were rated somewhat more legible than the samples written with the modified grip. The results of this rather small study prove the modified grip neither superior nor inferior in relation to the dynamic tripod (Otto *et al.,* 1966).

Same handwriting criteria – different grip descriptions. Rubin and Henderson (1982) and Schneck (1991) studied handwriting using the same six criteria to define the level of proficiency. Rubin and Henderson compared 40 ten-year-old pupils' handwriting to pencil grips described by the fine motor subtest of the Test of Motor Impairment (Larsen and Hammill, 1989). Schneck, on the other hand, compared 60 six-year-old pupils' handwriting to operational definitions of the pencil grips according to a five-point rating system. Rubin and Henderson found no association between poor handwriting and fine motor skills. Schneck, on the other hand, found a statistically significant difference in the handwriting score of children with a mature pencil grip *vs.* their peers with less mature grips. The results were in favour of the more mature grips.

Limitations of existing research on handwriting

Earlier research reviewed above has shown that there are both methods for and an interest in analysing the mechanics of handwriting, and their effect on both the writer and the reader. The emphasis of these studies has, however, been on assessment of the legibility of handwriting by different scales, and on analysing speed of writing by brief speedwriting tasks. The few studies on the relationships between pencil grip and handwriting suggest that variations in pencil grip do not appreciably influence fluency or legibility (Graham and Weintraub, 1996). However, the generality of such conclusions requires further testing, as there are several potentially important limitations. These include both the temporal extent of writing samples, the diversity of writing assignments and the comparability of the methods used for pencil grip description (Graham and Weintraub, 1996).

AIMS OF THE PRESENT THESIS

How can pencil grips be described in both a theoretically and a practically relevant way? The present thesis proposes a new descriptive two-dimensional model for pencil grip categorisation. This model is then applied in three descriptive studies of pencil grips and in a fourth one addressing writing skills.

What is the distribution of pencil grips in schoolchildren in Finland? This question is addressed in a cross-sectional study of the pencil grips in a large group of schoolchildren in Finland.

How stable are pencil grips over time? The stability *vs.* change of pencil grips is explored in a longitudinal study of a group of schoolchildren in Finland who were followed up for four years.

Are there cross-cultural differences in the pencil grips in Finland and the USA? Possible cross-cultural differences were searched for in a comparative cross-sectional study, which included pupils in Finland and the USA.

Do pencil grips correlate with mechanics of writing skill? This issue was explored in a study with a group of schoolchildren in Finland. Pencil grip categories were compared with assessment of writing fluency and legibility.

A MODEL FOR PENCIL GRIP CATEGORISATION

THE PROPOSED TWO-DIMENSIONAL MODEL

One of the aims of the present research is to contribute to the research on the mechanics of writing by presenting a general descriptive model for categorising pencil grip. This model is then applied in the subsequent empirical studies included in the thesis. The model is based on the knowledge of the functional hand and pencil grip development in the child and draws from the recommended and described pencil grips and grip descriptors. It can be used for research purposes as a method for data collection in both classroom settings and elsewhere.

The present model makes the following basic assumptions: the optimal pencil grip is stable and mobile and provides sensory feedback. Stability of the hand is achieved either by grip configuration or by level of ease. The grip can consequently be analysed by reference to the grip configuration dimension and to the level of ease dimension. Normal grip development in the child progresses from a power grip to a precision grip on the configuration dimension, and from pressure to ease on the level of ease dimension.

The proposed two-dimensional model for pencil grip is shown in Figure 8. Although not identical to, the two dimensions are consistent with, earlier classifications of prehensile grips into power or precision grips and functional or dysfunctional pencil grips, respectively (Elliot and Connolly, 1984, 284; Napier 1956, 902).

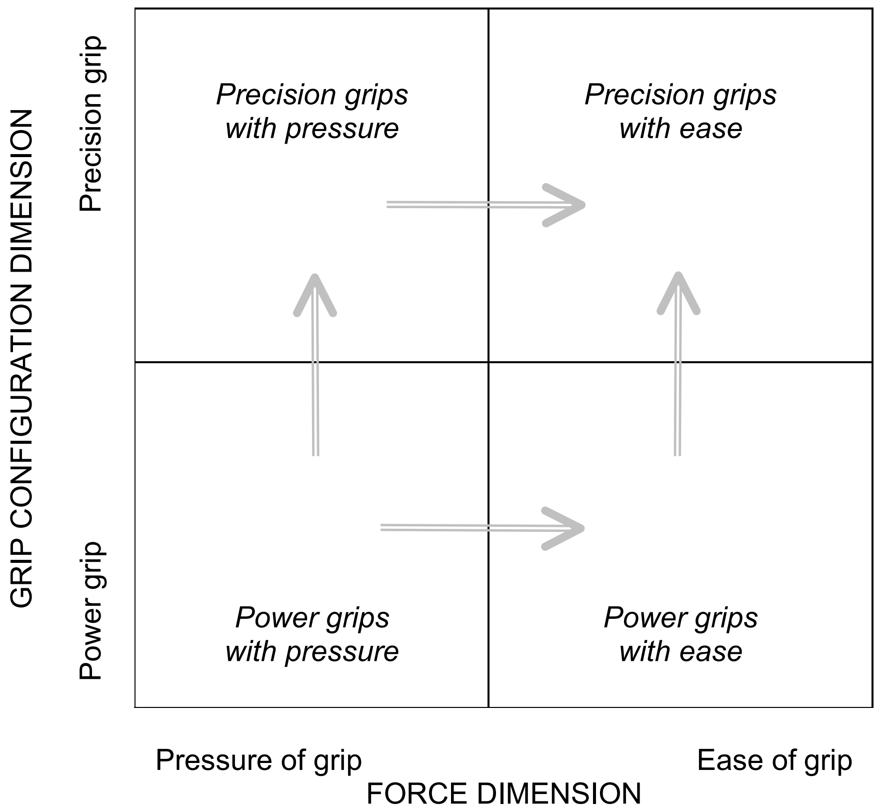


Figure 8. Proposed two-dimensional model for pencil grip categorisation based on stability and functionality. Stability is a necessary prerequisite for a functional pencil grip and can be attained by any of four combinations of force and grip configuration. The arrows represent refinement of pencil grip.

The grip configuration dimension

On the grip configuration dimension, pencil grip development is expected to progress from a power grip to a precision grip. In a power grip the writing tool is secured with the thumb against the index finger and/or against the other digits, which offer stability but restrict prehensile movement. The power grips are the *lateral tripod* and the *cross thumb,* as well as the *thumb tuck* and the *high index* grips depicted in Figure 9. In the latter two grips the pencil shaft is stabilised by the thumb and the index finger and steered by the fourth and the fifth digits with possible participation of the third digit. In a precision grip the fingers grasp the writing tool in a pad-to-pad position, which facilitates precise writing movements, stability, and sensory feedback. The *dynamic tripod* is classified as a precision grip. The *quadrupod* grip is also classified as a precision grip when the shaft of the pencil is resting at the tips of the third and the fourth digit and the writing tool is gripped between the thumb and the index finger. When the shaft is resting on the fourth digit and the third digit on top of the pencil, the *quadrupod* grip does not allow for the fine-motor movements of a precision grip. In such a case it must be categorised as a power grip.

The ease dimension

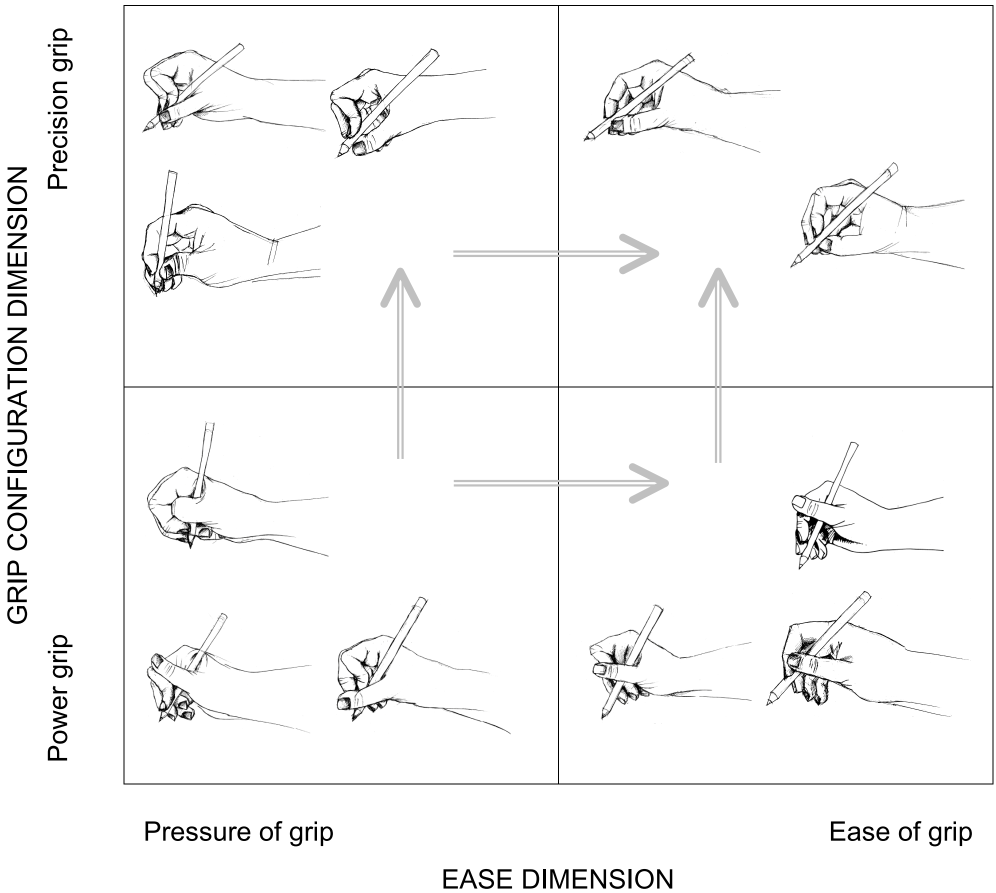
On the ease dimension, the pencil grip is expected to develop from a grip with pressure to a grip with ease of movement so that the combined effects of less pressure and more precision produce increased refinement of the pencil grip. The ease dimension is observed in the posture of the index finger and the thumb, the two digits that are best adapted to exercise fine motor control (Elliot and Connolly, 1984). Yet these digits are often seen in unorthodox positions (Benbow, 1995; Sassoon *et al.*, 1986; Ziviani, 1983) with the distal joints hyperextended and the proximal interphalangeal or metacarpophalangeal joints strained with whitened knuckles (Figure 7). On the ease dimension, the thumb, the index, or any finger having a hyperextended joint indicates a grip with inordinate pressure. An easy grip would be one in which the thumb and the index finger are in a relaxed state, slightly flexed or close to a straight finger shape. In terms of the model, flexed and straight finger joints are scored as belonging to the same category and the hyperextended joints into a separate category. This classification stems from the assumption that the flexed or straight joints aim at stability of the writing hand via a controlled pose while the hyperextension indicates stability through added pressure.

Table 2. *Previously reviewed pencil grips placed in appropriate pencil grip categories using the two-dimensional model. The letters in the parentheses refer to illustrations in Figures 3–6.*

Precision grips with ease, upper right quadrant	[g] the static tripod grasp [h] the four finger grasp, the quodrupod [j] the dynamic tripod grip [p] the adapted tripod, the combined pencil grip, the modified grip
Precision grips with pressure, upper left quadrant	Precision grips with pressure demonstrated by hyperextension and/or other visible tension of thumb and/or one or more fingers.
Power grips with ease, lower right quadrant	[f] the cross thumb grasp, the thumb right over [i] the lateral tripod grasp [m] the transpalmar interdigital brace [n] the supinate grip [k] the thumb wrap
Power grips with pressure, lower left quadrant	Power grips with pressure demonstrated by hyperextension and/or other visible tension of thumb and/or one or more fingers, and [l] the thumb tuck [1] [o] the index grip, the high index grip[1]

[1] these grips might exceptionally be regarded as grips with ease

Not categorised primitive grips rarely seen in non-dysfunctional schoolchildren:	[a] the radial cross palmar grip [b] the palmar supinate grasp, the transpalmar [c] the digital pronate grasp [d] the brush grasp, the top tongue grip [e] the grasp with extended fingers



Drawings by Sofia Flinck, 2002

Figure 9. Pictorial representations of the four pencil grip categories included in the two-dimensional model.

The four categories in the two-dimensional model

The four quadrants configured by the two dimensions are the basis of the model. The grips classified in each quadrant have certain distinctive characteristics in common. These are outlined below.

An easy precision grip configuration (upper right quadrant) provides stability, mobility and sensory feedback. The writing hand can perform well-coordinated movements with no need for excessive pressure. An easy power grip configuration (lower right quadrant) provides stability, but at the cost of mobility. Such a grip yields little sensory feedback since the fingertips are not in pad-to-pad opposition. When the pencil is held in a power grip, the hand moves as a whole. Typically, the principal movement is then in the wrist and sometimes in the arm. In another form of power grip, the fingers form a unit with movement seen in the metacarpophalangeal joints of the hand. Such power grip configurations, although unconventional, can function with ease.

A power grip configuration with pressure (lower left quadrant) tightens up the grip. This is demonstrated by hyperextended thumb or index finger joints and specifically by whitened knuckles. The gain in stability is nevertheless offset by a loss of mobility (due to increased tension) and this makes this type of grip tiresome to use.

A precision grip configuration with pressure (upper left quadrant) is similar to the traditional "tripod grip" although characterised by excessive pressure leading to low mobility and curtailed sensory feedback.

The observer only needs to ask two questions for any given grip configuration – is the grip a precision grip (descriptor 4) and is the hand at ease (descriptors 2 and 3)? (See page 58 and Figure 10 for details.) The observed pencil grip can then be categorised by its location on the dimensions and within the quadrants of the two-dimensional model, which thus can serve as an instrument for pencil grip categorisation in applied research. Table 2 includes previously reviewed pencil grips placed in appropriate categories using the two-dimensional model. Pictorial examples of the four pencil grip categories are given in Figure 9.

Discussion

One of the aims of the present research was to develop a model by which pencil grips could be reliably described as observed in real school-life situations. The result is a comprehensive two-dimensional model, where the two dimensions are grip configuration and level of ease. These dimensions are defined on the basis of detailed descriptions and definitions of pencil grip. The first dimension, grip configuration, is based on Elliot and Connolly's (1984) functional grip configuration, which in turn is a refinement of Napier's (1956) classification of power and precision grips. The second dimension, ease of grip, includes details of pressure *vs.* ease of manipulating the writing tool (Blöte, 1988; Sassoon *et al.,* 1986; Ziviani, 1983).

The model may replace some of the earlier classifications in exploring pencil grips in writers from seven years of age upwards. The model includes the major operational definitions of pencil grips, such as the dynamic tripod grip, considered close to a norm as described by Rosenbloom and Horton (1971), Wynn-Parry (1966) and others, and other operational definitions of pencil grips (Bergmann, 1990; Callewaert, 1963; Sassoon *et al.,* 1986; Schneck and Henderson, 1990; and Ziviani, 1983). The most notable shortcoming of these definitions is that, although the positioning of the fingers is included, the details affecting the level of ease, such as hyperextension of thumb and index finger joints, are not easily taken into account. The other approach, where pencil grips are described by several descriptors with variable parameters (Lyytinen-Lund, 1998; Sassoon *et al.,* 1986;

Ziviani, 1983), does not work in real-life situations. Too many details of the various grips are involved, together with their combinations, to be meaningfully analysed and interpreted.

Although the categorisation of pencil grips by the model is not always unambiguous, the present model, nevertheless, provides a simple conceptual framework to enhance our understanding of pencil grip functions. Moreover, it may easily be applied when studying dimensions relevant for the improvement of writing skills as shown in the present Study 4.

FOUR DESCRIPTIVE STUDIES

STUDY 1: A CROSS-SECTIONAL STUDY OF PENCIL GRIPS OF FINNISH PUPILS IN GRADES ONE THROUGH SIX

The aim of Study 1 was to describe pencil grips in a large sample of 7- to 12-year-old schoolchildren observed in a classroom setting. The pupils' pencil grips were classified according to the two-dimensional model presented in the previous chapter (Figure 8). Moreover, it was of interest to explore whether handedness and/or gender had any association with the four pencil grip categories or with specific descriptors (1–4).

A similar survey has not been reported before in Finland.

Method

Participants

Study 1 included 504 schoolchildren (239 boys, 47 per cent and 265 girls, 53 per cent). These pupils were drawn from a group of non-dysfunctional pupils observed one to four times each over the first six years of formal instruction. The pupils were 6 years 11 months to 12 years 6 months of age at the time of the observation.[1] The overall database of the total of 1747 observations of children in Finland and the USA, and details of the pupils included in Studies 1–4, are presented in Appendix D.

Setting

Finland has a public school system with practically no private schools. The language of instruction is Finnish or Swedish (94 per cent *vs.* 6 per cent in 2000). The present study was conducted in an elementary school [Cygnæus] with some 400 pupils at the time of the study [2000]. Cygnæus is a regular compulsory school for pupils in grades 1–6, differing from the majority of schools only by the

[1] Finnish children enter school in the month of August of the calendar year of their seventh birthday. On entry to grade 1, children are therefore generally aged between 6 years 8 months and 7 years 7 months.

language of instruction, namely Swedish. The school is situated in the City of Turku (Swedish: Åbo), which has a population of 170 000 [2001]. The school's headteacher and staff have been very supportive of this research project over the years. Despite, or maybe because of, the present research, no special emphasis on the manipulation of the pencil has been included in the lesson plans.

Procedures

The present author observed the pencil grips during age appropriate copy-writing assignments. Blöte and Dijkstra (1989, 515) argued that in observing writing behaviour as part of an assessment of children's neuro-motor status, a writing-like task should be used that elicits optimal performance. Similar suggestions have been offered by Rosenbloom and Horton (1971) and also by the present author (Lyytinen-Lund, 1998) who observed that the grip and hand movements were different when the child was tracing letterlike figures as opposed to drawing.

Initially the pupils were informed of the aim of the observations and of the procedure (*cf.* Graham, 1990). They were told that the aim was to learn more about the way pupils hold their pencils; and that the pupils would be observed while copywriting from their textbook (*cf.* page 21, Sassoon *et al.,* 1986, Ziviani, 1983). A photograph would be taken of the writing hand after approximately 10 minutes of writing. The writing assignment was carried out at a desk of standard height and size used by the school. Up to six pupils were simultaneously observed. For each task, a sheet of A4-sized lined paper (grade 1) or cross-ruled paper (grades 2 to 6) was presented at the pupil's midline. A sharpened HB2 pencil at least 10 cm in length was placed on top of the paper vertical to the pupil. The handwriting tools were the same as normally used in the school. After instruction and possible questions and answers, the pupils were asked to copy a textbook text (Lindell, Löfqvist, Nordlund, Rönnholm and Sjöblom, 1994, grades 3 to 6;

Zetterholm 1991, grades 1 and 2) until the necessary observations were completed, for a minimum of 10 minutes (*cf.* Harris and Rarick, 1963). Some pupils started by using the dynamic tripod pencil grip with a flexed index finger joint, switching over to the grip they would normally use after 2–3 minutes. Photos and final notes were taken after 10 minutes of writing. Additional sheets of paper, sharpened pencils, erasers, rulers and more texts to copy for the fastest were provided as needed.

Notes were recorded by a checklist type observation scheme (Appendices A and C) and were reviewed and double-checked against photographs taken after 10 minutes of writing (Appendix B). The author collected all observations and photographs included in the present study. The test–retest reliability of the observation scheme was determined in a previous study by the author (Lyytinen-Lund, 1998). In that study, the inter-rater reliability was determined by the kappa κ test for nominal data introduced by Cohen (1960) to provide a coefficient of agreement between two raters for nominal scales (Fleiss, Cohen and Everitt, 1969, 323) (*cf.* Ziviani, 1983).

At the initial stages of pencil grip observation, the checklist data were quite detailed (see Table 1). In the revising process, certain details were omitted. In the present author's judgement, the omitted items (*e.g.* finger closest to pencil tip, pronation/supination of arm) observed by Sassoon *et al.* (1986) and Ziviani (1982, 1983) were either irrelevant to the research at hand, or too vague to give valid information.

Observations

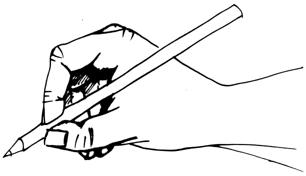
Four underlying descriptors characterised each observed pencil grip. (1) The angle of the wrist is categorised either as straight/extended backwards or flexed. Hooked. (2) The angle of the distal interphalangeal joint of the index finger is categorised either as flexed/straight or hyperextended, and (3) the angle of the interphalangeal joint of the thumb is categorised either as flexed/straight or hyperextended. The fourth variable (4) is an operational definition of the grip reflecting the positioning of a number of fingers on the pencil shaft. This descriptor has six categories, that is, five pencil grips, which are the dynamic tripod, the lateral tripod, the cross thumb, the high index, and the thumb tuck grips and the sixth category for miscellaneous unclassified grips. (See Figure 10.)

The categorisation of the pencil grips in the two-dimensional model (Figures 8, 9) draws from these four descriptors. The categorisation of each pencil grip in the model is identified by the value on the descriptors as discussed on pages 47 – 48.

Results

Gender and handedness are cross-tabulated with the four descriptors in Table 3. The cross-tabulation of gender and handedness with the four pencil grip categories is given in Table 4. Overall, it is evident that the most common category was the *precision grip with ease,* which was used by half of the pupils. Roughly a third of the pupils used a *precision grip with pressure.*

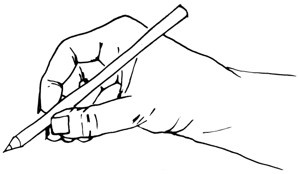
The angle of the wrist (descriptor 1):



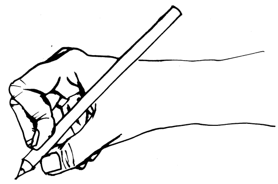
extended wrist

hooked wrist

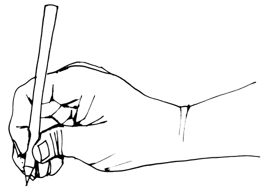
The angle of the distal interphalangeal joint of the index finger (descriptor 2) and the thumb (3):



joints of index finger and thumb in a flexed position

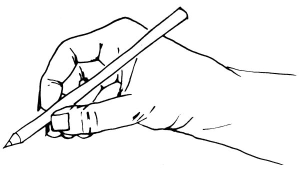


index finger joint in hyperextended position

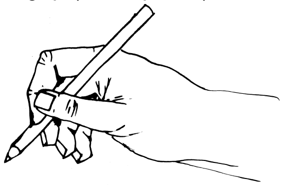


thumb joint in hyperextended position

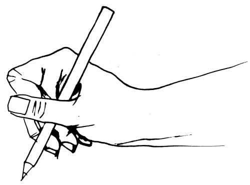
Operational definitions of the pencil grip (descriptor 4):



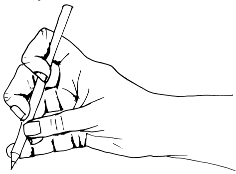
the dynamic tripod



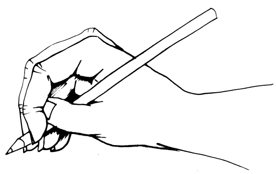
the lateral tripod



the cross thumb



the high index



the thumb tuck

Drawings by Sofia Flinck, 2002

Figure 10. Pencil grip descriptors and their categories as used when taking notes of observed writing hands. See also Appendix C.

Table 3. *Cross-tabulation of gender and handedness with four descriptors (illustrated in Figure 10) observed in each pencil grip of schoolchildren in Finland. Percentages calculated within groups.*

Descriptors	Categories	*n* = 504	%	Boys *n* = 239	%	Girls *n* = 265	%	Right-handed *n* = 455	%	Left-handed *n* = 50	%
	Right-handed	454	90	215	90	239	90				
	Left-handed	50	10	24	10	26	10				
1. Wrist position	Extended	485	96	229	96	256	97	439	97	46	92
	Hooked	19	4	10	4	9	3	15	3	4	8
2. Index finger joint	Flexed	323	64	165	69	158	60	292	64	32	64
	Hyperextended	181	36	74	31	107	40	163	36	18	36
3. Thumb joint	Flexed	499	99	235	98	264	99	450	99	49	98
	Hyperextended	5	1	4	2	1	1	4	1	1	2
4. Pencil grips	Dynamic tripod	404	80	202	85	202	76	367	81	37	74
	Lateral tripod	76	15	29	12	47	18	65	14	11	22
	Crossing thumb	11	2	3	1	8	3	10	2	1	2
	High index	8	1	3	1	5	2	7	2	1	2
	Thumb tuck	2	0.5	0	0	2	0.5	2	0.5	0	0
	Miscellaneous	3	0.5	2	1	1	0.5	3	0.5	0	0

Due to a relative lack of observations, two descriptor categories were omitted from further analyses. The first one was the *hyperextended thumb joint* (descriptor 3) with only five observations overall. The second was the *wrist position* (descriptor 1), where only 19 hooked wrist positions were observed The *operational definitions of pencil grips* comprising descriptor (4) were combined into precision grips (dynamic tripod) and power grips (lateral tripod and others).

The preferred writing hand had a similar distribution in both boys and girls. No ambi- or bidextrals were noted in the present study. A hyperextended *index finger joint* (descriptor 2) was observed in 35 per cent of both right- and left-handed pupils. Handedness was not associated with the two dimensions of the model, ease ($Chi^2 = 0.01$, $df = 1$, $p = .920$) and grip configuration ($Chi^2 = 0.93$, $df = 1$, $p = .335$).

With regard to gender, hyperextension of the index finger was observed in more girls than boys ($Chi^2 = 4.44$, $df = 1$, $p = .035$). Gender was also related to the distribution of the precision grips *vs.* power grips ($Chi^2 = 4.92$, $df = 1$, $p = 0.027$) with boys applying more precision grips than girls. Also, an association was noted between gender and the distribution of pencil grips on the two dimensions of ease ($Chi^2 = 4.38$, $df = 1$, $p = .036$) and grip configuration ($Chi^2 = 4.92$, $df = 1$, $p = .027$). Consequently more boys than girls were found in the upper right quadrant of the model applying a *precision grip with ease*, whereas girls were in the majority in the other three quadrants ($Chi^2 = 11.17$, $df = 3$, $p = .011$) (Table 4).

Table 4. *Cross-tabulation of gender and handedness of schoolchildren in Finland (absolute rates and per cent) with the four pencil grip categories in the two-dimensional model (see Figure 8).*

			Boys		Girls		Left-handed		Right-handed	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Precision grips with ease	253	50	138	58	115	43	21	42	232	51
Power grips with ease	68	14	26	11	42	16	10	20	58	13
Power grips with pressure	32	6	11	4	21	8	3	6	29	6
Precision grips with pressure	151	30	64	27	87	33	16	32	135	30
Total	504	100	239	100	265	100	50	100	454	100

Discussion

The assumption was that as a result of maturation and increased competence, as indicated in the two-dimensional model, most of the present pupils' pencil grips would be categorised as precision grips with ease, and consequently be found in the first quadrant of the model. The results placed 50 per cent of the pupils in the upper right quadrant. The lower left quadrant included 6 per cent of the pupils applying a power grip with pressure. These two grips would represent the diametric ends of recommended pencil grips or grips expected to be least or most constrained to write with. This leaves close to half of the grips in the study in the lower right power grips with ease and the upper left precision grips with pressure quadrants.

The study indicates more similarities than differences between right- and left-handed writers. Handedness did not differentiate within gender, angles of fingers, or descriptions of pencil grips. The hooked wrist position, which is the one descriptor typically believed to be a characteristic of the left-handed, was seen in both left- and right-handed pupils, but the rates were too low to allow statistical analysis. Thus, the present results neither refute nor support the notion that hooked wrists are specifically related to left-handedness.

The hyperextended index finger joint reveals the use of pressure on the ease dimension in the model for categorisation. The present results confirm that a hyperextended index finger joint is a fairly common feature though it is rarely mentioned in literature on handwriting. However, the percentage of Finnish pupils in this study demonstrating a hyperextended index finger joint is only 36 per cent (n = 504), while among British pupils the index finger hyperextension was observed in 64 per cent, n = 294 (Sassoon *et al.,* 1986). The observed differences may be specific to the two groups; they may also depict a cultural condition, or be related to the methodological differences discussed earlier.

Several gender-related differences were observed. Significantly more girls than boys used power grips rather than precision grips. Similarly, Schneck and Henderson (1990) noted that girls more often demonstrated a mature power grip configuration while boys used a mature precision grip configuration. Also, more girls than boys applied a hyperextended index finger joint. The girls did also add more pressure to their grips than boys *i.e.* an association between gender and the dimension of ease in the model is observed. The dimension of ease accounts for hyperextension in both the index finger and the thumb. Furthermore, fewer girls than boys were observed to apply a precision grip with ease (first quadrant in the model), which is considered the most mature of the pencil grips. This is in contrast to findings by Blöte and Dijkstra (1989) and Schneck and Henderson (1990) who found young girls' grips to be more mature than those of boys. However, Schneck and Henderson (1990) also noted that the differences decreased along with age up to six years.

The hand is highly adaptable. If a stable precision grip is not assumed, a number of corrective actions are undertaken to gain stability. For example, if the index finger, instead of forming an arch, is extended along the shaft to lead the pencil, the grip loses stability, which can result in less distinct writing or in increased pressure of the index for stability. This can in turn lead to hyperextension of the distal joint of the index finger.

Another posture providing the hand with stability is crossing the thumb so that the shaft of the pencil is stabilised with the distal or even the proximal part of the thumb, the latter version inhibiting all movement and sensory feedback of the thumb. The thumb tuck grip, on the other hand, is even more constrained and dependent on the movement of the wrist and more proximal joints of the upper extremities for the act of handwriting. Further, the high index grip places the tips of the thumb and digits 3, 4 and/or 5 against the pencil shaft while the fingers are tense and presumably adding more pressure than acceptable for sensory feedback. The fingers are spread along the shaft balancing for stability with the thumb as the balancing point. According to the observations of the present author, the movements in this grip are exceptionally localised to the thumb and digits 3 and/or 4 and 5. These digits rarely play such an important role in prehensile patterns. When describing the prehensile patterns of the hand the digits are identified as the thumb, the index finger, and digits 3, 4 and 5, reflecting the particular functional importance of the thumb and the index finger (Elliot and Connolly, 1984, 285).

Is there an advantage in adopting the traditionally recommended dynamic tripod grip at any cost? Perhaps an unconstrained power grip is to be preferred to a precision grip involving pressure? Ziviani (1983) and Sassoon *et al.* (1986) suggest that the concept of the dynamic tripod grip posture be widened to include the lateral tripod, a power grip. These two grips that represent different grip configurations will be further examined and their relationship to mechanical aspects of writing will be considered in Study 4.

In conclusion, the two-dimensional model provides a reasonably simple and reliable procedure for data collection in a classroom setting and for subsequent pencil grip categorisation. The model, which is based on four descriptors, is expected to provide a useful instrument for pencil grip research and will thus be used throughout the present work. Study 2 reports on stability *vs.* change in pencil grips, Study 3 compares pencil grips in a cross-cultural setting, and Study 4 examines pencil grips as related to mechanical aspects of handwriting.

STUDY 2: STABILITY *VS.* CHANGE: PENCIL GRIP DEVELOPMENT FROM GRADE ONE TO FIVE

The aim of Study 2 was to explore stability *vs.* change in children's pencil grips once formal instruction has started and the hand has assumed the writer's preferred pencil grip. Children may adopt the dynamic tripod grip by the time they enter school (Erhardt, 1994; Rosenbloom and Horton, 1971; Schneck and Henderson, 1990). Many children have not, however, adopted the dynamic tripod grip by the age of seven. Study 1 shows that a variety of pencil grips is observed in 7- to 12-year-olds and thus the question remains what happens with the pencil grip once handwriting becomes an everyday phenomenon. It has been suggested by Ziviani (1983) that pencil grip maturation continues through the school years. These assumptions are, however, based on cross-sectional studies, not on individual follow-up. The present study is set up as a longitudinal experiment.

The grips are classified by applying the two-dimensional model for pencil grip categorisation (Figure 8).

Method

Participants, procedures and observations

Non-dysfunctional pupils (*n* = 117), 64 boys and 53 girls (mean age: 7 years 8 months), were observed in grade 1 at the end of their first year of formal writing instruction (1993–1998) and in grade 5 four years later (1997–2002). The method of data collection was essentially similar to that in Study 1, see page 56.

Results

The pencil grips that were observed in grades 1 and 5 were classified in terms of the grip and ease dimensions into the four categories of the two-dimensional model (for definitions see page 51). The results are presented in Table 5, with the "cross-sectional" comparison to the left, and the follow-up observations describing stability *vs.* change in the individuals' grips to the right. The directions of change between the four pencil grip categories are illustrated in terms of the pencil grip category model in Figure 11. The figure also summarises the observed occurrences of each type of change within the model. The changes regarding the underlying descriptors are presented in Table 6.

Table 5. *Distributions of pencil grips in the same children (n = 117) observed in Grades 1 and 5. Data are construed as either "cross-sectional" (left) or longitudinal over four years (right). Observed changes within individuals in absolute numbers.*

	" Cross-sectional " comparison				Longitudinal comparison			
	Grades				Unchanged		Changed	
	1		5					
	n	%	*n*	%	*n*	%	*n*	*n*
Precision grips with ease	48	41	45	38	34	71	–14	+11
Power grips with ease	18	15	17	15	13	72	– 5	+ 4
Power grips with pressure	8	7	12	10	7	88	– 1	+ 5
Precision grips with pressure	43	37	43	37	32	74	–11	+11

"Cross-sectional" *vs.* longitudinal data analysis. To emphasise the distinction between conclusions made on the basis of cross-sectional and longitudinal data, the present observations were interpreted in both ways in Table 5. A "cross-sectional" comparison of the data in grades 1 and 5 seems to suggest that only eight individuals (7 per cent) would have changed their grips (Table 5, left). The data show that in grade 5 there are three individuals fewer in the precision grip with ease category (45 *vs.* 48), and one fewer in the power grip with ease category than in grade 1 (17 *vs.* 18). At the same time, at grade 5 there are more power grips with pressure than in grade 1 (12 *vs.* 8) whereas there is the same number of individuals (43) with a precision grip with pressure in grades 1 and 5. If the group data were interpreted as indicating change at the individual level, the stability ratio would be 93 per cent. However, the following longitudinal analysis shows that this would be a misleading conclusion.

The case-by-case analysis reveals four times as much variation as the cross-sectional analysis does. The follow-up data revealed changes in 31 individuals' pencil grips from grade 1 to 5, equivalent to 26 per cent of the 117 instead of merely 8 (7 per cent of the 117) as might be suggested by the cross-sectional data. Changes were observed in 22 per cent of the boys' pencil grips (14 of 64) *vs.* 32 per cent in the girls' grips (17 of 53) ($Chi^2 = 1.07$, $df = 1$, $p = .301$). McNemar tests on direction of change between the four pencil grip categories were all non-significant, indicating that changes "to" and "from" a category were not systematic (p-values .22 – 1.0).

Based on the longitudinal data, the observed stability ratio in the 117 pupils' pencil grips is 74 per cent (73 per cent in the 15 left-handed and 74 per cent in the 102 right-handed). More details on stability *vs.* change are presented in Table 5 (right) and in Figure 11.

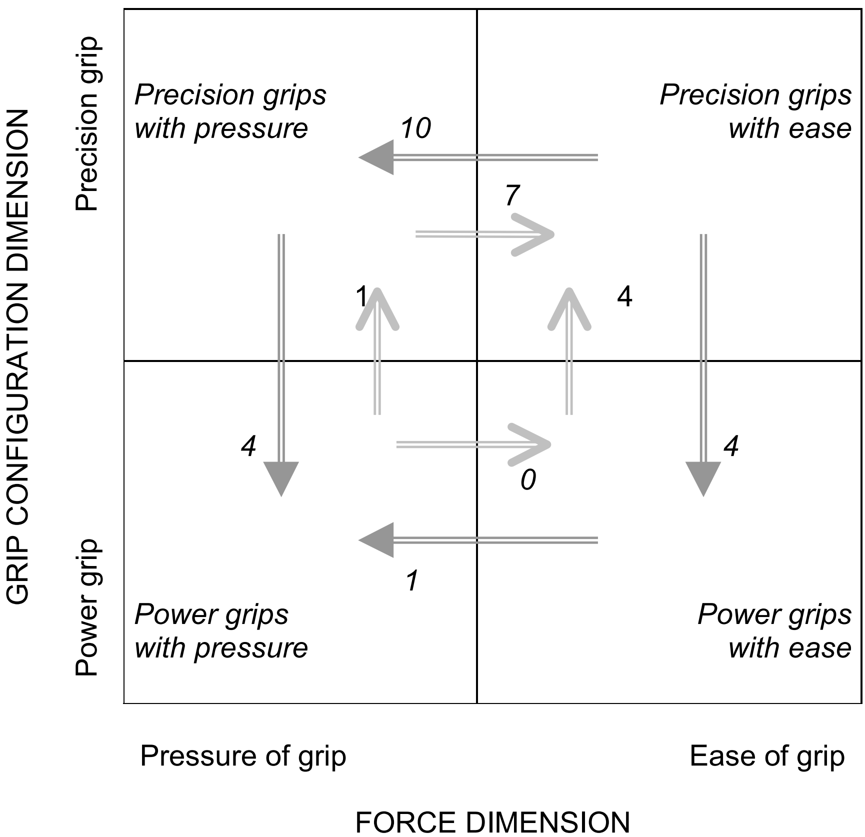


Figure 11. Changes in pencil grip visualised within the two-dimensional model for pencil grip categorisation: Number of observed changes over four years and their directions (*n* = 31 out of 117 children). No significant trends in the directions of these changes were observed.

Changes in pencil grips within the two-dimensional model are depicted in Figure 11. With refinement of grip, a person is expected to change on the grip configuration dimension from a power grip to a precision grip, and on the level of ease dimension from a grip with pressure to a grip with ease (see Figure 8). Such an expected change was seen in 12 pencil grips in that 3 boys and 2 girls changed from a power to a precision grip and 5 boys and 2 girls changed from pressure to ease of grip. The opposite (unexpected) change was observed in 2 boys and 6 girls on the grip configuration dimension and in 4 boys and 7 girls on the ease dimension, a total of 19 individuals. No pupil's pencil grip changed concurrently on both ease and grip configuration dimensions.

Changes within descriptors. A summary of the frequencies of the five descriptors of each pencil grip, as observed in grade 1 and four years later in grade 5, is presented in Table 6. Changes in the descriptors of the index finger, the thumb and the pencil grips (which describe the positioning of the fingers) may lead to the change in the categorisation of the grip. Within the grip descriptor, the change to and from the dynamic tripod reflects the location of each observation on the grip configuration dimension. Also, on the ease dimension, the change between a flexed and hyperextended thumb and finger joint defines whether the grip functions with ease or pressure.

In grade 1, a nearly significant gender-related difference was observed in the hyperextended index finger joints of the girls, 53 per cent, *vs.* the boys, 34 per cent ($Chi^2 = 3.32$, $df = 1$, $p = .068$). By grade 5, hyperextension of the index finger was significantly higher ($Chi^2 = 8.97$, $df = 1$, $p = .003$) in girls than in boys.

Table 6. *Changes in pencil grip by descriptors illustrated in Figure 10. Observations were made in Grade 1 and four years later in Grade 5 (n = 117; 64 boys and 53 girls).*

boys	girls	total					total		boys	girls
n	*n*	*n*	%				*n*	%	*n*	*n*
					(1) wrist position					
61	52	113	97	Extended	1	Extended	116	99	63	53
3	1	4	3	Hooked	4	Hooked	1	1	1	0
					(2) index finger joint					
42	25	67	57	Flexed	11	Flexed	63	54	43	20
22	28	50	43	Hyperextended	7	Hyperextended	54	46	21	33
					(3) thumb joint					
62	53	115	98	Flexed	–	Flexed	115	98	62	53
2	0	2	2	Hyperextended	–	Hyper-extended	2	2	2	0
					(4) pencil grip					
53	38	91	78	Dynamic tripod	6, 1, 1	Dynamic tripod	88	75	54	34
10	12	22	19	Lateral tripod	3, 1	Lateral tripod	24	21	9	15
0	2	2	1.5	Thumb tuck	–	Thumb tuck	3	2.5	1	2
1	1	2	1.5	Miscellaneous	2	Miscellaneous	2	1.5	0	2

Discussion

Stability within grip categories over time was seen in almost three quarters of pupils. However, changes in individuals' pencil grips were observed in 26 per cent of the cases, a phenomenon that would have been unnoticed in a cross-sectional study.

One might assume that a precision grip configuration with ease would provide a more or less ideal grip to write with. For some reason it is not always adopted and may sometimes even be abandoned, as shown in the present data. This might be due to a lack of stability in the grip, which diminishes the value of precise movements. If the grip is unstable, one of two things can happen in the highly adaptable hand. Either it abandons the precision grip with ease for a power grip with ease, or pressure is added to the precision grip for higher stability. In addition, the profile of pencil grip development might also be skewed. The present study does not show how many changes might have occurred between the two reported observations. The direction of development may also reverse before refinement has been reached, leaving the pupil with a power grip with pressure. In the present study, five of the 117 observed pupils' grips reversed to the lower left quadrant (with power grips with pressure) in which five additional individuals' grips seemingly had remained over time.

The degree of stability was the same in left- and right-handed pupils' grips.

Although changes were seen between the four quadrants in the model for pencil grip categorisation, changes within individuals' pencil grips occurred either on the *grip configuration* or the *ease dimensions*. None of the observed grips changed simultaneously over two dimensions. Regarding changes within the underlying descriptors, the analysis of the present longitudinal data do not support the conclusions by Ziviani (1983) suggesting a refinement of girls' pencil grip over age. Girls' index finger joints are more often hyperextended in grade 1, and increasingly so in grade 5, compared to the boys' finger joints. In grade 5 the difference between the genders was significant. Nevertheless, the reasons for the directions of change in pencil grips remain unclear and largely unpredictable.

STUDY 3: A COMPARISON OF PENCIL GRIPS OF PUPILS IN FINLAND AND THE USA

The aim of Study 3 was to compare the most prevalent pencil grips in schoolchildren cross-culturally. To this end, observations were collected in Finland and in the USA (see Appendix D). The difference in onset of formal instruction between these countries constituted both a complication and an opportunity. A pencil grip providing stability and mobility usually develops in a child by the age of seven (see page 8). Therefore it was thought that this would be reflected in all pupils in Finland (1–6 years of writing instruction) and in the American pupils from the age of seven (3–6 years of writing instruction). The intriguing question here is whether similar distributions of grips occur in American schoolchildren and their Finnish peers despite the two-year difference in the onset of formal writing instruction? The present study compared children with the same number of years of formal instruction but of different ages. The American children were overall two years younger than their peers in Finland. A comparison involving children of the same chronological age would also have been of interest but the group sizes were insufficient to allow such analyses.

Method

School start

Finnish children have their first formal writing lessons the year they enter school in grade 1 at the age of seven (between 6 years 8 months and 7 years 7 months). Day-care centres, operating under the social authorities, provide pre-school education for six-year-olds (new legislation in 1999). Many children attend private or public day-care prior to the pre-school year. Crayons and pencils are a natural part of all children's everyday surroundings. They are spontaneously used but there is no formal instruction or training in writing prior to the onset of school.

The American children participating in this study had their first guided writing lessons in a school setting the year they entered Kindergarten at the age of five (between 4 years 8 months and 5 years 7 months). Prior to that, material relevant to letterform exercises and writing related activities may have been used.

Handwriting is an issue in the regular schools involved in the studies. Pupils are guided to write in the handwriting recommended (Finland) or adopted (the USA) by the school authorities specifically in the first school years. The pencil grip becomes a concern when the pupil's handwriting is untidy. A variety of attempts to correct the grip and the handwriting are seen, *e.g.* modelling of the correct grip to pencil "grippers" placed on the shaft, big size pencils and handwriting exercise classes (*cf.* Ödman, 1987).

The schools

Two schools in the USA were invited to participate in the study comparing schoolchildren's pencil grips with the grip distribution observed in Cygnæus School in Åbo, Finland.

Cold Harbor Elementary School in Hanover County, Richmond, Virginia had 850 pupils in grades K-5 in 1998. The school has regular education and two special classes. Handwriting is part of the school curriculum. Pupils with untidy handwriting and awkward pencil grips can be referred to the consulting occupational therapist. Sixteen teachers agreed to participate in the study on pencil grips. In collaboration with the school's reading and resource teacher, the programme was set up and a letter was sent home to the parents asking for permission. The parents agreed to a 10-minute observation of the writing child, to a photograph being taken of the hand at work, and to the writing sample.

The Center of Reading and Writing at Rider University, Department of Graduate Education, Lawrenceville, New Jersey offers a Summer Course including an intensive six-week Reading Program for 160 pupils from Kindergarten to grade 9. Neither pencil grips nor formal teaching of handwriting are included in the programme but the present author was invited to observe the pupils at work.

Cygnæus School is a regular school for grades 1–6 with some 400 pupils in 2000. The language of instruction is Swedish and the school is situated in the City of Åbo in Finland. For more details see Study 1.

Participants

A total of 793 pupils, 504 Finnish and 289 American schoolchildren participated in the study (see Appendix D). The observations were compared by the years of formal writing instruction, by school, and by country (see Table 7).

Procedures and observations

The author observed the pencil grips during writing assignments. The observation of the writing hand was close to a real school-life situation. Initially the pupils were informed of the aim of the observation and the procedure. They were told that the aim was to learn more about the way children hold their pencils and that they would be observed while writing. A photograph would be taken of the writing hand after approximately 10 minutes of writing (*cf.* Harris and Rarick, 1963; Sassoon *et al.,* 1986; Ziviani, 1983).

After instruction, questions and answers, the pupils in Cygnæus and Cold Harbor were asked to copy age-appropriate textbook text until the necessary observations had been completed during a minimum of 10 minutes. The pencil grip observations, including the photographing of the pupils at Rider, were conducted while the pupils were working independently. They were not asked to copy anything specific or sit by the desk for the survey since that would have clashed with the objective of the programme at the Center. The pupils were engaged in individual everyday writing in response to curriculum and for pleasure.

Notes were taken by a checklist type observation scheme (Appendix C) and reviewed and double-checked against photographs (Appendix B). The grips are described by applying the two-dimensional model for pencil grip categorisation (Figure 8) and by descriptors (Figure 10).

Results

The frequencies of the observed pencil grips are presented in terms of the grip and ease dimensions and in the consequent four categories of the two-dimensional model (for the definitions see page 51) in Table 7. The cross-tabulation of gender and handedness with the detailed distribution of the four underlying descriptors in each pencil grip is presented in Appendix E for the Finnish and in Appendix F for the American pupils.

Table 7. *Frequencies of pencil grip categories observed in schools in Finland and the USA. Percentages calculated within groups. Statistical analyses of differences between groups by years of formal schooling were calculated within countries, and cross-cultural differences were analysed on the basis of data pooled over all groups.*

		Cygnæus school (Finland, *n* = 504)			Cold Harbor and Rider schools (USA, *n* = 289)			Finnish *vs.* American Schools	
	Years of writing	*n*	%	*z*	*n*	%	*z*	*z*	*p*
Precision grips with ease	1–2	170	47	1.83	15	14	0.46		
	3–6	83	59		16	9			
	1–6	253	50		31	11		6.19	.001
Power grips with ease	1–2	53	15	0.43	35	33	0.14		
	3–6	15	11		57	31			
	1–6	68	14		92	32		2.87	.01
Power grips with pressure	1–2	26	7	0.30	34	32	0.17		
	3–6	6	4		61	34			
	1–6	32	6		95	33		4.12	.001
Precision grips with pressure	1–2	114	31	0.62	23	21	1.46		
	3–6	37	26		48	26			
	1–6	151	30		71	24		0.85	*ns*

Prior to cross-cultural analysis of **the distribution of the four pencil grips described in the two-dimensional model**, the American data from the Cold Harbor Elementary School and Rider Reading Center were pooled. The respective pencil grip distributions were similar between the two schools both with regard to 1–2 years of writing ($Chi^2 = 0.23$, $df = 3$, $p = .97$) and to 3–6 years of writing ($Chi^2 = 1.33$, $df = 3$, $p = .72$). Neither did the pencil grip distribution differ by years of writing within schools (Cold Harbor School: $Chi^2 = 1.66$, $df = 3$, $p = .65$; Rider School: $Chi^2 = 1.34$, $df = 3$, $p = .72$). Analysis by years of writing within Cygnæus School data in Finland revealed a similar distribution of pencil grips within the four categories in both groups of pupils ($Chi^2 = 6.37$, $df = 3$, $p = .95$) and thus the data were pooled. The statistical analyses of the cross-cultural differences were carried out on the pooled data by standard z-test for the significance of differences in proportions (Hays, 1994). These analyses indicated that the proportional differences in the pencil grip distributions between the Finnish and American schoolchildren were significant in three categories. Regarding *precision grips with ease*, the grip was applied by half of the pupils in Finland *vs.* one in ten in the USA ($z = 6.19$, $p = 0.001$). The predominance was the opposite in both the *power grips with ease* ($z = 2.87$, $p = 0.01$) and the *power grips with pressure* ($z = 4.12$, $p = 0.001$). Differences regarding the proportional distribution of precision grips with pressure were non-significant ($z = 0.85$).

Handedness and gender as related to pencil grips. The preferred writing hand (left *vs.* right) was similarly distributed among boys and girls in the American pupils (9 per cent of the left-handed, Appendix F) as in the Finnish schoolchildren (10 per cent of the left-handed, Appendix E). Also the percentages of left and right-handed pupils over the other descriptors appear to be similar. In the USA the distribution of the pencil grips (descriptor 4) was not related to gender ($Chi^2 = 1.71$, $df = 1$, $p = .191$), whereas, in Finland, boys applied the dynamic tripod *precision grip* significantly more often than girls ($Chi^2 = 4.92$, $df = 1$, $p = .027$).

With regard to **the distribution of the four descriptors** in each pencil grip, the following cross-cultural observations were made.

As the rate of hooked wrist positions was very low with only 4 per cent of the pupils overall, no further statistical analyses were carried out on that descriptor.

With regard to the distribution of the precision grips *vs.* power grips, a cross-cultural difference in the distribution was noted (Chi^2 = 155.95, *df* = 1, *p* = .0001). More pupils in the USA than in Finland employed a power grip. Similar cross-cultural differences were seen with regard to hyperextension in the fingers as the differences in the distribution in the schoolchildren observed in the USA and Finland was significant in both the index finger (Chi^2 = 21.15, *df* = 1, *p* = .001) and the thumb (Chi^2 = 8.66, *df* = 1, *p* = .003). The hyperextended index finger joints were seen in 53 per cent of the Americans *vs.* 36 per cent in Finland. For the thumb joint, the percentages were 5 and 1 respectively (Appendices E and F). In the USA the distribution of hyperextension was not related to gender (Chi^2 = 2.39, *df* = 1, *p* = .122), while in Finland hyperextension of the index finger was observed in more girls than boys (Chi^2 = 4.44, *df* = 1, *p* = .035).

Discussion

The results reveal that significantly more American schoolchildren apply a power grip compared to their Finnish peers. Previous research has shown that a five-year-old child is more likely to use a power grip than a precision grip when handling a crayon or pencil. This is the age at which the average American child is introduced to daily writing activities. Also, the pencil grip is likely to remain unchanged in three in four of the schoolchildren over the four first years of formal instruction as revealed in Study 2. Consequently no significant change in pencil grip would be expected between those pupils who have had one to two *vs.* three to six years of formal instruction. Thus, one could assume that the majority of the pupils from the Cold Harbor and Rider schools would use a power grip configuration, rather than a precision grip, from age five on. This assumption was confirmed by the results.

Consequently, the results reveal that significantly more Finnish schoolchildren apply a precision grip compared to their American peers. Recalling that Finnish children commence their formal writing instruction in grade one (*i.e.*, in their seventh year) the pupils in Cygnæus were expected to write with a precision grip configuration rather than with a power grip, and this was confirmed by the results. Indeed, it appears that in the absence of everyday writing activities, children nevertheless develop a mature precision grip by the age of seven. The design of the study allowed for comparison of children by years of formal writing instruction. The interpretation of the results with respect to age should thus be regarded with some caution.

Concerning cross-cultural differences, this study suggests that there is a connection between the age of the child at the onset of formal writing instruction and the pencil grip adopted by the child. The results did also hint at an interaction of culture and gender in pencil grips. In the observed American schoolchildren, the boys' and girls' pencil grips were overall similar, while there were significant differences between boys' and girls' grips observed in Finland. Whether this is an effect of the onset of writing instruction at an earlier age or cultural differences remains to be studied.

In sum, the present cross-cultural comparison implies the general rule that the initially adopted pencil grip is the one that is later preferred whether it be a power grip as in the USA or a precision grip as in Finland. Which one finally prevails might depend on formal instruction strategies, motivational factors, personal writing habits, and other factors yet to be explored. However, bearing in mind that the design of the study was cross-sectional, this interpretation should be considered as preliminary. Nevertheless, the results exhibit a sufficiently distinctive pattern to suggest that further research to explore these possibilities is warranted.

STUDY 4: PENCIL GRIP AS RELATED TO WRITING FLUENCY AND LEGIBILITY

One reason why categorising pencil grip is important is the possibility that there may be a connection between the grip and the process and/or the product of handwriting. It can be expected that a writer with a precision grip with ease writes fluently and produces legible handwriting. On the other hand, a person writing with a power grip with pressure might not enjoy fluency of writing and might produce illegible handwriting as a result. At its worst "an improper grip on the writing instrument … may result in writer's cramp, a painful muscle cramp in hand and wrist" (Harris and Hodges, 1995). However, in the absence of empirical studies, statements like these remain mere speculations. Apart from studies on letter forms, systematic research on the relationship of pencil grip to writing skills seems to have been neglected to a surprising extent.

The present study looks for connections between the pencil grip categories described by the two-dimensional model (Figure 8) and writing, from two perspectives: (1) pencil grip and fluency, and (2) pencil grip and legibility. Fluency is defined in *The Literacy Dictionary* (Harris and Hodges, 1995) as the writer's ability to execute motor movements smoothly, easily and readily. Legibility is defined as how the reader perceives the writer's penmanship, style or manner of handwriting.

Method

Participants

Non-dysfunctional pupils (*n* = 61) were observed in their fifth year of formal education in grade 5 (2001–2002) at the Cygnæus School, Åbo, Finland (34 boys and 27 girls aged from 11 years 2 months to 12 years 1 month). Excluded from participation were immigrant children whose linguistic proficiency in Swedish (the language of instruction) was inadequate.

Materials and procedures

Pencil grips were observed as described above in Study 1 (see page 56). All participants completed three writing assignments to provide handwriting samples (*cf.* Berninger *et al.,* 1997; Harris and Rarick, 1963) and pencil grip observations. The author collected these data in real school-life situations. Pencil grips were classified in terms of the grip and ease dimensions and the resulting four categories of the two-dimensional model (Figure 8, pages 47 – 48).

Narrative (group assignment). The pupils were asked to write a composition in response to the photograph of a crow in its natural environment. The assignment was explained and the stimulus picture was projected on the classroom wall. There was no discussion about the picture, no restrictions as to the mode of writing or genre, and no time limit. The pupils were asked to write in cursive script, however, without reprimands should they mix in manuscript writing (Graham *et al.,* 1998b), and the duration of the writing was noted. The narrative writing assignment was developed and described by Mäki, Voeten, Vauras and Poskiparta (2001). The test administration and the restrictions in word counting of Mäki *et al.* (2001) was applied with titles and remarks indicating the end of the story being omitted, and compound words spelt out as two separate words counted as one.

Copywriting (group assignment). A group of approximately six pupils at a time were asked to copy age-appropriate textbook text (Lindell *et al.,* 1994) for 10 minutes. Each pupil had a book on the desk. The books were used as textbooks in the classes for mother tongue instruction. The procedure is described in more detail in Study 1 (pages 56 – 58).

Speedwriting (individual task). The pupil was asked to write a 20-letter six-word sentence in a decipherable cursive script as many times as possible during two minutes. The sentence "Jag vill ha en god kamrat" ["I want a good friend"] was easy to memorise and included a fair representation of 15 different letters of various shapes. After learning the sentence by heart and repeating it, the pupil was instructed to keep writing until told to stop. The author timed the assignment. Several reports present similar methods with 90 seconds to two-minute timing of handwriting for speed measurement, but with a written sample sentence to be copied (*cf.* Graham, 1986b).

Assessment of fluency and legibility

Writing skill was assessed by three converging operations of both fluency (production, mechanical and speedwriting fluency) and of legibility (reading and impression legibility and representation accuracy).

Production fluency was appraised from the narrative by counting the written words. The score was equal to the number of words in the narrative (*cf.* Graham, 1990).

Mechanical fluency was estimated from the copywriting task by counting the words written in ten minutes. The score was equal to the number of words (*cf.* length of writing in Graham, 1990).

Speedwriting fluency was measured from the speedwriting task by counting the letters produced in two minutes. The score was equal to the number of letters (*cf.* Berninger *et al.,* 1997; Graham, 1986b; Graham *et al.,* 1998a).

Reading legibility was gauged by the time needed by two teachers to read the narratives aloud. The teachers were not familiar with any of the children's handwriting beforehand and read the texts independently of each other. The scores were the number of words read by each teacher divided by the number of seconds used. In order to minimise potential bias due to variations in reading skill between the teachers, reader consistency was first evaluated by Spearman rank correlation. Since the correlation was highly significant ($rho = .71$, $p < .001$), reading legibility was scored as the average of the reading times by the two teachers.

Impression legibility was estimated by two teachers who each divided the copywritten text by visual impression into three groups (poor, acceptable and good penmanship). Ratings were given without reading the text. Subsequently the texts in each group were again subdivided into two groups, so that scores were obtained on a six-grade scale ranging from the poorest (1) to the best (6). In order to minimise potential bias due to variations in the teachers' attitudes towards various styles of penmanship, rating consistency was first evaluated by Spearman rank correlation. Since the correlation was highly significant ($rho = .79$, $p < .001$), indicating that no significant bias was present, the two rank orders were averaged to a single Impression legibility score. Similar ranking procedures have been employed by *e.g.* Graham (1986b) using a 1 to 5 scale, and by Alston (1983) and Ziviani and Elkins (1986) using a 1 to 7 scale.

Representation accuracy was estimated from the speedwriting text by two teachers counting the number of letters that accurately represented the intended one. Rater consistency was evaluated by Spearman rank correlation which suggested that inter-rater divergence was negligible ($rho = .99$, $p < .001$) and therefore the two scores were averaged to a single Representation accuracy score.

Results

Discriminant function analysis

The association of pencil grip with writing skill variables was explored by a direct discriminant analysis by SPSS10 (2002) according to the procedures described by Tabachnick and Fidell (1989). The aim was to examine whether particular writing skills might be related to the pencil grips defined by the four categories of the proposed two-dimensional model. To this end, a direct discriminant function analysis was performed using the six writing variables as predictors of membership in the four groups of pencil grip categories. The predictors were production fluency, mechanical fluency, speedwriting fluency, reading legibility, impression legibility, and representation accuracy. Groups were classified as [1] precision grips with ease (n = 22), [2] power grips with ease (n = 8), [3] power grips with pressure (n = 8) and [4] precision grips with pressure (n = 23). All 61 cases were included. Data screening suggested that two variables (production fluency and representation accuracy) were markedly skewed and these were reverted and/or log-transformed prior to analysis (see Table 8). No outliers remained after transformations. The within-groups correlations among predictor variables were low to moderate and no deviations from linearity were found by visual inspection. The Box test of equality of population covariances suggested that multivariate analysis was appropriate (F = 1.026, df = 63, 1882, p = .422).

The loading matrix of correlations between predictors and discriminant functions, as seen in Table 8, shows that three discriminant functions emerged with a combined Chi^2 = 32.9, df = 18, p < .017. After removal of the first function, which explained 74.7 per cent of the total variance, the remaining functions accounted for 19.1 per cent and 6.2 per cent, respectively. The categories of the model were significantly associated with the writing skill variables as indicated by the highly successful (70.5 per cent) categorisation of pencil grips. The results of the analysis are presented in Table 8.

Although three discriminant functions were identified, it appears that classification was primarily based on function 1, which loaded highly on mechanical fluency (-.82) and to a lesser extent on representation accuracy (-.52) and impression legibility (.51). Function 2 loaded highly on reading legibility (-.60) while the loadings on all other measures were low (< .50). Function 3 loaded highly on production fluency (.67) while other loadings were low (< .50). Among the predictors, speedwriting did not correlate highly with any discriminant function (all correlations < .50). The first function maximally separated *precision grips with ease* from *precision grips with pressure* and *power grips with ease*. The second function separated *power grips with ease* from all other grips, as shown in Figure 12.

Table 8. *Results of discriminant function analysis of writing skill variables: Correlations and univariate tests.*

Predictor variable	Correlations of predictor variables with discriminant functions			Wilks' Lambda	Univariate $F(3,57)$	p	Pooled within-group correlations among predictors				
	1	2	3				2	3	4	5	6
1. Production fluency[a] (number of words)	-.43	.46	.67	.87	2.75	*ns*	.45	.45	-.07	-.47	-.23
2. Mechanical fluency (words / 10 min)	-.82	.34	-.28	.73	7.13	.001		.65	.04	-.39	-.04
3. Speedwriting fluency (letters / 2 min)	.44	.45	.01	.88	2.52	*ns*			.07	-.24	.20
4. Reading legibility (words x 10)	-.21	-.60	.17	.93	1.40	*ns*				-.35	-.31
5. Impression legibility (scores 1, poor ñ 6, best)	.51	.44	-.31	.86	3.23	.05					.34
6. Representation accuracy[a,b] (per cent)	-.52	.40	-.48	.82	4.14	.01					
Canonical R	.59	.35	.21								
Eigenvalue	.53	.14	.04								

[a] log transformed data
[b] reverted data

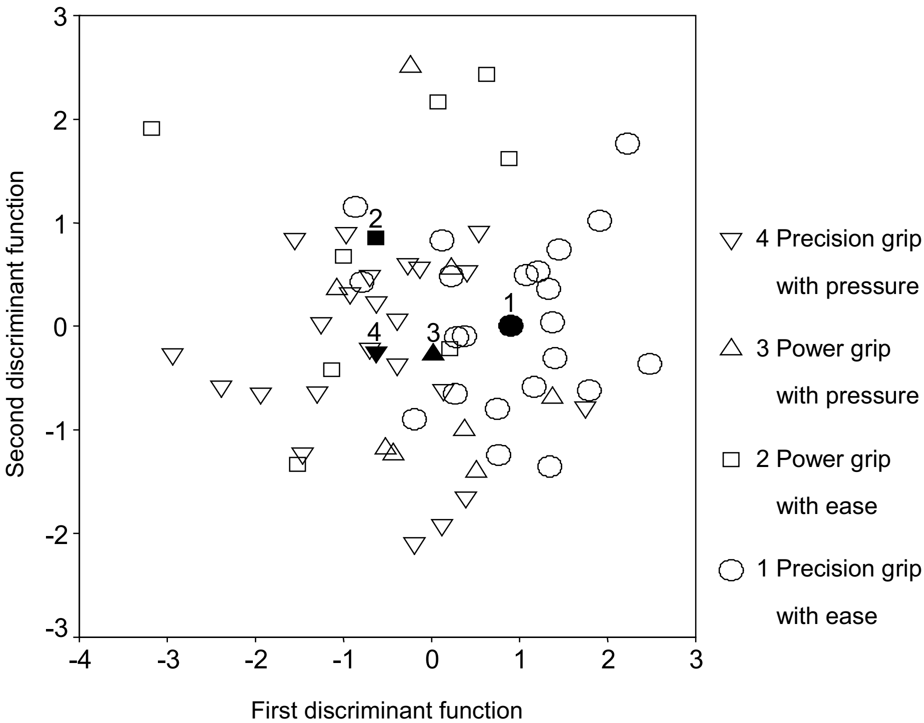


Figure 12. Distributions of six writing variables on the first two discriminant functions. Group centroids are represented by filled symbols. (*n* = 61)

Table 9. *Group statistics of discriminant function analysis of writing skill variables by pencil grip categories: Means and SD. Univariate analyses of handwriting measures by grip classification.*

	Pencil grip categories									
	Precision grips with ease *n* = 22		Power grips with ease *n* = 8		Power grips with pressure *n* = 8		Precision grips with pressure *n* = 23			
Predictor variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F* (3, 57)	*p*
Function 1:										
Mechanical fluency (words / 10 min)	80.3	23.8	119.4	28.7	92.0	34.9	111.1	24.4	7.13	.001
Representation accuracy (per cent)	.964	.028	.973	.035	.976	.048	.987	.013	2.58	.10
- reverted data log transformed	.592	.265	.409	.380	.333	.379	.306	.230		
Impression legibility (scores 1, poor – 6, best)	4.11	1.37	3.50	1.44	3.13	.99	2.93	1.30	3.23	.05
Function 2:										
Reading legibility (words x 10)	26.0	4.23	25.5	7.00	28.0	3.86	28.1	3.04	1.40	*ns*
Speedwriting fluency (letters / 2 min)	146.9	39.1	187.8	37.4	156.9	45.7	168.5	37.1	2.52	.10
Function 3:										
Production fluency (number of words)	123.1	68.5	234.6	133.4	158.4	45.2	164.8	88.2	3.48	.05
- log transformed data	2.03	.240	2.30	.265	2.18	.135	2.15	.266		

The writing measures are presented by pencil grip category in Table 9. High scores on mechanical and speedwriting fluency suggest endurance and functionality of grip. While a high score on production fluency cannot be accounted for by the pencil grip alone, the presence of fluency suggests that the writing process was at least not restrained by the pencil grip. The highest group means on all three measures of fluency were found among children using power grips with ease, while the lowest group means were found in children applying precision grips with ease. The precision grips with ease, on the other hand, were linked to high representation accuracy and impression legibility, indicating precise letter formation.

Grips with pressure coincided with the highest group means on reading legibility, the measure best reflecting the ease of access or reader-friendliness of the handwriting quality. Consequently, children applying grips with ease received the lowest scores on this measure of legibility.

In order to investigate whether there were systematic differences between the four handwriting grips and the children's performance on the six handwriting measures, handwriting variables were analysed separately by grip classification. One-way ANOVAs were conducted for each handwriting measure with grip classification as the independent variable. The results indicated that pencil grip categories were related to three of six handwriting measures: mechanical fluency, representation accuracy and impression legibility (Table 9). Levene's test for equality of variances revealed unequal variances for the production fluency and representation accuracy measures. Because of this, and concerns about unequal sample sizes, the effects of ease *vs.* pressure were investigated by t-tests, separately within the precision grip and power grip categories, assuming unequal variances where indicated.

Within-precision-grips analyses indicated that ease *vs.* pressure did not consistently improve or reduce all handwriting measures. Mechanical fluency was significantly raised as a result of increased pressure (t = 4.28, df = 43, p = .001) as was representation accuracy (t = 3.54, df = 43, p = .001 [unequal variances assumed]). Impression legibility, on the other hand, was significantly advanced by ease of precision grip (t = 2.96, df = 43, p = .01). (This is consistent with the findings presented in Table 8 where these three handwriting measures define the primary discriminant function.) The three remaining handwriting measures were not significantly related to ease *vs.* pressure.

Within-power-grips analyses did not yield any significant effects of ease *vs.* pressure for any handwriting measure. This outcome should be viewed with caution due to the small number of cases.

Discussion

The high success ratio of the classification should be regarded with some caution because the results are *post hoc* and obtained with a relatively small number of participants. Unfortunately, the limited data set also precluded the application of cross-validation procedures, which would have been advisable to estimate the extent to which the proportion of explained variance might have been exaggerated by factors specific to the current selection of participants.

The results of previous research (Elliott and Connolly, 1984, 283; Napier, 1956, 902) were, however, confirmed, in that stability seems to be an essential prerequisite for a functional pencil grip. The *power grip with ease* provides stability of grip and the comfort of writing fluency, although the handwriting as such is not appraised as particularly readable.

The letters produced by the traditionally recommended *precision grip with ease* are the most accurate, and the handwriting looks the most appealing, but the results indicate low endurance of grips. From the writer's perspective, there is no evidence in support of any advantage associated with the precision grip with ease, but neither should the results be understood as explaining writing difficulties. The results offer no support for the merits of any one grip but they do suggest that the power grip with ease should be added to the recommended pencil grip alternatives. The benefits of this grip affect the process of writing more by enhancing the writer's endurance than by the aesthetic appeal of the finished text. These features can after all be amended by re-writing or by technical means.

GENERAL DISCUSSION

Pencil grips are generally believed to affect handwriting. These assumptions are particularly common when an individual's handwriting process is tedious in combination with an awkward pencil grip. Furthermore, untidy or illegible handwriting can also direct the attention to an unusual pencil grip. Under other circumstances such diverse pencil grips might go unnoticed. Either way, whether pencil grips really matter has so far remained a hard question to test. Attempts have previously been made to describe the pencil grips of school age children by a number of operational definitions and by a rather large set of descriptors. These reports have, however, not presented a practical method which would allow for comparative studies in a school setting. A new observation tool was needed for comprehensive descriptions of the variety of pencil grips.

From details to a comprehensive model

The two-dimensional model for pencil grip categorisation, developed in the course of the present work, is a methodological contribution to research on pencil grips. The model provides an opportunity for systematic and economical research on pencil grips as they occur and their relations to other aspects of handwriting such as fluency and legibility. The model was developed through an inductive process, from which two basic components emerged. These were the grip configuration dimension and the ease of the grip dimension. The postulation of the dimensions was based on the initial research on grip development (Napier, 1956), the appraisal of the role of grip stability (Elliott and Connolly, 1984) and the analyses of the role of each descriptor in relation to the functional pencil grip. Through an iterative process preceding the construction of the model, a checklist was developed with the aim of integrating the merits of previous research. It included descriptors (Sassoon *et al.,* 1986; Ziviani, 1983) and operational definitions (Benbow, 1995; Bergmann, 1990; Blöte, 1988; Rosenbloom and Horton, 1971; Sassoon *et al.*, 1986). Ten years of observations and photographing resulted in a tool meeting its purpose. Finally, each of the observed pencil grips could be included in the model.

The present research leading to the proposed two-dimensional model started with an attempt to deal with a multitude of operational definitions (see Benbow, 1997; Bergmann, 1990; Rosenbloom and Horton, 1971), as well as descriptors (see Ziviani, 1983), or their combinations (see Blöte, 1988; Lyytinen-Lund, 1998; Sassoon *et al.,* 1986). It soon turned out that the diversity of details was so overwhelming that it became an obstacle to analysis. However, some modest progress was made.

At descriptor level the checklist and the photographs made it possible to compare subtype frequencies. Comparison with previous studies was feasible both with regard to the critical variable of the angle of the index finger joints and differences between boys and girls. However, problems were encountered when including operational definitions in the analysis. At grip level, previous studies gave no directions on how to analyse and how to weigh the effect of detailed descriptors on the pencil grip.

Furthermore, the analysis was restricted to nominal level data. Extensive attempts to explain and describe categories from details to a whole were executed using non-parametric statistics (Siegel, 1956) and statistical methods such as Neural Data Analysis (NDA), which applies self-organising maps (SOM) (Häkkinen, 2001) with no explanatory patterns emerging.

Previous studies on descriptors and operational definitions were not mutually compatible. The picture of the pencil grips remained unclear. Reported studies gave no indication on whether any given grip would be the same or should be reclassified if it included a hyperextended finger joint, a detail which can be expected to influence finger functionality. This was surprising, because this particular feature of the index finger was relatively frequently observed in the present study both in the Finnish and in the American children (Studies 1–3). The results thereby confirm the findings by Sassoon *et al.* (1986) and Ziviani (1983) who found hyperextension to be a prevalent characteristic in school age children's pencil grips.

Eventually, returning to the beginning of the process and answering the basic questions of what is relevant for the functional pencil grip resulted in the model and its four categories. Such a model for categorisation, which is based on observations, lacks the perfection of laboratory research (*cf.* van Galen, 1991; Smith and Murphy, 1963; Søvik 1975; Wann and Jones, 1986; Wann *et al.,* 1991). However, it provides the advantage of an instrument within reach for both the teacher in the classroom and for research purposes.

Changes in pencil grips

The longitudinal design of the present Study 2 is so far unique in the sense that it includes the follow-up of 117 individual schoolchildren's pencil grips over four years from grade 1 to grade 5. Moreover, the same person made all observations, thus adding to the reliability of the study. Previous studies on children's pencil grips have been conducted in cross-sectional settings. The study by Schneck and Henderson (1990) described children's grip development up to 6 years of age, and the studies by Sassoon *et al.* (1986) and Ziviani (1983) described the pencil grips observed in schoolchildren of different ages. Although the designs of these studies were cross-sectional, the authors also tried to identify time-dependent changes in pencil grip by concluding that observations of different age groups predicted continuous development towards more mature grips, particularly in girls.

To draw conclusions on individual development from cross-sectional studies is next to impossible. In the present data, the age-related change was statistically non-significant at the group level between the pencil grip categories, a result confirming previous research findings that little change appears to occur in the pencil grip over time (Sassoon *et al.,* 1986). But a follow-up of individuals revealed that one out of four in fact changed their pencil grip from one category to another, with the changes cancelling each other out at the group level. Such a change can hardly be considered non-significant at an individual level.

Also, previous assumptions on the direction of change are challenged by the present follow-up study. Based on cross-sectional data, it has been suggested that hyperextension decreases with age (Ziviani, 1983). The present studies revealed no support for such a trend in that two-thirds (19 of 31) of the changes were in the unexpected direction on the grip configuration and ease dimensions.

With regard to the two-dimensional model, it is worth noting that no pupil's pencil grips changed concurrently on both of the two dichotomous dimensions, ease of pencil manipulation and pencil grip configuration.

The question as to why some children's grips change while others remain unchanged over time remains to be studied. In the light of the present material, these changes appeared as random (with the exception that they always happened within a dimension).

Cross-cultural observations

The cross-cultural design in Study 3 is unique in the sense that the same method and procedure of pencil grip observations were applied in classroom situations both in Finland and in the USA.

Earlier studies of pencil grip development in young children have shown how a process of maturation leads to the child using a precision grip by the age of seven years (Erhardt, 1994; Rosenbloom and Horton, 1971; Schneck and Henderson, 1990). Therefore it was surmised that the majority of both the American and the Finnish schoolchildren would use a mature precision grip by the age of seven. The results from Study 3 did not support the hypothesis.

Most of the participating Finnish children used a version of the precision grip. These are the grips expected to develop in the child by the age of seven, which coincides with the age by which formal writing instruction begins in Finland. The majority of the participating American children used a version of the power grip. Such grips are expected in the five-year-old children, which is the age by which writing instruction was initiated in the group studied in the USA.

It should be considered whether the timing of school start might explain some of the differences between the grips observed in the two countries. The results imply that some children's pencil grip maturation process is interrupted before the precision grip is developed. This may be explained by the engagement in daily writing activities before a precision pencil grip has developed. Furthermore, children who are engaged in writing prior to formal writing instruction may have a grip development shaped by modelling by their parents, grandparents, siblings and day-care personnel, that is, people in their everyday life engaged in writing. On the other hand, children beginning their school career without a habitual pencil grip may be more likely to be influenced by their teachers' and peers' pencil grips.

The process of finding the optimal pencil grip might be facilitated. Before attempting to intervene in the development of the pencil grip, its connections to writing need to be clarified.

Connections to handwriting

Two findings in the present study provide evidence for a connection between pencil grip and handwriting.

Predictability of pencil grip from handwriting. The results confirmed the connection between types of handwriting and the grips. By analysing the handwriting it was possible to predict which pencil grip category the writer applied. The writing measure which loaded highest as predictor for pencil grip categorisation was mechanical writing fluency (explaining 67 per cent of the variance) calculated from the narrative writing, which reflects both endurance and ease of grip. Of course, these attributes are most useful for the writer. Production fluency, on the other hand, predicted roughly half of the variance of the third function, which accounted for only 6 per cent of the variance as a predictor of pencil grip category. The results confirmed the expected. This variable, number of words the writer chose to write on a narrative during an unlimited period of time, was not a predictor that was expected to be dependent on the pencil grip.

Effect of pencil grip on handwriting. Fluency is most important from the writer's perspective. The power grip with ease proved to be the most successful grip configuration on all three measures of fluency (*cf.* the pencil grips observed in the USA). Therefore, the present results suggest that the pencil grip can have an effect on the writer by increasing endurance of writing. Consequently the grip can also decrease writing endurance.

Legibility, or readability, is most important from the reader's perspective. The reader is influenced by the handwriting. Untidy penmanship is known to evoke negative attitudes towards the content (*cf.* Briggs, 1970). Therefore to the extent that the pencil grip affects handwriting it can also indirectly have an effect on the reader who might be reluctant to decipher the writing. On the other hand, if the pencil grip improves legibility it is also indirectly inviting to the reader. The present results on legibility in connection with pencil grip categories were somewhat ambiguous, thus leaving the question open.

Gender as related to pencil grip. A significant association with gender was noted for the dimensions of ease and grip configuration, and for the distribution of pencil grips in the four categories of the model.

An interesting note concerning pencil grips in connection to writing in the early school years is that, in the present results regarding schoolchildren in Finland, so-called mature pencil grips are more often found in boys than in girls from seven years on. Earlier studies suggest that girls' grip development was ahead of the boys' up to six years at which point the boys caught up (Blöte and Dijkstra, 1989; Schneck and Henderson, 1990). Could it be that boys are more interested in other activities than fine motor performance like handwriting, thus giving the grip more time to develop before the grip is stabilised? Also, boys' grip strength increases more during school years than girls' (Levine, 1987). This might explain why boys do not need to use a power pencil grip or to add pressure to the same extent as girls. This may, however, be partly culturally related as, in the present study, such mature pencil grips are not in the majority in the American pupils either by age-group or by gender.

Recommendations and implications

Recurrent queries over the years have been "What does a correct pencil grip look like?" and "Is this pencil grip good?"

Recommendations. The frequently recommended traditional dynamic tripod grip is still a grip to encourage. Its functional attraction lies in a combination of mobility and stability without unwarranted pressure involved. There is, however, reason to expand the number of recommended pencil grips to include power grips with ease. The results of the present study thus support the analogous suggestion by Sassoon *et al.* (1986). The positive results in writing fluency by a power grip with ease confirm earlier studies in that stability over mobility is a prerequisite for a functional hand (Elliot and Connolly, 1984). Furthermore, based on the analyses in Study 4, there are no pencil grips to be banned *a priori* for being indisputably dysfunctional.

The analysis of the pencil grip in connection to aspects of writing may add to the understanding of the whole picture of writing. The present model for pencil grip categorisation may prove to be a functional tool to be utilised in future studies tapping connections not examined in the present study. Such areas of research could range from sensory and motor factors to the writer's self-efficacy.

Implications. A question of particular interest for pre-school personnel and teachers has been: What should I do to change awkward pencil grips? Pencil grips are largely stable over time. The results from Studies 2 and 3 confirm that three of four grips are stabilised by the time the individual is engaged in everyday writing. The results suggest that if the aim is to influence a child's pencil grip, efforts should be made when the child is engaged in spontaneous daily writing or at the latest when writing instruction is commenced. Callewaert (1963) made similar suggestions. The child's love for learning should, however, not be disrupted by undesired intervention. If change is called for, intervention should be initiated when an awkward, clumsy and tense grip hinders writing or daily play writing. In such an instance the modelling person could show the child how the fingertips meet in a relaxed pose, ask the child to do likewise and then help the child shape the fingers around the pencil. Most importantly, the writing (adult) persons should use the same grip as they modelled.

There is no evidence suggesting interference with the grip that is used by the child when drawing and painting, or that specific grippers or big size pens should be used in the early days of grip development (Carlson and Cunningham, 1990; Ziviani, 1981).

Schoolchildren and adults showing signs of fatigue of the hand and inconvenience of grip should be offered options. It would be useful to introduce alternative precision and power grips with ease (Figure 9) and unusual grips like the combined or adapted pencil grip (Figure 6). The latter grip has been found as functional as the traditional tripod grip in a study by Otto *et al.* (1966). A discussion on how pencil grips can affect fluency and penmanship could be informative. Some individuals prefer removable grippers on their writing tools, gummy shafts and a variety of pencil, ball point or felt tip tools for convenience of writing. Pupils have the right to guidance and suggestions in the mechanics of writing. To achieve results, a combination of motivation and instruction is needed.

REFERENCES

Abbott, R. B. and Berninger, V. W. (1993). Structural equation modeling of relationships among developmental skills and writing skills in primary- and intermediate-grade writers. *Journal of Educational Psychology, 85,* 478–508.

de Ajuriaguerra, J. and Auzias, M. (1980). Preconditions for the development of writing in the child. In J. Hartley (Ed.), *The Psychology of Written Communication.* London: Billing & Sons, 68–81.

Alston, J. (1983). A legibility index: Can handwriting be measured? *Educational Review, 35,* 237–242.

Bailey, C. A. (1984). An investigation into the effects of pencil grip on the speed and quality of children's handwriting. *Unpublished M.Sc.Thesis. Institute of Education.* London University.

Barbe, W. B, Milone Jr., M. N. and Wasylyk, T. M. (1983). Manuscript is the "write" start. *Academic Therapy, 18,* 397–405.

Benbow, M. (1995). Principles and practices of teaching handwriting. In A. Henderson and C. Pehoski, (Eds.), *Hand function in the child: Foundation for remediation.* Chicago: Mosby, 255–281.

Benbow, M. (1997). *Neurokinesthetic approach to hand function and handwriting.* Workshop handout. Rocky Mount: Advanced Seminars Inc.

Bergmann, K. (1990). Incidence of atypical pencil grasps among nondysfunctional adults. *American Journal of Occupational Therapy, 44,* 736–740.

Berninger, V. W., Abbott, R., Rogan, L., Reed, E., Abbott, S., Brooks, A., Vaughan, K. and Graham, S. (1998). Teaching spelling to children with specific learning disabilities: The mind's ear and eye beat the computer or pencil. *Learning Disability Quarterly, 21,* 106–122.

Berninger, V. W., Fuller, F. And Whitaker, D. (1996). A process model of writing development across the life span. *Educational Psychology Review, 8,* 193–218.

Berninger, V. W. and Graham, S. (1998). Language by hand: A synthesis of a decade of research on handwriting. *Handwriting Review, 12,* 11–25.

Berninger, V. W., Vaughan, K. B., Abbott, R. D., Abbott, S. P., Rogan, L. W., Brooks, A., Reed, E. and Graham, S. (1997). Treatment of handwriting problems in beginning writers: Transfer from handwriting to composition. *Journal of Educational Psychology, 89,* 652–666.

Blöte, A. W. (1988). The development of writing behavior. *Doctoral dissertation,* University of Leiden.

Blöte, A. W. and Dijkstra, J. F. (1989). Task effects on young children's performance in manipulating a pencil. *Human Movement Science, 8,* 515–528.

Briggs, D. (1970). The influence of handwriting assessment. *Educational Research, 13,* 50–55.

Bruinsma, C. and Nieuwenhuis, C. (1991). A new method for the evaluation of handwritten material. In J. Wann, A. M. Wing and N. Søvik (Eds.), *Development of graphic skills. Research, perspectives and educational implications.* London: Academic Press, 41–51.

Burnhill, P., Hartley, J. and Davies, L. (1980). Lined paper, legibility and creativity. In J. Hartley (Ed.), *The Psychology of written communication.* London: Billing &Sons.

Butterfield, E. C. (1994). Diverse data about writing processes and their theoretical implications. In E. C. Butterfield and J. S. Carlson (Eds.), *Advances in cognition and educational practice, 2.* Greenwich, CT: JAI Press, 199–208.

Butterfield, E. C. and Carlson, J. S. (Eds.) (1994). *Advances in cognition and educational practice, 2*. Greenwich, CT: JAI Press.

Callewaert, H. (1963). For easy and legible handwriting. In V. D. Herrick (Ed.), *New horizons for research in handwriting*. University of Wisconsin Press, 39–54.

Carlson, K. and Cunningham, J. L. (1990). Effect of pencil diameter on the graphomotor skill of preschoolers. *Early Childhood Research Quarterly, 5,* 279–293.

Clark, M. M. (1974). *Teaching left-handed children*. London: Hodder and Stoughton.

Codling, R. M. and Gambrell, L. B. (1997). The motivation to write profile: An assessment tool for elementary teachers. *Instructional resource, 38*. National Reading Resource Center, College Park: University of Maryland.

Coles, R. and Goodman, Y. (1980). Do we really need those oversized pencils to write with? *Theory Into Practice, 19,* 194–196.

Elliott, J. M. and Connolly, K. J. (1984). A classification of manipulative hand movements. *Developmental Medicine & Child Neurology, 26,* 283–296.

Enstrom, E. A. (1967). Improving handwriting. *Improving College and University Teaching, 15,* 168–169.

Erhardt, R. P. (1994). *Developmental Hand dysfunction, Theory, assessment, and treatment. Erhardt Developmental Prehension Assessment.* Laurel, MD: RAMSCO.

Exner, C. E. and Henderson, A. (1995). Cognition and motor skill. In A. Henderson and C. Pehoski, (Eds.), *Hand function in the child: Foundation for remediation*. Chicago: Mosby, 93–10.

Fleiss, J. L., Cohen, J. and Everitt, B. S. (1969). Large sample standard errors of Kappa and Weighted Kappa. *Psychological Bulletin, 72, 5,* 323–327.

Furner, B. A. (1969). Recommended instructional procedures in a method emphasizing the perceptual-motor nature of learning in handwriting. *Elementary English,* 1021–1030.

van Galen, G. P. (1991). Handwriting: Issues for a psychomotor theory. *Human Movement Science, 10,* 165–191.

Graham, S. (1986a). A review of handwriting scales and factors that contribute to variability in handwriting scores. *Journal of School Psychology, 24,* 63–71.

Graham, S. (1986b). The reliability, validity, and utility of three handwriting measurement procedures. *Journal of Educational Research, 79,* 373–380.

Graham, S. (1990). The role of production factors in learning disabled students' composition. *Journal of Educational Psychology, 82,* 781–791.

Graham, S. (1992). Issues in handwriting instruction. *Focus on exceptional children, 25,* 1–14.

Graham, S., Berninger, V. W., Abbott, R. D., Abbott, S. P., and Whitaker, D. (1997). Role of mechanics in composing of elementary school students: A new methodological approach. *Journal of Educational Psychology, 89,* 170–182.

Graham, S., Berninger, V. W., Weintraub, N. and Schafer, W. (1998a). Development of handwriting fluency and legibility in grades 1–9. *Journal of Educational Research, 92,* 42–52.

Graham, S., Boyer-Shick, K. and Tippets, E. (1989). The validity of the handwriting scale from the test of written language. *Journal of Educational Research, 82,* 166–171.

Graham, S. and Harris, K. (1997). Self-regulation and writing: Where do we go from here? *Contemporary Educational Psychology, 22,* 102–114.

Graham, S., Harris, K. and Fink, B. (2000). Is handwriting causally related to learning to write? Treatment of handwriting problems in beginning writers. *Journal of Educational Psychology, 92,* 620–633.

Graham, S., Schwartz, S. S. and MacArthur, C. A. (1993). Knowledge of writing and the composing process, attitude toward writing, and self-efficacy for students with and without learning disabilities. *Journal of Learning Disabilities, 26,* 237–249.

Graham, S. and Weintraub, N. (1996). A review of handwriting research: Progress and prospects from 1980 to 1994. *Educational Psychology Review, 8,* 7–87.

Graham, S., Weintraub, N., and Berninger, V. W. (1998b). The relationship between handwriting style and speed and legibility. *Journal of Educational Research, 91,* 290–296.

Gray, W. S. (1956). *The teaching of reading and writing*. UNESCO. Chicago: Scott Foresman.

Harris, T. L. and Hodges, R. E. (Eds.) (1995). *The Literacy Dictionary. The Vocabulary of Reading and Writing.* Delaware: International Reading Association.

Harris, T. L. and Rarick, G. L. (1963). Physiological and motor correlates of handwriting legibility. In V. D. Herrick (Ed.), *New horizons for research in handwriting.* University of Wisconsin Press, 55–94.

Hayes, J. R. and Flower, L. S. (1980). Identifying the organization of writing processes. In L. W. Gregg and E. R. Steinberg (Eds.), *Cognitive processes in writing.* Hillsdale, NJ: Erlbaum, 3–30.

Hayes, J. R. and Flower, L. S. (1986). Writing research and the writer. *American Psychologist, 41,* 1106–1113.

Hays, W. L. (1994). *Statistics.* Orlando: Harcourt Brace.

Holle, B. (1980). *Normala och utvecklingshämmade barns motoriska utveckling* [Motor development in normal and developmentally impaired children]. Lund: Ekstrands.

Holle, B. (1983). *Läsberedd–skrivberedd? Praktisk vägledning* [Ready to read – ready to write? A practical guide]. Lund: Ekstrands.

Hyldgaard, L. (1982). *Öva själv. En lärobok om perception och motorik och sambanden däremellan* [Practise on your own. A handbook on perception and motor development and their correlation]. Uppsala: Manulette produktion: PROFFSet.

Häkkinen, E. (2001). Design, implementation and evaluation of neural data analysis environment. *Studies in computing 12.* Jyväskylä: University of Jyväskylä.

Jacobson, C. and Sperling, L. (1976). Classification of hand-grip. *Journal of Occupational Medicine, 18,* 395–398.

Jarman, C. (1979). *The Development of Handwriting Skills.* Oxford: Basil Blackwell.

Jean, G. (1992). *Writing, The story of alphabets and scripts.* New York: Harry N. Abrams.

Jones, D. and Christensen, C.A. (1999). Relationships between automaticity in handwriting and students' ability to generate written text. *Journal of Educational Psychology, 91,* 44–49.

Judd, J. (2000). The secret of school success lies partly in the pencil case. In *The Independent* 28.8.2000.

Kao, H. S. R. (1976). An analysis of user preference toward handwriting instruments. *Perceptual and Motor Skills, 43,* 522.

Kear, D. J., Coffman, G. A., McKenna, M. C. and Ambrosio, A. L. (2000). Measuring attitude toward writing: A new tool for teachers. *Reading Teacher, 54,* 10–23.

Knudson, R. E. (1995). Writing experiences, attitudes, and achievement of first to sixth graders. *Journal of Educational Research, 89,* 90–97.

Krzesni, J. (1971). Effect of different writing tools and paper on performance of the third grader. *Elementary English, 48,* 821–824.

Landsmeer, J. M. (1962). Power grip and precision handling. *Annals of the Rheumatic Diseases, 21,* 164–170.

Larsen, S. C. and Hammill, D. D. (1989). *TOLH, Test of Legible Handwriting. An Ecological Approach to Holistic Assessment.* Austin: Pro-Ed.

Levine, M. D. (1987). *Development, Variation and Learning Disorders.* Cambridge: Educators Publishing.

Lindell, E., Löfqvist, G., Nordlund, B., Rönnholm, P-O. and Sjöblom, I. (1994). *Rättskrivning 3,4,5,6* [Orthography]. Esbo: Editum.

Lyytinen-Lund, A-S. (1998). Developing and trialling a system for describing pencil grips. *Handwriting Review, 12,* 26–42.

Martlew, M. (1983). Problems and difficulties: Cognitive and communicative aspects of writing. In M. Martlew (Ed.), *Psychology of Written Language.* Chichester: John Wiley & Sons, 295–333.

Morrison, A. (1987). Occupational therapy for writing difficulties in spina bifida children with myelomeningocele and hydrocephalus. *British Journal of Occupational Therapy, 41,* 394–397.

Mäki, H. S., Voeten, M. J. M., Vauras, M. M. S. and Poskiparta, E. H. (2001). Predicting writing skill development with word recognition and preschool readiness skills. *Reading and Writing: An Interdisciplinary Journal, 14*, 643-672.

Napier, J. R. (1956). The prehensile movements of the human hand. *Journal of Bone and Joint Surgery, 38B,* 4, 902–913.

Otto, W., Rarick, G. L., Armstrong, J. and Koepke, M. (1966). Evaluation of a modified grip in handwriting. *Perceptual and Motor Skills, 22,* 310.

Otto, W. and Smith, R. J. (1980). *Corrective and remedial teaching*. Boston: Houghton Mifflin.

Reisman, J. E. (1991). Poor handwriting: Who is referred? *American Journal of Occupational Therapy, 45,* 849–852.

Repo, P. (2002). Uusi rennompi kynäote säästää kättä [A new relaxed pencil grip favours the hand]. In *Helsingin Sanomat* 10.2.2002

Rosenbloom, L. and Horton, M. E. (1971). The maturation of fine prehension in young children. *Developmental Medicine and Child Neurology, 13,* 3–8.

Rubin, N. and Henderson, S. E. (1982). Two sides of the same coin: Variations in teaching methods and failure to learn to write. *Special Education Forward Trends, 9,* 17–24.

Saida, Y. and Miyashita, M. (1979). Development of fine motor skill in children: Manipulation of a pencil in young children aged 2 to 6 years old. *Journal of Human Movement Studies, 5,* 104–113.

Salminen, J. (1982). *Lukemaan ja kirjoittamaan oppimisen vaikeuksista* [On difficulties in learning to read and write]. Espoo: Weilin & Göös.

Sassoon, R. (1993). *The Art and Science of Handwriting*. Oxford: Intellect Books or Bath: Bath Press.

Sassoon, R., Nimmo-Smith, I. and Wing, A. M. (1986). An analysis of children's penholds. In H. S. R. Kao, G. P. van Galen and R. Hoosain, (Eds.), *Graphonomics*. North-Holland: Elsevier, 93–106.

Scardamalia, M. and Bereiter, C. (1986). Written composition. In M. Wittrock (Ed.), *Handbook of research on teaching (3rd edn)*. New York: Macmillan, 778–803.

Schneck, C. M. (1991). Comparison of pencil-grip patterns in first graders with good and poor writing skills. *American Journal of Occupational Therapy, 45,* 8, 701–706.

Schneck, C. M. and Henderson, A. (1990). Descriptive analysis of the developmental progression of grip position for pencil and crayon control in nondysfunctional children. *American Journal of Occupational Therapy, 44,* 10, 893-900.

Siegel, S. (1956). *Nonparametric statistics for the behavioural sciences.* Tokyo: McGraw–Hill.

Smith, K. U. and Murphy, T. J. (1963). Sensory feedback mechanisms of handwriting motions and their neurometric bases. In Herrick, V. D. (Ed.), *New Horizons for Research in Handwriting.* University of Wisconsin Press, 111–157.

SPSS10 for Windows (2002). [Computer software]. Chicago: SPSS Inc.

Sweedler-Brown, C. O. (1992). The effect of training on the appearance bias of holistic essay graders. *Journal of Research and Development in Education, 26,* 24–29.

Søvik, N. (1975). *Developmental cybernetics of handwriting and graphic behavior.* Oslo: Universitetsforlaget.

Søvik, N., Arntzen, O. and Thygesen, R. (1987). Writing characteristics of "normal", dyslexic and dysgraphic children. *Journal of Human Movement Studies, 13,* 171–187.

Tabachnick, B. G. and Fidell, L. S. (1989). *Using multivariate statistics.* New York: Harper & Row.

Tinker, M. A. (1955). Prolonged reading tasks in visual research. *Journal of Applied Psychology, 39,* 444–445.

Tseng, M. H. (1998). Handwriting assessment for Chinese elementary school students. *World Federation of Occupational Therapists Bulletin, 37,* 17–23.

Tseng, M. H. and Cermak, S. A. (1993). The influence of ergonomic factors and perceptual-motor abilities on handwriting performance. *American Journal of Occupational Therapy, 47,* 919–926.

Tseng, M. H. and Murray, E. S. (1994). Differences in perceptual-motor measures in children with good and poor handwriting. *Occupational Therapy Journal of Research, 14,* 19–36.

Wann, J. P. and Jones, J. G. (1986). Space-time invariance in handwriting: Contrasts between primary school children displaying advanced or retarded handwriting acquisition. *Human Movement Science, 5,* 275–296.

Wann, J., Wing, A. M. and Søvik, N. (Eds.) (1991). *Development of graphic skills. Research, perspectives and educational implications.* London: Academic Press.

Weil, M. J. and Cunningham Amundson, S. J. (1994). Relationship between visuomotor and hadwriting skills of children in kindergarten. *American Journal of Occupational Therapy, 48,* 982–988.

Weintraub, N. and Graham, S. (2000). The contribution of gender, orthographic, finger function, and visual-motor processes to the prediction of handwriting status. *Occupational Therapy Journal of Research, 20,* 121–140.

Wynn-Parry, C. B. (1966). *Rehabilitation of the Hand* (*2nd edn.*). London: Butterworth.

Zetterholm, F. (1991). *Saras årsbok* [Sara's yearbook]. Stockholm: Natur och Kultur.

Ziviani, J. (1981). *Effects of pencil shape and size on motor accuracy and pencil posture of 8-year-old children.* ERIC: Document reproduction services.

Ziviani, J. (1982). Children's prehension while writing. A pilot investigation. *British Occupational Therapy Journal, 45,* 306–307.

Ziviani, J. (1983). Qualitative changes in dynamic tripod grip between seven and fourteen years of age. *Developmental Medicine and Child Neurology, 25,* 778–782.

Ziviani, J. and Elkins, J. (1984). Evaluation of handwriting performance. *Educational Review, 36,* 249–261.

Ziviani, J. and Elkins, J. (1986). Effect of pencil grip on handwriting speed and legibility. *Educational Review, 38,* 247–257.

Ödman, A. (1987). *Min skrivstil* [My cursive handwriting]. Esbo: Svenska läromedel.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Appendix A. The checklist of descriptors and associated features in schoolchildren [in Swedish], 1995. Drawings by Johan Lund. Two pages.

BESKRIVNING AV PENNGREPPET

G,H datum____________________

E lärarens namn______________________________

Ä lärarerfarenhet____________ år

A elevens namn______________________________

I

Ö kryssa för
- 01 klasslärare
- 02 speciallärare
- 03 annan

D klass _____________

F skola_____________

KRYSSA FÖR det alternativ som närmast motsvarar din observation.
Skriv gärna kommentarer för att förtydliga din observation.

ELEVENS ARBETSSTÄLLNING OCH RÖRELSER

M Eleven skriver med
- 01 höger hand
- 02 vänster hand
- 03 omväxlande höger och vänster hand

X Elevens arbetsställning är
- 01 normal, god
- 02 kraftigt framåtböjd
- 03 sned
- 04 en annan, beskriv __________________________

V Den icke skrivande handen
- 01 vilar på papperet
- 02 vilar i famnen
- 03 deltar i skrivandet med medrörelser
- 04 gör något annat, vad?______________________

O Den skrivande handens arm
- 01 vilar på bordet.
- 02 vilar inte på bordet
- 03 Annat att kommentera, vad?_________________

T,U Skrivrörelserna utförs
- 01 med fingrarna
- 02 med handen
- 03 med armen
- 04 Annat att kommentera, vad?_________________

N Skrivhandens handled är
- 01 rak eller böjd baktåt.
- 02 böjd framåt
- 03 Annat att kommentera, vad?_________________

PENNGREPPET

Y Pennan greppas **närmast** pennspetsen av ett eller två fingrar (eventuellt två kryss)
- 01 tummen
- 02 pekfingret
- 03 långfingret
- 04 ringfingret
- 05 lillfingret

R
- Fingrarna greppar pennan 01 på ett funktionellt avstånd från spetsen.
- Fingrarna är 02 för nära pennspetsen, skymmer texten
- Fingrarna är 03 spridda över pennskaftet

Appendix A. continued.

Q	Pekfingrets yttersta led är	01	framåt böjd
		02	rak
		03	vikt bakåt
Q1	Tummens yttersta led är	01	framåt böjd
		02	rak
		03	vikt bakåt

P Vilket av följande penngrepp liknar mest det observerade penngreppet

01 tummen och pekfingret håller om pennan som vilar mot långfingret

02 tummen, pekfingret och långfingret håller om pennan som vilar mot ringfingret

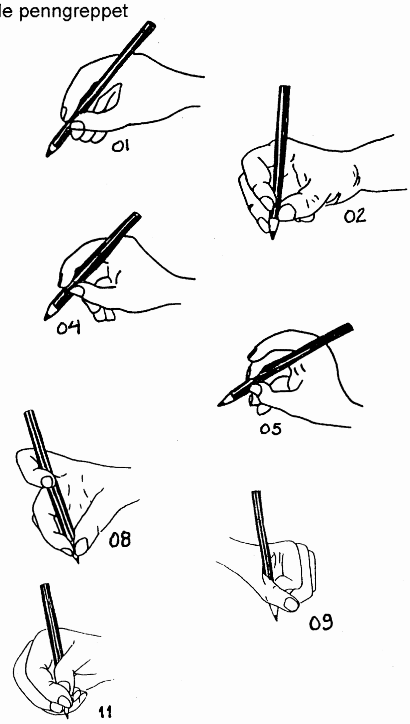
04 endast tummen och pekfingret håller om pennan, pennan vilar inte mot långfingret

05 tummen och långfingret håller om pennan, pekfingret ligger ovanför mot pennskaftet

08 tummen och långfingret håller pennan mellan fingertopparna; pekfingret greppar pennan med en fingerkrok högt uppe på pennskaftet

09 pekfingret och långfingret ligger under varandra på pennan, tummen ligger över fingertopparna

11 tummen ligger på pennan under pekfingret



12 ett annat penngrepp, beskriv det____

Z	Anser du att eleven har ett	01	fungerande penngrepp?
		02	oändamålsenligt penngrepp?
		03	Jag kan inte säga.

Å Har din bild av elevens penngrepp förtydligats?

01 ja
02 nej

Å1 Har din bild av elevens arbetsställning förtydligats?

01 ja
02 nej

Appendix B. Examples of photographs used for double-checking of checklist notes.

Appendix C. The checklist of pencil grip descriptors and their categories in schoolchildren [in English], 1998. Drawings by Johan Lund.

OBSERVATION SCHEDULE 1998 for Describing Pencil Grip

A student__________________________ **I code** __________ **I corr code**__________

Photo of the correct grip (according to observee) ☐ **Photo after** ______ **minutes** ☐

Ö observation by: _________________________

F school ______________ **D class**______ **E teacher's name** ________ _______

THE STUDENT'S WORKING POSTURE AND MOVEMENTS

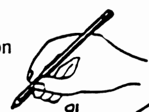
M	**The student is writing with**	01 the right hand 02 the left hand 03 alternately both hands	**X**	**The student's writing posture is**	01 normal, good 02 leaning over 03 slanting to the side 04 other, describe
V	**The non-writing hand**	01 rests on the paper 02 rests in the lap 03 makes association movements 04 does something else, describe	**O**	**The arm of the writing hand**	01 rests on the table 02 does not rest on the table
T,U	**The writing movements are conducted with**	01 the fingers 02 the hand 03 the arm	**N**	**The wrist of the writing hand is**	01 extended or turned back 02 flexed

THE PENCIL GRIP

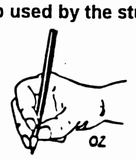
Y	**The finger or the fingers closest to the tip of the pencil**	01 thumb 02 index finger 03 middle finger 04 ring finger	**R**	**The pencil grip is** **The fingers are** **The fingers are**	01 at a functional distanc from the tip of the pencil 02 too close to the paper 03 spread over the shaft
Q	**The distal joint (DIP) of the index finger is**	01 flexed 02 extended 03 in hyperextention	**QT**	**The distal joint (DIP) of the thumb is**	01 flexed 02 extended 03 in hyperextention

P Which of the following pencil grips bears the greatests resemblance to the grip used by the student

01 the thumb and the index finger in pad-to-pad pposition pencil rests on the middle finger

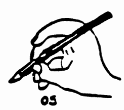


02 the thumb, index and middle fingers in pad-to-pad opposition,pencil does not rest on the middle finger



04 the thumb and the index finger in pad-to-pad pposition pencil does not rest on the middle finger

05 the thumb and the middle finger in pad-to-pad opposition, the index finger is on the shaft



08 the thumb and the middle finger in pad-to-pad pposition the index finger hooks the shaft higher up

09 the index and the middle fingers are pad against the shaft, the thumb covers the finger tips

11 the thumb is pad against the shaft covered by the index finger

12 other, describe

Z Do you consider the student's pencil grip

01 functional
02 dysfunctional
03 I cannot say

Appendix D. The total number of 1747 pencil grip observations in the database including observations of 940 individuals in four schools, and the number of participants in the four studies per school and grade. The database also includes observations not presently reported.

				Studies					
	Finland	USA		1.	2.	3.			4.
	Cygnæus	3 schools	Total	Cygnæus	Cygnæus	Cygnæus	Cold Harbor	Rider	Cygnæus
Preschool / Kindergarten	106[1]	43	149				39[3]	4[3]	
Grade 1	234	66	300	234	117	234[3,4]	34	30	
Grade 2	248	65	313	129		129	45[4]	19[4]	
Grade 3	174	51	225	3		3	23	20	
Grade 4	125	73	198	22		22	43	13	
Grade 5	264	27	291	16	117	16	7	12	61
Grade 6	196	14	210	100		100		5	
Grade 7		8	8						
Grade 8	39[1]	10	49						
Grade 9		4	4						
Total	1386	361	1747	504[2]	117	504[2]	191	98	61

[1] Cygnæus' school pupils during grades 1–6, tested prior or after enrollment.
[2] The first observation of each individual during grades 1–6 was included in the study.
[3] The first year of formal writing instruction.
[4] Seven-years-old.

Appendix E. Cross-tabulation of gender and handedness with four descriptors (illustrated in Figure 10) observed in each pencil grip of school children in Finland. Percentages calculated within groups.

				Boys		Girls		Right-handed		Left-handed	
		n = 504	%	*n* = 239	%	*n* = 265	%	*n* = 455	%	*n* = 50	%
	Right-handed	454	90	215	90	239	90				
	Left-handed	50	10	24	10	26	10				
Descriptors	Categories										
1. Wrist position	Extended	485	96	229	96	256	97	439	97	46	92
	Hooked	19	4	10	4	9	3	15	3	4	8
2. Index finger joint	Flexed	323	64	165	69	158	60	292	64	32	64
	Hyperextended	181	36	74	31	107	40	163	36	18	36
3. Thumb joint	Flexed	499	99	235	98	264	99	450	99	49	98
	Hyperextended	5	1	4	2	1	1	4	1	1	2
4. Pencil grips	Dynamic tripod	404	80	202	85	202	76	367	81	37	74
	Lateral tripod	76	15	29	12	47	18	65	14	11	22
	Crossing thumb	11	2	3	1	8	3	10	2	1	2
	High index	8	1	3	1	5	2	7	2	1	2
	Thumb tuck	2	0.5	0	0	2	0.5	2	0.5	0	0
	Miscellaneous	3	0.5	2	1	1	0.5	3	0.5	0	0

Appendix F. Cross-tabulation of gender and handedness with four descriptors (illustrated in Figure 10) observed in each pencil grip of schoolchildren in the USA. Percentages calculated within groups.

				Boys		Girls		Right-handed		Left-handed	
		n = 289	%	*n* = 138	%	*n* = 151	%	*n* = 262	%	*n* = 27	%
	Right-handed	262	91	125	91	137	91				
	Left-handed	27	9	13	9	14	9				
Descriptors	Categories										
1. Wrist position	Extended	279	96	134	97	145	96	253	97	26	96
	Hooked	10	4	4	3	6	4	9	3	1	4
2. Index finger joint	Flexed	136	47	72	52	64	42	121	46	15	56
	Hyperextended	153	53	66	48	87	58	141	54	12	44
3. Thumb joint	Flexed	276	95	129	93	147	97	252	96	24	89
	Hyperextended	13	5	9	7	4	3	10	4	3	11
4. Pencil grips	Dynamic tripod	103	36	55	40	48	32	97	37	6	22
	Lateral tripod	74	26	37	27	37	24	68	26	6	22
	Crossing thumb	15	5	4	3	11	7	13	5	2	7.5
	High index	53	18	22	16	31	21	47	18	6	22
	Thumb tuck	26	9	12	8	14	9	21	8	5	19
	Miscellaneous	18	6	8	6	10	7	16	6	2	7.5

The study introduces a descriptive two-dimensional model for the categorisation of pencil grips, which is suitable for application in a classroom setting. The model is used in four empirical studies of children during the first six years of writing instruction. A depiction of pencil grips and their development is presented. A cross-cultural comparison of grips observed in Finland and the USA showed that the distribution of the pencil grips observed in the American pupils was significantly different from those found in Finland. The relationship between pencil grips and handwriting is investigated, and theories that certain grips lead to illegibility and/or to strain in the hand are in general not confirmed. Certain pencil grips that previously were considered deleterious might therefore be included among those accepted by schools.

Åbo Akademi University Press