FACTORS AFFECTING THE CHINESE HANDWRITING PERFORMANCE OF CHILDREN IN HONG KONG

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A thesis submitted in partial fulfillment of the requirements for the Degree of

Master of Philosophy

Department of Rehabilitation Sciences

The Hong Kong Polytechnic University

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CERTIFICATION OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written nor material which has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Signed: ______________________________

Candice, Wai-Shan CHEUNG

(Candidate)

DEDICATION

This thesis is dedicated to my dearest Lord father with his support and power. I would also like to dedicate the work to my parents and my sister Cherry.

ABSTRACT of thesis entitled

"**Factors Affecting the Chinese Handwriting Performance of Children in Hong Kong**" submitted by **Candice Wai-Shan CHEUNG** for the degree of "**Master of Philosophy**" at The Hong Kong Polytechnic University in February 2007.

Background:

Handwriting has long been an effective means to record information, transmit message and project feelings (Chu, 1997) for communication among people. Performance in written production has been used to identify children who have risk of academic failure (Moore & Rust, 1989) and found to be linked with children's academic achievement (Opper, 1996), their school participation and social integration (Mancini & Coster, 2004), and also the adulthood development (Sutton Hamilton, 2002). Understanding on the crucial factors that affect children's handwriting performance is essential in formulating effective helping strategies and treatment.

Through analysis of the performance components, handwriting demanded a child's cognitive and executive function, neuromuscular control, kinesthetic and tactile sensitivities, visual motor co-ordination and visual perceptual skills (Feder, 2005; Rosenblum, Weiss & Parush, 2003; Ziviani & Watson-Will, 1998).

Research aims & Methodology:

This study aimed to find out the crucial factors which would affect, or predict, children's performance in writing Chinese under the social and learning culture of Hong Kong. There are 3 phases in the study.

Phase I of the study aimed to validate an assessment for Chinese handwriting performance in terms of time, length, speed, pressure, and legibility, hand strength, ocular motor control, visual perceptual skills and visual motor integration. 10 children, 6 girls and 4 boys, studying in Primary 1 in Hong Kong (mean age=7.3, SD=0.5) recruited via convenience sampling were assessed twice at 1 week interval to evaluate the test-retest reliability, inter and intrarater reliability, internal consistency and construct validity of the tools. Reliability analysis (ICC), Cronbach's alpha, Mann Whitney U Test and discriminant analysis were used for these reliability tests respectively.

Phase II of the study aimed to investigate the crucial factors affecting handwriting performance with use of multiple regression analysis. 240 children, with 118 (49.2%) girls and 122 (50.8%) boys, studying in Primary 1 (mean age=6.5, SD=0.4) were recruited from three randomly drawn primary schools. The same procedure was applied as in Phase I while evaluation of fine motor skills was added into the assessment protocol.

Phase III of the study aimed to evaluate an intervention derived from the findings in Phase II. 30 children (aged 7-10) with specific learning difficulties were recruited via convenience sampling. They were provided with ocular motor control training, visual perceptual and visual motor integration skills training, or no training as control. Their Chinese handwriting performance in terms of time, length, speed, pressure, and legibility, ocular motor control (including fixation, regression and excursion), visual perceptual skills and visual motor integration were assessed before, after, and one-month after the training. Besides the descriptive data, ANOVA tests under general linear model were used in analyzing the within group and between group effects of the ocular motor control training program and the visual perceptual/ visual motor integration training program as compared with the control group.

Results & Discussion:

Several major findings were obtained in this thesis.

The result of the reliability tests in Phase I suggested that the current assessment protocol should be reliable for the evaluation of Chinese handwriting among children in Hong Kong. The result of Phase II revealed that visuo-motor skills including the visual perceptual skills, visual motor integration, and ocular motor control were the main factors affecting Chinese handwriting performance. The visual perceptual skills were found as predictors for the time factors including total time, in air time, and the ground to air time ratio in the model ($|\beta|$ ranged from 0.140 to 0.189, p ranged from 0.004 to 0.035), with an R-square of 0.020, 0.036, and 0.024 respectively. Moreover, eye movement reflected by the Developmental Eye Movement Test (DEM) time was found to be a significant factor for significantly predicting length, speed, and pressure during handwriting, with a $|\beta|$ ranging from 0.132 to 0.320 (p ranged from 0.000 to 0.046). Besides the DEM, both the VMI and BO scores were also found predictive to the speed. Beta value was 0.214 ($p=0.001$) and 0.139 ($p=0.037$) for mean of speed, while it was -0.175 ($p=0.009$) and 0.156 ($p=0.023$) for speed variation respectively. Predictors for legibility (discriminant function> 0.40) revealed by discriminant analysis were the Developmental Test of Visual Motor Integration (VMI) score (0.696), gender (0.667) and the Motor-free Visual Perceptual Test-Reised (MVPT-R) socre (0.543). Hence, preliminary 5-week 10 sessions training protocols for ocular motor control and for visual perception and visual motor integration were produced and conducted respectively in Phase III.

Results from the Phase III showed children who had received ocular motor training demonstrated significant differences in handwriting performance including pen in air time, speed and pressure. They also presented a higher legibility score after training. However, no statistically significant difference was observed in the general linear model ($p>0.05$) when compared with both the VP/VMI group and the control group, though, subjective feedbacks from parents reflected improvement in attention and sustainability in doing homework. Therefore, these qualitative findings need further standardized investigation for verification.

Conclusion:

The current results suggested that besides visual perceptual and motor skills, ocular motor control was another crucial factor in writing Chinese characters. While the importance of perceptual and motor skills has been frequently reported in previous literature, the identification of ocular motor control as being important might reflect the unique requirement of eye fixation and tracking in writing Chinese. Prelim findings also suggested the effect of ocular motor control training on handwriting performance. Further investigation is needed to verify the current findings and modification on the training protocol should be made in the future studies based on the results obtained in this study.

Key Words:

Handwriting legibility, speed, eye movement, visual perception, visual motor integration

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Cheung, C. W. S. & Li-Tsang, C. W. P. (2007) Transfer of skills to teachers and parents in enhancing handwriting performance. The Tenth Biennial Conference of the International Association of Special Education (IASE). International Association of Special Education (p122). Hong Kong: IASE.

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Chapter 1 Introduction

1.1 Introduction

Handwriting is a kind of human skills that is commonly used for communication (Thomassen, Keuss & van Galen, 1984; Chu, 1997). Using the hands, we construct forms and symbols with simple strokes. With a given meaning, the forms and symbols are used for transmitting information and projecting feelings (Chu, 1997). This process was described as handwriting, which is, a language by hand (Berninger, 2004; Berninger et al., 2002).

Handwriting is also used as a tool for learning. Children usually spent half of their school days engaging in fine motor tasks such as paper and pencil activities and handwriting tasks (McHale & Cermak, 1992; Opper, 1992; Tseng & Chow, 2000). Handwriting skills have become an automatic tool which helps children organize their thoughts and express their knowledge (Phelps, Stempel & Speck, 1985). Performance in written production has been used to identify children who have risk of academic failure (Moore & Rust, 1989). It was also one of the most important predictors for academic achievement of children in Hong Kong (Opper, 1996).

Children with handwriting difficulties were usually referred by their teachers to occupational therapists for intervention (Hammerschmidt & Sudsawad, 2004; Bonney, 1992). There were increasing referrals for handwriting training on those children experiencing motor difficulties and coordination dysfunction (Rosenblum, Weiss & Parush, 2003; Miller et al., 2001). According to a report by American Psychiatric Association (APA) in 1994 (DSM-IV), children with Developmental Coordination Disorder (DCD), Special Learning Disability (SLD) and those defined as ‘clumsy’, had higher prevalence to handwriting difficulties. Overall, the percentage of the elementary school children experiencing difficulties in handwriting was about 10% to 30% (Rosenblum, Weiss & Parush, 2004).

In Hong Kong, children having a diagnosis of reading and writing problems accounted for seventeen percent among those referred to Child Assessment Service (Lam, 1999). Another local report conducted in 2004 by the Heep Hong Society reported that five to ten percent of the school-aged population in Hong Kong experienced reading and writing difficulties (unpublished local report, 2004).

Bonney (1992) reported that handwriting difficulties could be *“experienced by children with physical, sensory, intellectual or learning disabilities, or by children with no other identified difficulty”*. No matter the type of diagnosis, children in this population would experience different extent of difficulties in performing the handwriting task and also in the development of other aspects in their lives. However, their problems were usually overlooked and misconceived as being unmotivated, lazy and less capable (The Chinese University of Hong Kong, 1998). In fact, various impacts have been described in previous studies for the children with handwriting difficulties. Their problems in handwriting were usually associated with difficulties in attention and learning (Miller et al., 2001). This group of children also experienced difficulties in academic achievement, social participation and integration as well as psychological well-being (Opper, 1996; Mancini & Coster, 2004; Rosenblum, Weiss & Parush, 2003; Preminger, Weiss & Weintraub, 2004), which would affect their future development in adulthood (Sutton Hamilton, 2002).

With an ultimate goal to facilitate the social integration and role functioning of this group of children, occupational therapists made use of activities to facilitate the performance in different fundamental skills such as motor skills, sensory perceptual skills, and visuo-motor integration skill. Therefore, it is worthwhile to investigate the role of different fundamental skills in affecting the handwriting skills such that effective screening and intervention could be developed.

1.2 Theoretical framework

1.2.1 The Occupational Performance Model

The Occupational Performance (OP) Model was commonly adopted by the occupational therapists as a frame of reference. As described by Pedretti (1985), the OP Model gave an organized reference on different domains of concern of occupational therapy. Throughout the years, various modifications have been done on the model to account the developmental issues of the child (Fearing, Law & Clark, 1997; Strong et al., 1999; Baum & Law, 1997; Canadian Association of Occupational Therapist, 1997). Despite the modifications, eight major concepts of the model have been widely applied, including the occupational performance, occupational performance roles, occupational performance areas, components of occupational performance, core elements of occupational performance, environment, space and time (Chapparo & Ranka, 1997).

As shown in Figure 1.1, the concepts in the theoretical structure of the model were interrelated. For example, while the occupational performance was defined depending on the person's occupational role, the role was also affected by the environmental context in particular space and time. Occupational therapists were trained to remediate the dysfunctions of components of different occupational performances with the ultimate goal to improve the occupational performance such as handwriting (Rice, 2000; Baum & Law, 1997; Strong et al., 1999; Fearing, Law & Clark, 1997; Chu, 1997). Prior to treatment planning, therapists had to collect information about the child's function and dysfunction such that individualized treatment objectives could be set according to their needs.

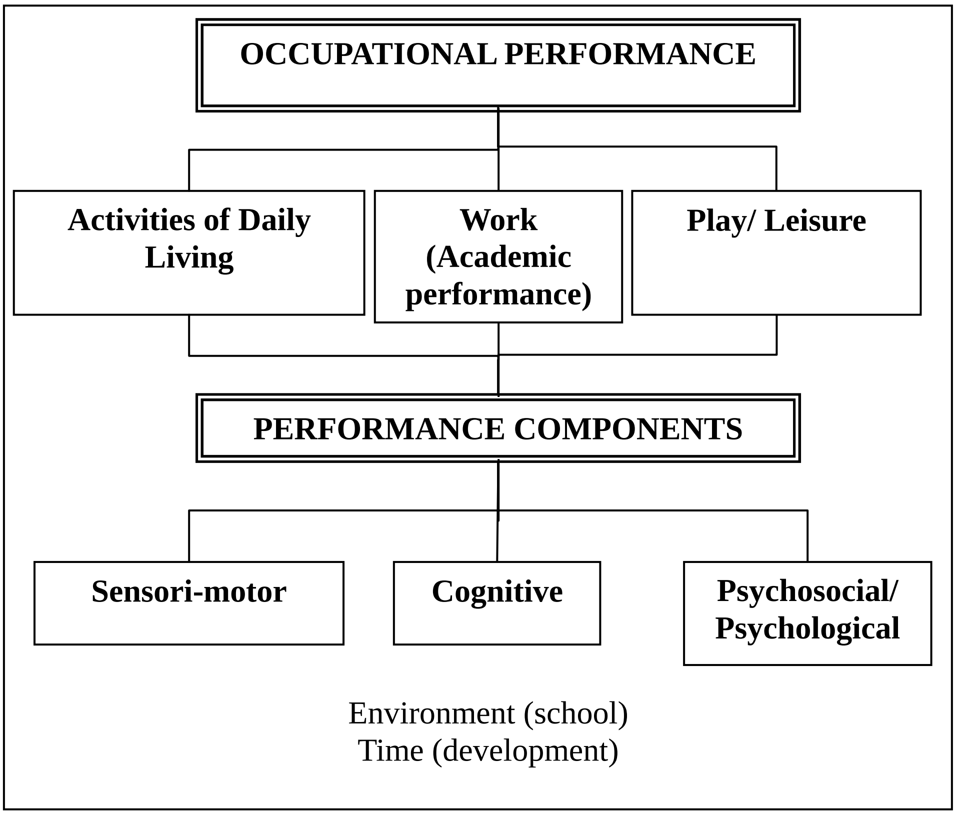

Figure 1.1 The Occupational Performance Model (OP Model)

1.2.2 The Conceptual Model for Performance in Handwriting

In 1997, the Conceptual Model for Performance in Handwriting was introduced by Chu (1997) as a reference for handwriting evaluation and training. In his model, Chu (1997) expressed that handwriting was one of the productive activities among children. Three aspects of handwriting performance were highlighted:

a. Biomechanical and ergonomic factors: sitting posture, pencil grip, writing tools and papers;
b. Quality of writing: leveling, directionality and spacing in letter formation;
c. Observations and other considerations: associated reactions and behavioural responses.

Other than the concept of environmental and temporal contexts, the concept of performance components was also adopted from the OP Model. Chu (1997) claimed that handwriting was affected by various performance components such as kinesthetic sensation, visual perception and visual motor skills. It was believed that the deficits in the performance components would affect children's functional performance in handwriting.

For example, a child's deficit in praxis and motor function might limit or affect the quality of movement, hence, affecting the quality in writing. This impact might result in a poor performance in handwriting.

1.2.3 The Modified Conceptual Model for Handwriting Performance

In this study, the theoretical concepts from the OP Model and the Conceptual Model for Performance in Handwriting were used as frame of reference for the analysis of handwriting and research design. A modified conceptual framework, namely the Modified Conceptual Model for Handwriting Performance (Figure 1.2), was developed and adopted throughout this study.

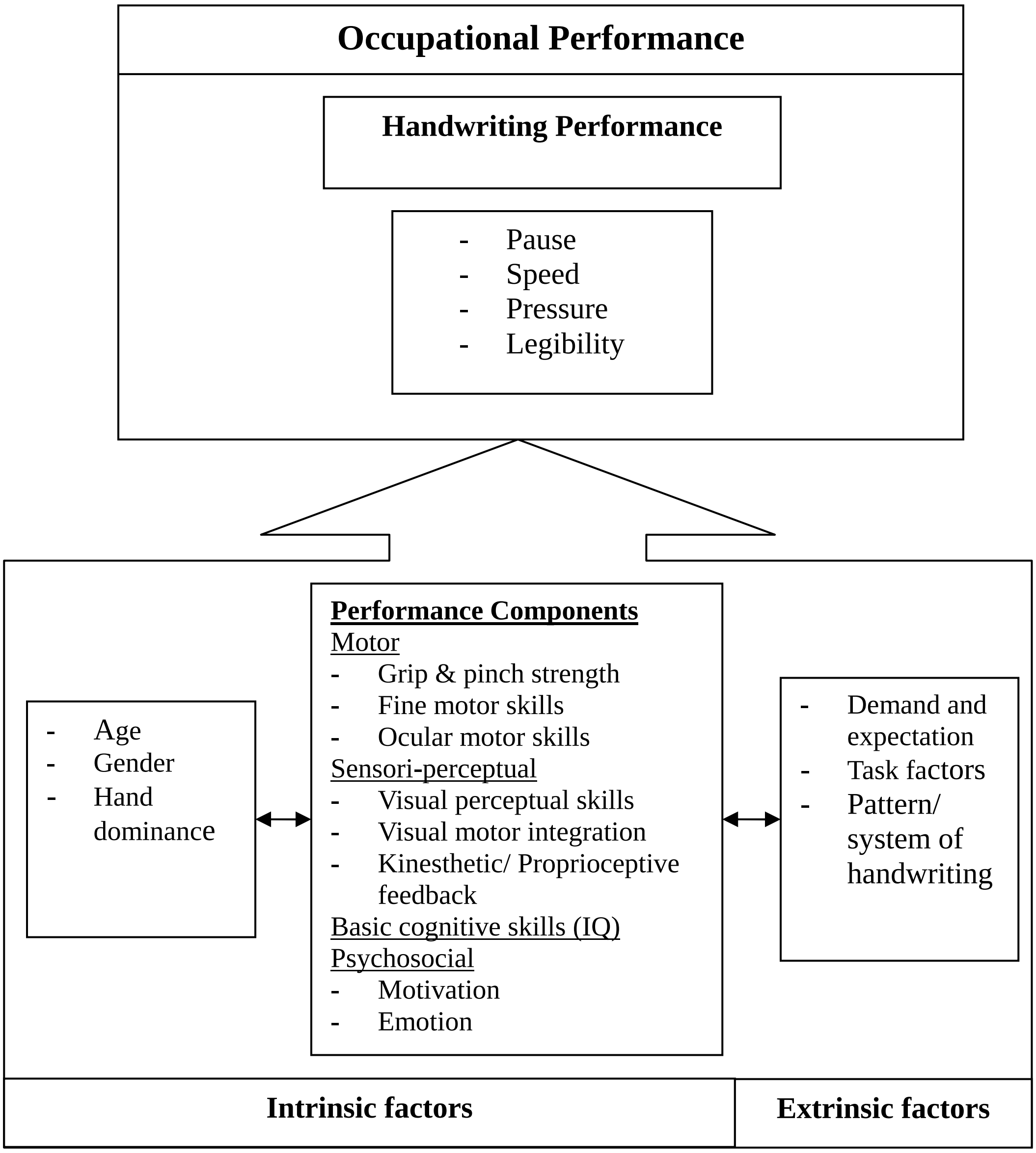

Figure 1.2 The Modified Conceptual Model for Handwriting Performance

In this model, handwriting was the occupational performance as defined in the OP Model. Various components in the handwriting performance including the pause time, speed, pressure, and legibility were the constructs of handwriting performance.

As suggested by Chu (1997), various performance components involved in handwriting were adopted in this model as the intrinsic factors affecting the handwriting performance. In addition, other intrinsic factors including age, gender and hand dominance of the child as well as the extrinsic factors including culture demands and expectation, the task factors and pattern or system of handwriting were added into the model so as to account these factors as covariates. The factors may have various degrees of impact on the handwriting performance. On one hand, the deficit or limitation in the factors would worsen the performance in handwriting; on the other hand, facilitation or modification on these factors could help improve performance in handwriting.

With the use of the Modified Conceptual Model for Handwriting Performance, this study targeted to explore and examine the relationship between these factors and the handwriting performance. The crucial factors in terms of performance components would be identified for evaluation of their effectiveness for facilitating the handwriting performance among children.

1.3 Justification of the study

1.3.1 Role functioning and school integration in primary study

Writing is one of the main learning objectives in Chinese and English curriculum (Curriculum Development Council, HKSAR, 2004, p.9). It is important to help children with learning or handwriting difficulties to accomplish the school tasks so that they can integrate better into the school system.

However, not all children can master appropriate handwriting. According to a local unpublished report by the Heep Hong Society (unpublished, 2004), five to ten percent of school-aged children presented with difficulties in handwriting and reading. Their unsatisfactory quality in handwriting would have poor impact on their academic performances (Amundson & Weil, 2001; Rosenblum, Parush & Weiss, 2003), psychological well-being and social functioning (Cornhill & Case-Smith, 1996; Kaminsky & Powers, 1981). Early identification of handwriting difficulties is essential in preventing further impact on children's development. In Hong Kong, children are expected to write legibly and effectively in primary school especially in academic tasks such as dictation. Understanding their characteristics of Chinese handwriting performance would be helpful for estimating the handwriting ability that helps in planning early intervention for children with writing difficulties and prepares them a better adaptation in primary studies and facilitates their role functioning as a student (Handley-More et al., 2003). Thus, children with handwriting difficulties could better be prepared for their primary education and learn better under the mainstream primary education system with better integration, hence minimizing the negative impacts resulting from poor handwriting in their academic development and psychosocial well-being.

1.3.2 Factors affecting handwriting performance

Handwriting was described as a complex process that requires a child's cognitive, kinesthetic, and perceptual-motor skills (Rosenblum, Weiss & Parush, 2003). These skills, called the performance components (PC) by occupational therapists, were treated so as to improve the functioning of occupational performance (OP) using a bottom-up approach (Rice, 2000; Baum & Law, 1997; Strong et al., 1999; Fearing, Law & Clark, 1997). They were described as the underlying components that are essential for the achievement of occupational performance in the Model of Occupational Performance. Understanding the correlation and predictability of these component skills is helpful for the clinical reasoning in scopes of screening, assessment and treatment. While there have been an increasing number of studies devoted to examining the relationship between handwriting performance and other factors, most of them were performed on phonetic-based language such as English and Hebrew. Categorized as a morphemic language, research on factors affecting Chinese handwriting performance is needed and should be more helpful for the Chinese children with handwriting difficulties.

1.3.3 Evaluation on handwriting performance

Handwriting is a complex functional task that involves various components. Previous studies have mainly focused on the evaluation and treatment was mainly on legibility and speed (Tseng & Hseuh, 1997; Tseng & Chow, 2000). The quality of handwriting and its process were often missed or rated too subjectively (Rosenblum, Weiss & Parush, 2003; Hammerschmidt & Sudsawad, 2004). In recent years, researchers have suggested that the writing process was also an important area to find out the handwriting problems which would be helpful in the specific identification of handwriting difficulties (Rosenblum, Weiss & Parush, 2003; Longstaff & Heath, 1997). While both information on product and process of handwriting are essential in identifying and helping children with handwriting difficulties, a comprehensive investigation of handwriting profile and the underlying factors on these two dimensions of handwriting is needed.

1.3.4 Characteristics of Chinese handwriting

Different written languages have their unique characteristics and format according to their originality and development. While most western languages were developed based on the Latin words, Chinese seemed to have its own characteristics as compared to other languages (Tan et al., 2000; Tseng & Hsueh, 1997; Matthews, Fu & Chan, 2002; Leong & Tamaoka, 1998; Siok et al., 2004).

Moreover, the composition of the Chinese characters with discrete strokes and separated parts might have different requirements on basic components of the children. And the more, evaluation instruments developed based on the principle of English handwriting might not be valid among Chinese population and in writing Chinese words. Thus, the characteristics and the factors affecting Chinese handwriting among children deserve research attention.

1.4 Objectives of the study

The main goal of this study was to validate an assessment protocol and use it to identify the crucial factors which would affect the Chinese handwriting performance. The findings would then be applied in a therapeutic training for evaluating its effects on enhancement of the Chinese handwriting performance among children.

According to the goal, four primary objectives were targeted to be investigated:

1. To evaluate the reliability and validity of the assessment protocol for objective measures in performance components and handwriting performance, in terms of
    a) test-retest & raters (inter and intra) reliabilities;
    b) internal consistency;
    c) construct validity;
2. To find out the characteristics and profile of children performance in writing Chinese words;
3. To explore the crucial performance components affecting various constructs of the Chinese handwriting performance among children;
4. To evaluate the effectiveness of an intervention protocol based on the identified performance components on children's handwriting performance including time, speed and its variability, pressure and its variability, and the legibility.

1.5 Research design

Three phases were proposed and developed for the investigation. Prior to the implementation, approval has been given by the Human Subjects Ethics Committee, The Hong Kong Polytechnic University for the research proposal and corresponding consent forms were collected. (Appendix A: consent form and letter of approval)

Phase I of the study was a cross sectional study. Several performance components were first identified as the key factors affecting the process of handwriting with reference to the literature. Then, standardized tests for the evaluation of each of these factors were chosen with justification, and the reliability values were obtained. Since the investigation in the main study relies on a reliable and suitable assessment protocol for outcome measures, systematic evaluation of the assessment protocol could provide information on its suitability and identify the possible difficulties during the implementation process.

Phase II of the study was also a cross sectional study which aimed to explore the predictability among performance components for the handwriting performance in terms of time, speed and its variability, pressure and its variability, and the legibility. The findings helped to identify the key factors that would affect Chinese handwriting performance among the primary school children in Hong Kong. In this phase, the correlation between profile of the Chinese handwriting performance and the performance components was investigated to determine whether the proposed performance components were the crucial factors related to the process of Chinese handwriting in Hong Kong children, who were learning Chinese language regardless the phonological components of a character.

Based on the findings of phase II, intervention protocols were developed and evaluated using a matched subject design. The program was reviewed and modified based on opinions of the clinical experts in the field so that it would not pose any potential danger to the children when implemented. Clinical effectiveness of the program was evaluated by assessing children's handwriting performance before, after and one month after the program.

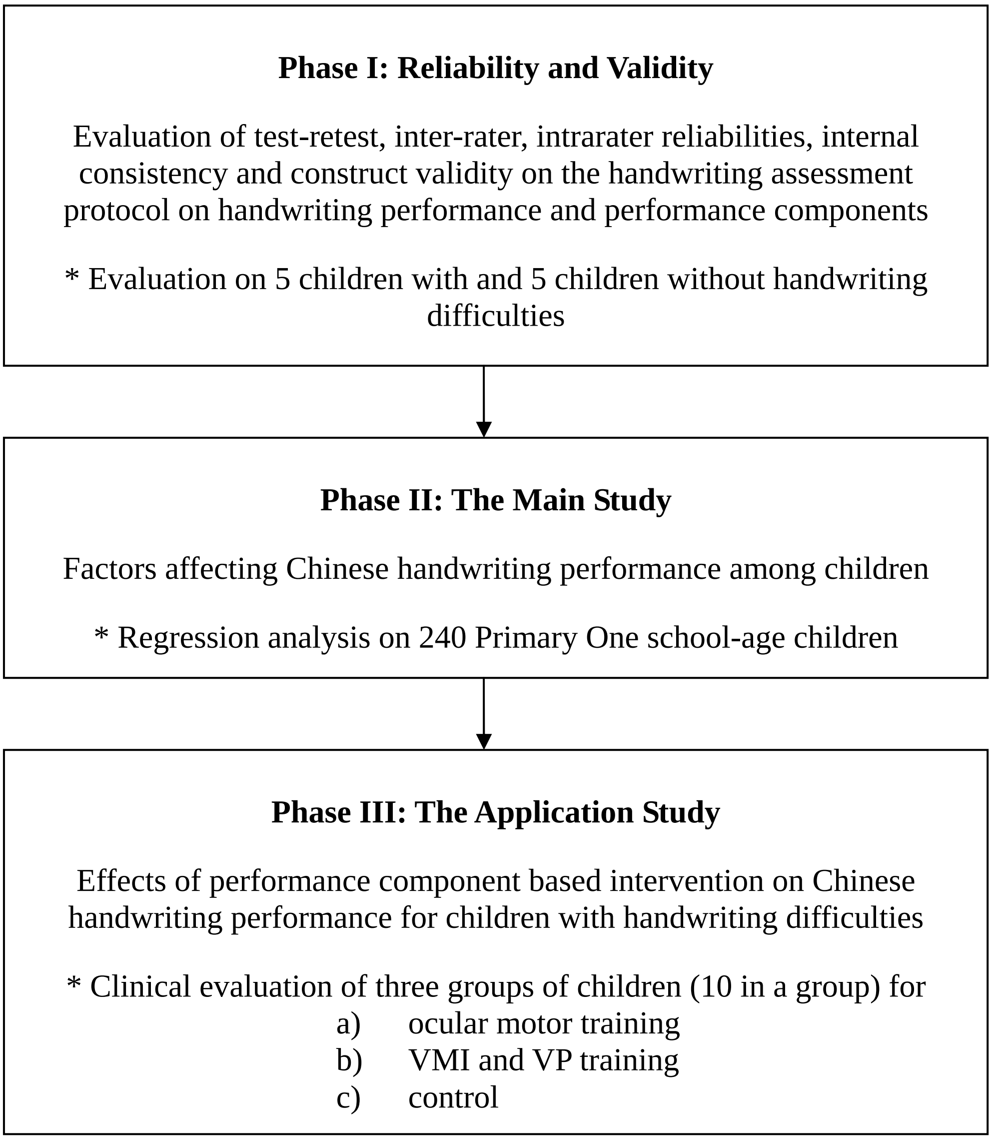

Figure 1.3 The flow of the study on handwriting performance of school-aged children in Hong Kong

Chapter 2 Literature review

2.1 Introduction

This chapter aimed to provide comprehensive information for understanding different components of handwriting skills among children. Constructs of handwriting performance including legibility, speed, pressure, and pause were first described based on previous studies. The factors that may affect handwriting performance were then presented. The evaluation of handwriting performance was finally introduced.

2.2 Handwriting performance

Handwriting was described as a multi-constructs human skill which involved various aspects in evaluation. According to the study conducted by Schwellnus and Lockhart (2002), spatial organization, legibility and formation of the written word, physical tolerance, and the rate of output were the four main issues addressed by occupational therapists as pertinent to children with handwriting difficulties. Legibility, accuracy, and speed were thus regarded as the basic constructs in the evaluation of handwriting performance.

Problems presented during the process of writing such as frequent pause, high writing pressure, and poor handwriting motivation were also seen as common features in poor handwriters (Ziviani & Watson-Will, 1998; Hammerschmidt & Sudsawad, 2004; Graham & Weintraub, 1996; Bonney, 1992; Kaminsky & Powers, 1981) and as reasons influencing their written outputs (Summers & Catarro, 2003). These elements were presented as the constructs in process of handwriting by Rosenblum, Weiss and Parush (2003). They suggested that one way for evaluation on handwriting process was achieved by "real-time measures of various performance criteria during the actual performance of handwriting" using computerized analysis. This might reflect the importance in addressing the continuous and changeable characteristics of the process of handwriting.

In this study, the *product of handwriting* was defined as evaluation of the performance using the final product of work which included the legibility and speed, while the *process of handwriting* was defined as the performance of children during writing including the inter-pause during writing and handwriting pressure.

2.2.1 Legibility

There has been a long history when the end product of the written text was often used as a tool for handwriting evaluation (Tseng, 1991; Woods et al., 2005). Most of the past researchers reported that the handwriting performance was evaluated based on subjective feedback from class teachers on neatness, tidiness and legibility (Tseng & Hsueh, 1997; Rosenblum, Weiss & Parush, 2003; Hammerschmidt & Sudsawad, 2004). Some studies even revealed that it relied on the subjective judgment of teachers in differentiating the good and poor handwriters (Cornhill & Case-Smith, 1996; Tseng & Murray, 1994; Tseng & Chow, 2000). Rosenblum, Weiss and Parush (2004) critiqued various assessment scales for handwriting and concluded that the evaluation scales based on analysis of a written passage for an overall judgment were commonly accepted for evaluation of the handwriting performance. This primary way of assessment targeted to determine the quality, readability, or legibility of the handwriting through the product of handwriting.

2.2.2 Speed

Legibility and efficiency in writing were generally accepted as fundamental educational skills and important constructs to define handwriting (Ziviani & Elkins, 1984; Bonney, 1992; Quant, 1946; Chow, Choy & Mui, 2003; Schwellnus & Lockhart, 2002). Negative impact of poor performance in handwriting speed on motivation and participation was suggested (Graham & Weintraub, 1996). Summers and Catarro (2003) also reported that speed, which was known as fluency in movement, was a factor affecting performance in examination. Furthermore, Wann and Jones (1986) investigated the variability of handwriting speed between proficient and non-proficient handwriters during the performance of a writing task. Like Bonney (1992) in his similar study, they did not find a significant difference in overall performance speed. Despite the different schools of thoughts, handwriting speed remained as an important construct in handwriting performance. However, most norms on handwriting speed were developed based on writing of English. Chow and colleagues (2003) expressed the concerns and needs of investigating the characteristics and the factors affecting Chinese handwriting speed among children with the uniqueness of Chinese characters in their structure and processing system.

2.2.3 Pause (Pen in air time)

The importance of handwriting pause has been stated in the study of Wann and Jones (1986) which indicated that the degree of variability in individual handwriting speed and duration of intermissions (e.g. pause) during handwriting performance were the best indicators of handwriting difficulties. More intra-task pauses were found in the non-proficient handwriters. Their suggestion that pen in air time might be a better indicator of handwriting difficulties was underpinned by a similar study by Schomaker and Smits-Engelsman in 1997. They found that more dysfluency and longer inter-stroke pause intervals were shown in movement patterns of the clumsy children. This finding was also reported in Rosenblum, Parush and Weiss (2003)'s study on 50 proficient and 50 non-proficient handwriters (aged 8 to 9). It was found that the 'pen in air' (i.e. pause) time the proficient writers spent was significantly shorter than that of the non-proficient writers. Longstaff and Heath (1999) explained the phenomenon by the idea of coordination of motor movement in which smooth and fluent handwriting was achieved by coordinating and translating the psychomotor system to motor memory stable. Other possibilities, such as attention and motor planning, were also suggested to account for a long pausing time during handwriting.

2.2.4 Pen pressure exerted on paper

Children with poor handwriting performance were generally found to have problems in controlling pen pressure during writing, thus leading to poor handwriting proficiency. Poor grip force modulation was often reported among children with poor handwriting, in which excessive amount of force would be exerted on the writing surface. Tseng and Cermak (1993) stated that children with low muscle tone generally wrote in lighter pressure on the surface. Effort and energy were spent for keeping their posture and stabilizing their hand on the writing tool. This was supported by Wann (1987)'s study in which non-proficient handwriters had significantly greater impulse, force, power costs and jerk movements compared with proficient writers. He concluded that more effort was made and power cost spent on the handwriting tasks was higher for non-proficient handwriters.

Tseng and Cermak (1993) found that handwriting speed and legibility had a greater correlation with the variability of pressure as compared to the static pressure. The result was explained by the disruption of motor coordination during increase of speed and pressure variability, which negatively impacted the legibility. Wann and Nimmo-Smith (1991) also reported that the modulation of pressure varied corresponding to the spatial dimensions, size and speed of the handwriting. A 10-15% increase of pen pressure was reported along the horizontal and vertical strokes. Despite of the non-significant result reported in other studies (Smits-Engelsman and colleagues, 2001), pressure in handwriting remains as a worthwhile construct for investigation.

2.3 Factors affecting handwriting performance

To help children overcome difficulties in handwriting, therapist and teachers should understand the reasons why children encounter the specific types of problem. There are various possible factors involved when children perform a handwriting task. The section below discussed the role of two types of factors: intrinsic and extrinsic factors in handwriting performance according to previous studies.

The intrinsic factors included the performance components and characteristics of the children such as age, gender, hand dominance to which his or her level of skill competence and characteristics were referred. On the contrary, extrinsic factors included the human and non-human environmental factors involving the culture expectations, the set up of space and use of tool during the handwriting task.

2.3.1 Intrinsic factors

2.3.1.1 Performance components

To achieve fluent and legible handwriting, children were required to have certain extent of basic skills components (Tseng & Cermak, 1991), which were defined as the *Performance Component*s in the Modified Conceptual Model of Handwriting Performance proposed in the current study.

2.3.1.1.1 Fine motor skills

It was suggested by Berninger (2004) that, handwriting was a ‘language by hand’ which involved contribution of graphomotor system. It was a multi-joints activity requiring control of hands and fingers to achieve fine movements (Longstaff & Heath, 2003). Coordination and sequencing in fine motor skills were important in writing. Sequencing skill was reported as the only common factor that contributed to the performance of reading, writing and speech (Orton, 1937, as cited in Haines, 2003). The pen shifting movement which involved finger sequencing movement and in-hand manipulation was found correlated to performance in language, spelling and writing (Powell & Bishop, 1992; de Hirsch, Jansky & Langford, 1966; Haines, 2003). In Haines (2003)'s study about motorized sequencing ability of children, significant association was reported between rhythm repetition and the fine motor task of coloring with crayon and use of scissors ($N=796$, r ranged from 0.22 to 0.31, $p<0.05$) across age ranges (aged 4 to 6). Haines suggested that motorized sequencing ability in fine motor was a component involved in the handwriting development, which might in other words, handwriting is a reflection of development of fine motor skills.

A high prevalence of handwriting difficulties was reported among children with coordination and motor control problems (Smits-Engelsman, Njemeijer & van Galen, 2001; Rodger et al., 2003; Coleman, Piek & Livesey, 2001; Longstaff & Heath, 2003). As cited by McHale and Cermak (1992), a study in 1977 found that 90% of the children survived with disabilities in learning also experienced difficulties in fine motor as well as handwriting. Though the role of fine motor in handwriting skills has been reported in many studies, this was not supported by the study conducted by Yochman and Parush (1998) on 191 Israeli children in Hebrew handwriting, as well as the study by Ziviani, Jayls, and Chart (1990). On the other hand, study on Chinese handwriting by Tseng and Murray (1994) revealed significant association between legibility and finger praxis as well as motor accuracy. This might be due to the difference in handwriting between Chinese and other languages in the requirements of sub-elements of the fine motor skills.

2.3.1.1.2 Proprioceptive and kinesthetic feedback of the hand

The important role of proprioceptive and kinesthetic feedback in handwriting is well-known (Cubbelli & Lupi, 1999; Olive & Piolat, 2002; Levine, Oberklaid & Meltzer, 1981; Chu, 1997). Tseng and Cermak (1993) summarized findings of kinesthetic feedback and concluded that the input of kinesthetic sense, which provides information of the body and fingers movement, was important in skilled movement such as handwriting (Tseng & Cermak, 1993; Bairstow & Laszlo, 1981; Bonney, 1992). Moderate correlation (r=0.76) was reported for association of the kinesthetic perception and memory with the neatness in handwriting. Cubbelli and Lupi (1999) stated that errors in writing could be prevented by the kinesthetic and proprioceptive feedback of the hand. This was supported by earlier studies in which kinesthetic acuity was significantly correlated to accuracy in writing and significantly differentiated good and poor writers (Lord & Hulme, 1987; Copley & Ziviani, 1990; as cited in Bonney, 1992).

Schneck (1991) suggested that decreased finger proprioceptive awareness was linked to lower grasp scores. Furthermore, children with poor finger awareness might grip with excessive force for a more secure sense of gripping due to insufficient kinesthetic and proprioceptive feedback. The phenomenon was often observed in children with handwriting difficulties (Schwellnus & Lockhart, 2002). Summers and Cartarro (2003) suggested that this would result in an experience of fatigue which might further cause tiredness, and reduction of power and capacity for appropriate motor response.

2.3.1.1.3 Ocular motor skills

As illustrated by Erhardt & Meade (2005), oculomotor skills involved three aspects of functions: (i) extraocular muscles control, (ii) visual perceptual skills (VP), and (iii) visual-motor coordination and integration. Goldstand, Koslowe and Parush (2005) categorized oculomotor skills and binocular visual function as the basic visual skills which were different from the higher-level visual information processing skills including VP and VM.

Although limited research has been done on the direct relationship between extraocular muscles control and handwriting performance, study on brain activity showed that visual scanning performance as well as symbol recognition played role in motor planning and intention to write (Longcamp et al., 2003). Goldstand, Koslowe and Parush (2005) suggested that basic visual skills were responsible for accurate and efficient visual feedback. In fact, the coordinated eye movement ability could also help correctly and efficiently track the information to be written. Kulp and Schmidt (1996) raised the importance of the visual skills on functional performance such as copying from the blackboard. In their study on 90 kindergarteners and 91 first graders, the accommodative facility (eye focusing or quick localization towards objects) of the children was found to be significantly predictive to the reading performance of the children.

Coordination and smooth ocular movement allowed input of information from visual feedback for effective reading and handwriting achievement. Cubelli and Lupi (1999) stated that visual feedback was an important factor for accuracy during copying. Quant (1946) used the eye movement pattern as an indicator for handwriting legibility in his study. He claimed that effective eye movement was reflected by a less incidence of and shorter duration of fixation, and also infrequent regression (less tendency of the eye to move backward). Children with difficulties in ocular control made more regressive movement during reading so as to compensate the loss of information.

2.3.1.1.4 Visual perceptual skills

Many researchers linked the visual perceptual skills with handwriting which requires recognition and perception of shapes and symbols (Maeland, 1992). A study by Feder (2005) in preterm children's handwriting performance found that visual perception significantly predicted the letter legibility. Moore and Rust (1989) also suggested that poor eye-hand coordination and visual perceptual skills were indicative of learning disability.

Furthermore, moderate correlation was also found in Maeland's study (1992) between figure-ground ability and handwriting skills in terms of accuracy of letter formation, uniformity of letter size and slope, spacing, and alignment. It was found the sequential memory of visual perception was predictive to handwriting speed, according to the study by Tseng and Chow (2000) for Chinese handwriting.

In contrast, the perceptual ability measured by Developmental Test of Visual Perception was not found to be related to good or poor handwriters (Yost & Lesiak, 2001). Although controversial findings were reported, occupational therapists generally commented visual perceptual skills as an important component in their evaluation and training module for handwriting skills, both for English and Chinese.

2.3.1.1.5 Visual motor integration

Visual motor integration (VMI) was defined as a combination of fine motor components, visual perceptual component, and the abilities in integrating the perceptual input with motor output (Beery, 1997). According to Rigby and Schwellnus (1999), handwriting performance was found to be consistently linked with the VMI score of Test of Visual Motor Integration which required children to copy shapes in developmental sequence. This was supported by Daly, Kelley and Krauss (2003) who found a strong relationship between VMI and handwriting skills in a group of kindergarten children. While handwriting was known as a visual-motor activity (Bonney, 1992), Berninger, Mizokawa and Bragg (1991) expressed the importance of the integration of visual and fine-motor functions in the process of writing. In Yochman and Parush's study (1998), VMI was found to be the only significant predictor (r ranged from 0.20 to 0.33. $p<0.05$) for handwriting legibility, and the fine motor praxis and coordination skills. Similar results were reported in other studies (Marr, Windsor & Cermak 2001; Weil & Amundson, 1994; Sovik, 1975; Maeland 1992). Barnhardt and colleagues (2005) further echoed by their study results in which poor alignment and errors were more prominent in the group of children with low visual motor integration. Therefore, visual motor integration was qualified as one of the key predictors for children's handwriting performance.

2.3.1.2 Gender

Previous studies have proved that gender differences existed in children performance in different motor tasks across the childhood and adolescent years (Thomas & French, 1985). Gender difference in handwriting performance was also reported regardless of age and culture (McCarthy et al., 2001). Studies reported that girls generally wrote at faster speed and with smaller size and fewer errors as compared with boys (Ziviani & Elkins, 1984; Groff, 1961). However, inconsistency of gender differences was reported both in English and Chinese handwriting. In the study of Ziviani and Watson-Will (1998), comparison of the handwriting speed across few age ranges showed that boys tended to write faster at ages 11 to 12 years while girls generally wrote a little faster at ages 7 to 10 years. On the other hand, Tseng and Hsueh (1997)found that Chinese girls wrote faster than boys in grades 3 to 6 (mean age ranging from 8.55- 11.53) while boys studying in grade 2 (mean age =7.61) wrote faster than girls. Regardless of the inconsistency, Rosenblum, Weiss and Parush (2003) concluded that gender appeared to be a factor influencing writing speed. Thomas and French (1985) suggested that influence of biological growth, environmental context such as development of gender role, and the interaction between the two genders could be the possible explanations for the handwriting performance differences. Thus boys were developed to survive with better gross motor skills, while girls performed better in fine motor tasks such as handwriting.

2.3.1.3 Hand dominance

Dominance of hand developed at about seven of age. According to a survey conducted thirty years ago by Teng et al. (1979) on 4143 Chinese subjects in Taiwan, only about 1% of children preferred to use left hand for writing. A pathological view was suggested by some researchers to explain the phenomenon of hand preference (Ross, Lipper & Auld, 1992; Teng, et al., 1979), and it was generally believed that the development of hand dominance reflected the lateralization of brain function which results in different levels of competency rather than injury.

Although performance in handwriting among the left handwriters was found less fluent and poorer in legibility (as cited in Graham, 1986), controversial findings were reported (Smith and Reed, 1959, as cited in Ziviani & Elkins, 1984; Suen, 1983; Ziviani, 1984, as cited in Summers & Catarro, 2003).

The handedness was also being related to the directionality of writing by researchers. In Chinese and English handwriting, the order of writing or direction of strokes was for the movement of right-sided hand. For example, alphabets are arranged from left to right in English words, while, the sequence of strokes in Chinese handwriting was also orientated in a direction of up to down, and left to right (Law, Chung & Lam, 1998).

2.3.1.4 Age

Difference in handwriting performance across ages has been well reported. Such a difference was explained by the development and maturation of basic skills components and a result of learning (Yochman & Parush, 1998; Ziviani & Elkins, 1984).

Influence of age was consistently reported in handwriting speed. Tendency of increase in speed with the increase of age was reported in various studies (Rosenblum, Weiss & Parush, 2003). This tendency was also reflected in studies on Chinese handwriting. For a study on Chinese handwriting speed among children in Taiwan (Tseng & Hsueh, 1997), significant increase ($F(4,1515) = 329.49$, $<.001$) was observed in handwriting speed with the increase of grade. Previous studies showed that the handwriting speed of the children increase with age which might due to the maturation of skills across developmental process. Different age range of the children might produce different correlations of the factors affecting handwriting performance.

2.3.2 Extrinsic factors

The behaviors and skills of children could be encouraged and affected by the culture demands and expectations (Rosenblum, Parush & Weiss, 2001). Difference in cultural demands or expectations as well as the task factors would shape and affect the development of skills and thus the performance among children.

2.3.2.1 School requirements in Hong Kong

In Hong Kong, children usually enter the school system at as early as the age of three. That is to say, children may start to learn how to write at three. As an international city, bilingual education is generally expected in Hong Kong. Writing in both Chinese and English is one of the main objectives in the curriculum learning

(Curriculum Development Council, HKSAR, 2004, p.9).

In primary school, certain level of handwriting performance is expected for the children. According to the Curriculum Development Institute, HKSAR (2002), one of the educational goals for children in primary one to three is to write with neatness and accuracy for both Chinese and English characters while reasonable speed in outputs is required in the upper grades (P.4 to P.6).

2.3.2.2 Characteristics of Chinese characters

As stated by Tan and colleagues (2001), written Chinese had square configurations which mapped with morpheme for meaning instead of phonemes for pronunciation. Being categorized as a morphemic language (Tseng & Hsueh, 1997; Matthews, Fu & Chan, 2002; Leong & Tamaoka, 1998) and logographic system (Siok et al., 2004), writing Chinese characters was said to be different from writing in alphabetical or phonetic-based language such as English and Italian (Tan et al., 2000, 2001; Chow et al., 2000). Instead of having syllables allowing segmental analysis (Siok et al., 2004), Chinese characters are made up of intricate strokes which form parts of a single character. Different composition, proportion and orientation of the parts could form different characters and carry totally different meanings and pronunciation.

Chow, Choy and Mui (2000) compared the writing patterns of Chinese and English. They stated that the 26 alphabets, also known as the basic units in English handwriting formed words with meanings under various combinations. On the other hand, Chinese handwriting involved complex geometric figuration and stroke arrangement within a squared area (Chow, Choy & Mui, 2000; Tan et al., 2001).

Chinese words were composed by combination of eight basic strokes patterns and 43 stroke variants including various types of dots, straight lines, and curve lines (Chow, 2000; Law, Chung & Lam, 1998).

Tseng (1998) has earlier suggested that composition of different strokes in Chinese characters required more pen lifts and sharp turns during writing; while in English, the pattern was more continuous and smooth. Tan, Hoosain and Soik (1996) even criticized that the configure properties of stroke pattern in Chinese words did not give any clue in where to start and which stroke to follow in writing Chinese.

Hence, the requirement of basic skills such as fine motor skills for writing Chinese was suggested to be different, which would affect the handwriting performance among children. In addition, it was suggested by Meulenvroek and Thomassen (1991) that jumping of the pen influenced the amount of visual feedback. As a result, other components such as ocular motor skills and visual motor integration might be required in advance in Chinese handwriting to compensate the lack of visual feedback as a result of its discrete and complex writing pattern, as compared with other language such as English handwriting.

2.4 Evaluation of handwriting performance

Occupational therapists relied very much on teachers' judgment on children performance in handwriting to differentiate good from poor handwriters and to make referral for the therapy (Reisman, 1991; Cornhill & Case-Smith, 1996; Tseng &

Murray, 1994; Tseng & Chow, 2000). Simple, accurate and user-friendly screening guidelines were important for teachers to make appropriate judgment. However, this means of evaluation was criticized for its subjectivity. Thus, testing on reliability of teacher's overall judgment was important for ensuring reliable evaluation.

On the other hand, standardized test which provides standardized instruction and scoring with comprehensive norm references allows therapists to document children's progress in a quantified and objective way (Reisman, 1991). In this case, the psychometric properties of the tools appeared to be an important indicator for their reliability and validity.

In this study, an assessment protocol (Tables 3.1 & 4.1) was used for the evaluation on Chinese handwriting performance as well as the performance components. Review of their psychometric properties is given below.

2.4.1 Evaluation on Chinese handwriting performance

As discussed, handwriting is a complex task with multiple constructs. Evaluation on children's handwriting performance should not limit to the product of handwriting, that is, the legibility. Hence, the evaluation on both the process and the product of handwriting was included in the protocol.

2.4.1.1 Handwriting pause, speed and pressure

A digital-based handwriting evaluation tool, namely *Penmanship Objective*

Evaluation Tool (POET) (Rosenblum, Parush & Weiss, 2003), was used for evaluating the Chinese handwriting process. Information on time (total and pen in air), speed, and pressure (i.e. the force) exerted on the writing surface could be recorded as quantitative temporal data as well as objective measurement. The POET system was installed into a laptop computer and used along with a WACOM digitizer which could sample the location, direction, orientation, and the on surface pressure with respect to the grip pen (Figures 2.1 and 2.2). Two Chinese templates (Appendix B), one with 6 words and the other with 20 words, adapted from the Hong Kong Development Assessment Checklist (HKDAC) (Lam, Shum, Chan & Li-Tsang, 2002), were used in the study. The 6 words template was initially designed for kindergarten children, and used as a warm up writing task in this study while the 20 words template was used for analysis. The Chinese characters in the templates were chosen with inclusion of the structures of Chinese characters such as left–right, up-down, and in-out.

The POET measurement provided quantified data on constructs of handwriting performance, i.e. time, speed and its variabilities, and pressure and its variabilities, which would be used to correlate with other performance components in main study.

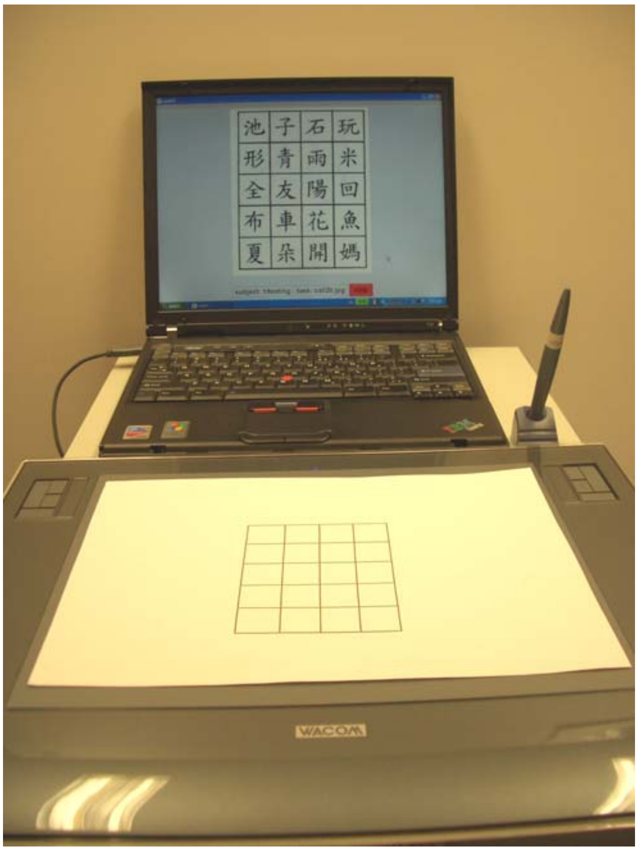

Figure 2.1 The POET-WACOM digitized tablet system

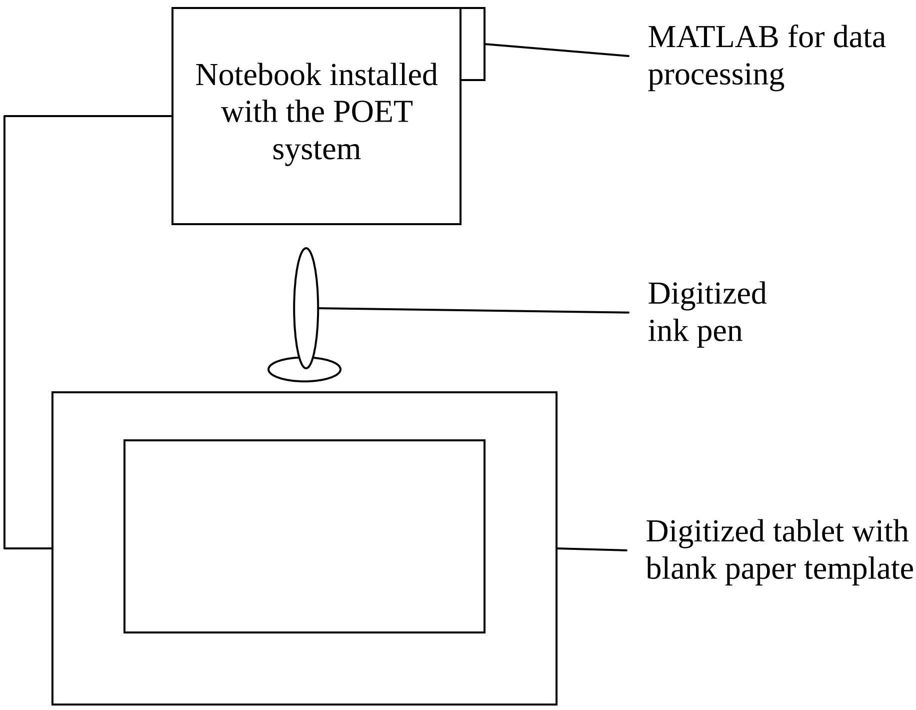

Figure 2.2 Graphical illustration of the POET system

The POET has been validated on its test-retest reliability with nine children (4 boys, 5 girls) who were studying in a traditional mainstream primary school in Hong Kong with an age of 73 to 84 months (Chan, 2005). The test-retest was conducted at one-week interval. Results found that the POET had a promising test-retest reliability with the Intraclass correlation coefficient (ICC) ranging from 0.971 to 1.000 (level of confidence higher than 0.90) among the constructs of handwriting process. As suggested by Chan, the POET was reliable in measuring the handwriting process. Also, good concurrent validity was reported with the 60 words Tseng;s Handwriting Speed Test.

Time and length of handwriting were recorded in second (s) and millimeter (mm) respectively. Hence, with a calculation of writing speed equal to length written in a second, the speed was represented by millimeter per second (mm/s). A time ratio of on ground to in air time was also employed to show the proportion of time that children spent on writing during the process of handwriting process. Moreover, pressure data by the POET was represented by a non-scale unit. A validation study (Cheung & Li-Tsang, 2006) had been conducted previously to calibrate the pressure scale of POET and to convert it into a more functional unit, force in Newton (N) (Figure 2.3). The study showed that correlation between pressure scale of POET had an excellent linearity ($r^2 = 0.96$) (Figure 2.4). According to the result of that study, the pressure data (in non-scale unit) could be converted into force scale in Newton by the equation *POET pressure scale = 45.43 + 301.30* force (* equals to 'times' in multiply).*

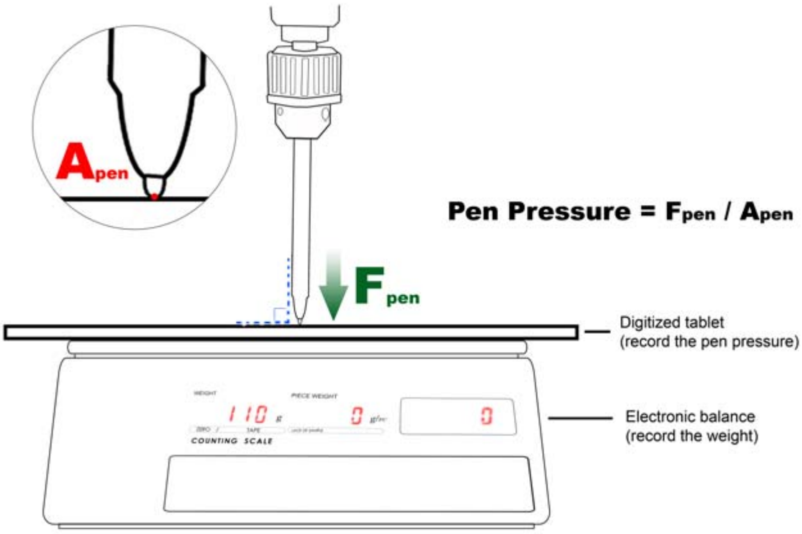

Figure 2.3 The experiment set up for validation on pen pressure measurement (F=force; A=area).

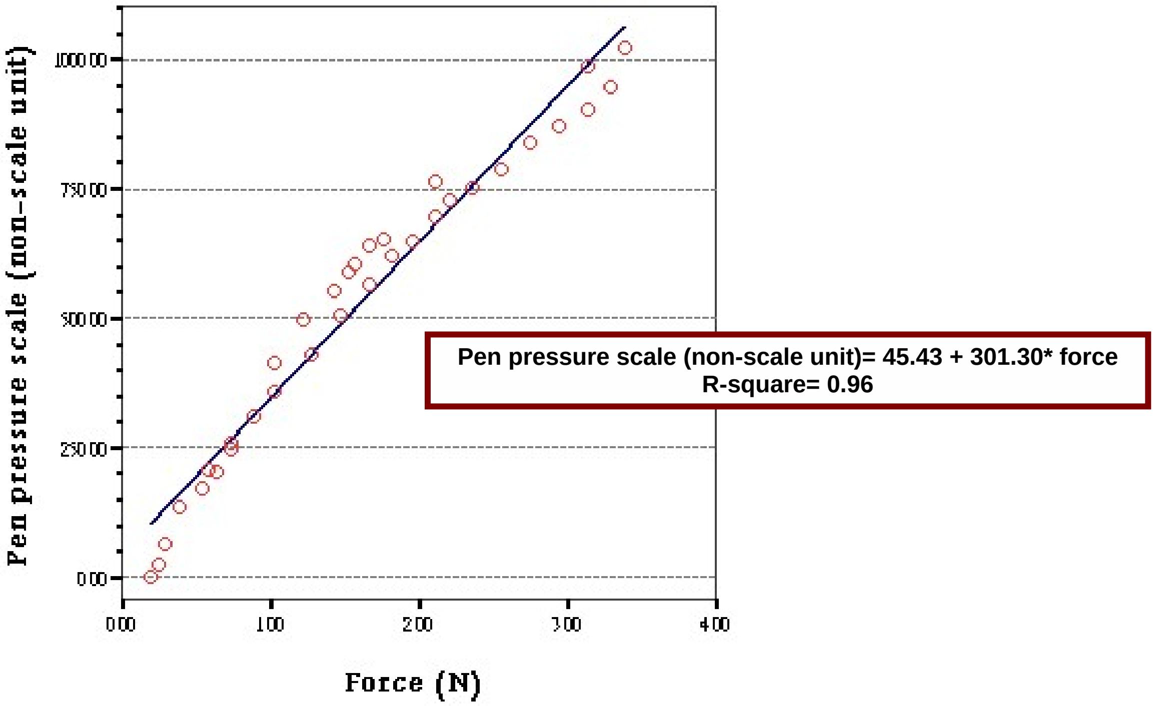

Figure 2.4 Regression analysis on linearity and reproducibility of pressure measurement by the POET

2.4.1.2 Legibility

The handwriting products by the POET without knowing the identity of the writers were given to their school teachers for rating on the overall legibility. The rating was given with a 3-point scale. The scale is an ordinal scale in which a score of "0" represents poor legibility, "1" represents satisfactory legibility, and "2" represents good legibility. The scale was adopted based on a general agreed marking standard among the teachers.

2.4.2 Evaluation of the intrinsic factors

2.4.2.1 Grip and pinch strength

The strength of grip and pinch was assessed using the *EVAL hand evaluation system*. The EVAL hand evaluation system is a computerized measuring tool that allows a very fine assessment of the grip and pinch strength. The data recorded were reported in 2 decimal places in kilograms (kg).

The coefficient of variations (CV) in percentage was also reported by the computer. This value indicates the variation among the three measurements with a higher CV value representing higher variability and lower consistency. Data with a CV value greater than 10% would be considered for re-assessment for that particular item.

2.4.2.2 Ocular motor control

Developmental Eye Movement Test (DEM), a visuo-verbal test, was used to evaluate the ocular motor performance of the children. Prior to the main testing task, children should pass the pretest on number knowledge and articulation. The DEM test included three tasks which were designed to measure the eye movement, in particular the saccadic movement and automaticity in reading, required the children to read out numbers orientated in vertical and horizontal directions respectively they were designed to measure. The total time was recorded in addition to the number of errors (addition, omission, substitution, and transposition) while reading. Then, the time would be adjusted with the calculation using the following equation:

Adjusted time= Total Time x [(80+a-o)/80]

In which there were a total of 80 numbers to be read in the test (Tests A & B for vertical direction; Test C for horizontal direction), ‘a’ represents the number of addition errors and ‘o’ represents the number of omission errors. According to the test manual (Richman & Garzia, 1987), fair to good reliability was reported for test-retest (r= .57 to .89) and interrater (r= .57 to .91) tests among items of the vertical time, horizontal time and the time ratio. However, reliability was not significant in errors items (r=.07). Significant correlations between DEM and the Wide Range Achievement Test were report in the Reading subtest (|r| ranged from .55 to .79). Correlation to the education level was significant in vertical and horizontal time across age from nine to thirteen.

Moreover, the DEM has been validated in a group of Cantonese speaking children in Hong Kong by Pang (2004). From his study, a norm reference for Cantonese speaking children was produced from age six to eleven. Comparison was done among the Cantonese speaking, English speaking, and Spanish speaking children. Results showed that errors were significantly fewer for Cantonese speaking children aged six as compared with the English speaking and Spanish speaking children with the same age. Hence, findings in the study would be compared based on the Cantonese norm reference.

2.4.2.3 Visual perceptual skills

Motor-free Visual Perceptual Test-Revised (MVPT-R) (Calarusso & Hammill, 1996) was a standardized test revised from the original version in 1972. It takes about 20 minutes to administer and provide a quick and general non-motor visual perceptual evaluation. It contains 40 pictorial multiple-choice items with a norm reference for children from 4 to 11 years of age. The subcomponents of visual perceptual skills to be assessed were adopted from the categorization by Chalfant and Scheffelin (1969) and included spatial relationships, visual discrimination, figure-ground, visual closure, and visual memory. As cited from the manual, the test aimed to be a quick screening test for overall visual perceptual problems. However, identification of specific visual perceptual deficits could not be made.

Test-retest reliability was reported with moderate to good ICC values ranging from 0.77 to 0.83 across ages (Colarusso & Hammill, 1996). Similar results were reported by Burtner and colleagues (2002). In their study among children with learning disabilities, test-retest reliability of the MVPT-R was moderate with an ICC ranging from .63 to .79 for the perceptual quotient scores, and .69 to .86 for perceptual age scores. Significant correlations between MVPT-R and other visual perceptual tests were reported with the Developmental Test of Visual Perception (DVPT) (r=.73), DVPT-2 (.78), and Metropolitan Readiness Tests (Matching subtest; r= .40).

In 2002, Burtner and colleagues conducted another study on the discriminative validity of the MVPT-R in children with and without learning disabilities. The study compared two groups of 38 children who were aged from seven to ten. Their results showed that children with learning disabilities scored significantly lower in the MVPT-R test. It implied that the test was able to discriminate children with or without learning disabilities.

2.4.2.4 Visual-motor integration

The Beery-Buktencia Developmental Test of Visual-Motor Integration (VMI) (Beery, 1997) consisted of three parts of test on visual perceptual, motor coordination, and visual motor integration. In this study, only the test for visual motor integration would be used. This part of the test consisted of a sequence of geometric forms which require the children to copy with paper and pencil. The test content included three imitation items and 24 copying items. The performance was evaluated based on the total scores obtained from all the items. Each item was counted with one mark, and the total score equaled to 27. Total administration time was estimated to be 10 to 15 minutes according to the manual but was not calculated into the score. This standardized test was developed for assessing the extent to which individuals can integrate their visual and motor abilities, from preschool through adult ages.

The test has demonstrated with high interrater and test-retest reliabilities with a correlation of .94 and .87 respectively which was much higher than a reliability coefficient of .80 usually appropriate for screening tests. Moreover, moderate concurrent validity was reported between the VMI with the Developmental Test of

Visual Perceptual (DTVP-2, Copying subtest) (r=.75) and the Wide Range Assessment of Visual Motor Abilities (WRAVMA, the Drawing subtest) (r=.52).

2.4.2.5 Fine motor skills

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978) was a standardized test measuring the discrete fine motor skills of children of 4.5 to 14.5 years of age. The fine motor composite (subtests 6-8) of the test was used alone to obtain an index of fine motor proficiency in this study. The fine motor subtests measured the response speed, visual-motor control, and upper-limb speed and dexterity. It was estimated to take 20 minutes in completing the 17 items in the fine motor subtests. Bruininks (1978) reported a test-retest reliability of .88 in the fine motor subtests among children in grade 2, which was equivalent to age 7 to 8. High rater reliability was also reported in the study of Wilson, Kaplan, Crawford & Dewey (2000).

The BOTMP has been widely used by clinicians in identifying children with motor problems and evaluating the treatment effectiveness (Wilson et al., 1995; Connolly & Michael, 1986). Moreover, it has been adopted by researchers as the golden standard in evaluating the concurrent validity for the development of tools for motor skills (Zhang, Zhang & Chen, 2004; Hassan, 2001; Liao, Mao & Hwang, 2001). Flegel and Kolobe (2002) used the assessment result of the BOTMP as a standard reference to study the predictive validity of the Test of Infant Motor Performance.

Chapter 3 Phase I of the study

3.1 Introduction

This phase of the study aimed to find out the reliability and validity of the assessment protocol adopted in phase II of the study for the evaluation of the Chinese handwriting performance and the performance components which are essential for handwriting. The performance components included the power grip and tripod pinch strength, ocular motor skills, visual perceptual skills and visual motor integration. The reliability of the tests was evaluated based on the interrater, intrarater and test-retest reliabilities. The construct validity was evaluated via analysis on the discriminant factors for good and poor handwriters in terms of their characteristics in the performance of Chinese handwriting and performance components with use of the assessment protocol. This pilot study also aimed to facilitate further modification on the assessment protocol so as to prepare for the phase II of the study.

3.2 Objectives of the study

a) To study the test-retest reliability of the assessment protocol including EVAL hand evaluation system, Developmental Eye Movement Test (DEM), Motor-free

Visual Perceptual Test – Revised (MVPT-R), and Developmental Test of Visual-Motor Integration (VMI);

b) To study the interrater and intrarater reliability of the assessment protocol including standardized tests for grip and pinch strength, ocular motor skills, visual perceptual skills, and visual motor integration;

c) To study the internal consistency of the objective evaluation of handwriting performance by the Penmanship Objective Evaluation Tool (POET); of the measurement of power grip and tripod pinch grip by the EVAL hand evaluation system; and, of the measurement of ocular motor skills by the Developmental Eye Movement Test (DEM);

d) To study the construct validity of the assessment protocol by comparing the profile of Chinese children in their handwriting performance and other performance components between good and poor handwriters.

e) To suggest modifications on study design and assessment protocol for the main study in phase II.

3.3 Methodology

3.3.1 Sampling method

Ten children studying in Primary 1 (aged 6-7) in a mainstream school in Hong Kong were recruited by convenience sampling method. Among the 10 children, 5 were identified by their teachers as poor handwriters (or having handwriting difficulties) while the other 5 were regards as good handwriters. The school was selected from the list of primary schools in Hong Kong printed in the Yellow Page using a draw lots method.

Once verbal agreement has been obtained, consent forms with a cover letter explaining the purpose and details of the study were sent to teachers and distributed to parents of the referred children.

3.3.2 Selection criteria

3.3.2.1 The inclusion criteria

Children who would be recruited in the study should be:

a) between six to seven years old;

b) studying primary one in the mainstream school in Hong Kong;

b) able to use Traditional Chinese and Cantonese as the primary language in written and spoken communication.

3.3.2.2 The exclusion criteria

Children should not:

a) have any physical, visual and hearing impairment;

b) have any cognitive impairment or intelligence limitation;

c) be observed to have behavioral and emotional problems at home, school, or during the assessment session.

3.3.3 The assessment protocol

The assessment protocol including standardized and validated instruments was used in this study for evaluation of the Chinese handwriting performance and the performance components (Refer to Section 2.4).

In this phase of the study, since the test on fine motor skills using BOTMP-FM was not considered during the implementation of the study, investigation on its reliability was not conducted.

Table 3.1 The assessment protocol used in Phase I of the study

Component in the **Modified Conceptual Model of Handwriting Performance** (Section 1.2.3)	Instrument	Test items
Chinese Handwriting performance	Penmanship Objective Evaluation Tool (POET) Teacher legibility rating (3 point Likert scale)	20 Chinese words - pen in air time - speed and its variability - pressure and its variability - legibility
Grip and pinch strength	EVAL hand evaluation system	- Tripod pinch - Power grip
Ocular motor skills	Developmental Eye Movement Test (DEM)	- Time ratio (horizontal to vertical) - Vertical adjusted time - Horizontal adjusted time
Visual perceptual skills	Motor-free Visual Perceptual Test – Revised (MVPT-R)	MVPT score (Total=40)
Visual motor integration	The Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI)	VMI score (Total=27)

3.3.4 Procedure

Figure 3.1 is a flow chart illustrating the procedure. Ethics approval was obtained from The Hong Kong Polytechnic University prior to recruitment of subjects.

After the consents were obtained, recruited children were assessed by the assessors using the assessment protocol. The assessment was conducted individually in a quiet classroom at the school that the children were familiar with. Demonstration was provided with verbal instruction before the actual assessment. Each child was assigned with a code that was not known together with their names. Assessors would only record the code of the child onto the assessment record sheets regardless of the child's name.

For the objective evaluation of handwriting performance, children were required to perform two writing tasks, the 6 words and 20 words templates. The handwriting templates (Appendix B) were shown on 14" laptop screen. Children were required to copy the words vertically from right to left to the blank template on the WACOM digitizer. After conducting the handwriting assessment, the handwriting script was printed and distributed to their class teachers for legibility rating using a three-level Likert scale. A score of "0" indicates poor legibility; "1" stands for satisfactory legibility; and "2" for good legibility.

After all the information from the first assessment session was collected, children were arranged for another assessment *after one week* for testing the repeatability (Chan, 2005). Among the 10 children, 5 were arranged to be rated by two assessors at the same time for evaluation of the test accuracy by rater difference. On the other hand, some children were arranged to conduct a re-evaluation by a particular rater at a two week interval to test the intra-rater reliability.

3.3.5 Data analysis

After the assessment, raw scores were obtained from the assessors. Demographic data including date of birth, gender, hand dominance, and grade of study were collected from the teacher and entered into the SPSS by a helper who was blinded to the assessment protocol and the data analysis procedure.

Data analysis was conducted using the Statistical Package SPSS, version 12.0 for Windows (SPSS Inc., Chicago, IL, USA). The raw scores obtained in assessment were also entered into the SPSS by a helper who was blinded to the study objectives, protocol, and the purpose of data analysis. Using the SPSS, all the data were analyzed and processed with the subject code.

Corresponding assessment tools used to perform the reliability and consistency testing were listed in Table 3.2.

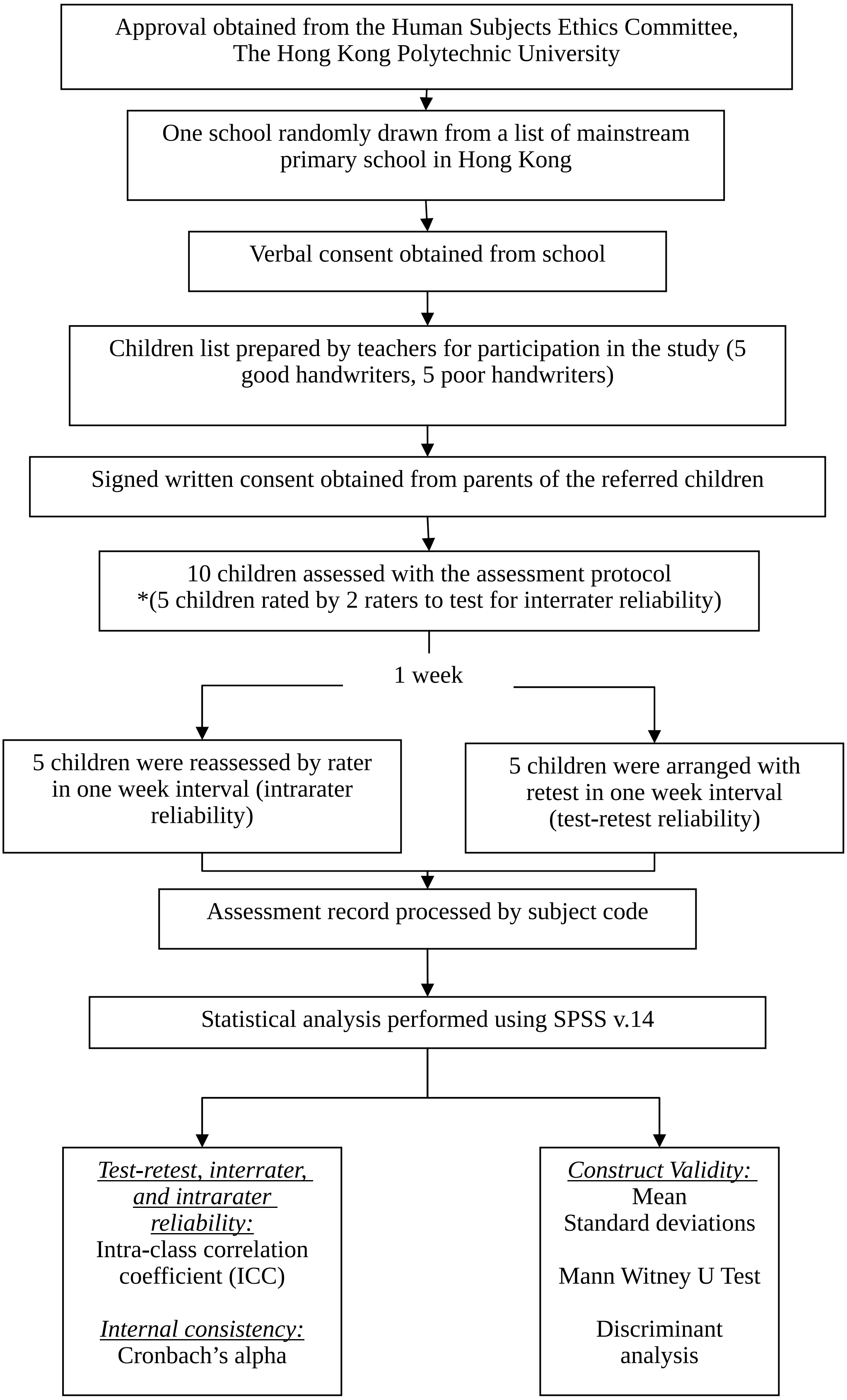

Figure 3.1 The flow of study in Phase I: Validation on the assessment protocol

Table 3.2 The reliability and consistency tests performed in the assessment instruments.

	Test-retest reliability	Inter-rater reliability	Intra-rater reliability	Internal consistency
POET Time Speed Pressure	× Adopted the result of a local unpublished study (Chen, 2005)	× Not applicable for computerized measurement	× Not applicable for computerized measurement	✓
Legibility rating	✓	✓	✓	× Not applicable for single measurement
EVAL Tripod pinch Tip pinch	✓	× Not applicable for computerized measurement	× Not applicable for computerized measurement	✓
DEM Vertical adjusted time Horizontal adjusted time Time ratio	✓	✓	✓	✓
MVPT	✓	✓	✓	× Not applicable for single measurement
VMI	✓	✓	✓	× Not applicable for single measurement

3.3.5.1 Measurement of reliability

3.3.5.1.1 Test-retest, inter-rater and intra-rater reliability

Test-retest reliability was conducted for evaluation on the repeatability of the measurements. To prevent the impact of learning effect and also the maturation effect, repeated measures were scheduled one week after the first measurements. Intraclass correlation coefficients (ICC) were used to show the level of test-retest reliability using the two-way mixed model (3,1). Item statistics including the mean, standard deviation, change of mean in the repeated measure, and also the 95% confident interval were reported.

The two-way random model [ICC (2,1)] and the two-way mixed model [ICC (3,1)] were used to test the inter-rater reliability and intra-rater reliability of the assessment instruments respectively. The models were chosen because generalization of the test was assumed in the inter-rater condition but not the intra-rater condition.

ICC value over 0.75 was regarded as having good test-retest reliability (Portney & Watkins, 2000, p.65).

3.3.5.1.2 Internal consistency

Analysis of the internal consistency was conducted for the instruments which involved multiple parameters in evaluating a performance. These parameters were usually constructs of the performance. In this study, consistency testing for internal items was carried out for the POET, EVAL hand evaluation system, and the DEM test.

Internal consistency of the assessment tools was analyzed using Cronbach's alpha (α). A value of α close to 1.00 represented a high internal consistency among items of the assessment instruments, while an α close to 0.00 might indicate that the items were for measuring different traits. High consistency was defined as having an alpha level higher than 0.80.

3.3.5.2 Construct validity

Children's performance in the handwriting skills and performance components was summarized in tables. Comparison on the performance between the good and poor handwriters was done with the descriptive and inferential analysis. Mean and standard deviation of the performance among good and poor handwriters were presented in tables for descriptive analysis. The Mann Whitney U Test was used for inferential analysis with z-statistic and p-value. A significant difference between the groups was indicated by a p-value below 0.05.

Discriminant analysis was used to study the construct validity of the tools in discriminating children as 'good' and 'poor' handwriters according to teacher's perceptions. A high eigenvalue, which scaled from 0.00 to 1.000, indicated a high degree of explanation on the grouping by the independent variables. The correlations between the discriminating variables and the standardized canonical discriminant functions were obtained as the indicator for strength of association of individual variable to the grouping. Definition of degree of association was the same as the standardized coefficient correlation (β). In addition, classification table was used to show the percentage of correctly classified grouping with reference to the entered independent variables. The procedure was then repeated by entering various performance components as the discriminating variables. This was to examine which performance components were predictive to teachers' perception of good and poor handwriters.

3.4 Results

3.4.1 Demographic characteristics of the children

The analysis relied on the data collected from 10 children (6 males, 4 females) studying primary one in a Hong Kong mainstream primary school located in Kowloon district. Their age ranged from 79 to 94 months (mean=81.7, SD=5.4), equivalent to an age of 6.6 to 7.8 years (mean=7.3, SD=0.5). All of them wrote with their right hand. Table 3.3 showed the demographic characteristics of the children participating in this phase of the study.

Table 3.3 Demographic characteristics of the children participating in the study (N=10)

Characteristics		N= 10
Age in years	Mean (SD)	7.3 (0.5)
	Max	7.8
	Min	6.6
Gender N (%)	Boys	6 (60%)
	Girls	4 (40%)
Hand dominance N (%)	Right	10 (100%)
	Left	0 (0%)

3.4.2 Measurement of reliability

The results of the reliability tests for the assessment protocol were shown in Tables 3.4 to 3.7. They were presented one by one in the following sections.

3.4.2.1 The Penmanship Objective Evaluation Tool (POET)

Test-retest reliability of POET has been studied by Chan (2005) among nine Hong Kong school-aged children. The age of children ranged from 73 to 84 months, equivalent to 6.08 to 7 years old. The POET was reported to be reliable in repeated measures with an ICC value ranging from 0.971 to 1.000. All 95% confident intervals were reported higher than 0.90. Also, as the POET is a computerized tool, the accuracy of data capture was not influenced by the rater effect. The impact of rater bias was not assumed. Thus, interrater and intrarater reliability was not tested for this tool.

Result in current study showed that overall Cronbach's alpha of POET (20 word) was 0.650. The moderate level of internal consistency might suggest the ability of POET in assessing multi-facets in handwriting skills such as speed and pressure.

3.4.2.2 Legibility rating by teacher

The legibility of children handwriting product was rated subjectively by their teacher using a 3 point rating in which "0" represents poor, "1" represents satisfactory, and "2" represents good. The definition on whether legibility is poor or good mostly depended on the perception of the rater, that is, the teachers. A full value of ICC (ICC=1.000, 95% CI ranged from 1.000 to 1.000) was obtained in the evaluation of test-retest reliability and intrarater reliability, both in one week interval. The interrater reliability was slightly lower (ICC=0.800) with a 95% confident interval from -0.032 to 0.977. This might indicate the impact of individual perception and definition on the legibility performance in subjective rating.

3.4.2.3 The EVAL hand evaluation system

Evaluation of the EVAL hand evaluation system revealed good to excellent test-retest reliability in the tripod pinch only (ICC=0.864, 95% CI ranged from 0.174 to 0.985). Low reliability was found in the measurement of power grip strength (ICC=-0.079, 95% CI ranged from -0.837 to 0.783).

Overall internal consistency indicated by the Cronbach's alpha was found moderate (α= 0.470), indicating that the tripod pinch and power grip had different traits in the measurement.

3.4.2.4 The Developmental Eye Movement Test (DEM)

The performance of eye movement by the DEM contained items of vertical adjusted time, horizontal adjusted time, and the time ratio. Good to excellent reliability was reported in the vertical adjusted time (ICC= 0.916, 95% CI ranged from 0.408 to 0.991) and also the horizontal adjusted time (ICC= 0.847, 95% CI ranged from 0.112 to 0.983).

On the other hand, items of the DEM test were reported to be moderate to excellent in terms of the interrater (ICC ranged from 0.753 to 0.996) and intrarater reliability (ICC ranged from 0.978 to 0.999). For the internal consistency, moderate consistency was reported in terms of the adjusted time (α=0.570). This might suggest a certain degree of correlation among the items while it also measures different traits in eye movement.

3.4.2.5 The Motor-free Visual Perceptual Test-Revised (MVPT-R)

The Motor-free Visual Perceptual Test-Revised (MVPT-R) contained 40 multiple choice questions on perception of pictures. According to Table 3.4, the MVPT-R had an excellent reliability in both the interrater and intrarater reliability tests (ICC=1.000, 95% CI ranged from 1.000 to 1.000). However, test-retest reliability of MVPT-R was found to be only moderate (ICC=0.594, 95% CI ranged from -0.420 to 0.948).

3.4.2.6 The Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI)

The Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) required a child to copy a printed figure onto a blank paper within a grid. Rating on children performance relied on the marking criteria given in the test manual. Among the reliability tests, test-retest reliability was found the lowest for the VMI (ICC=0.448, 95% CI ranged from -0.571 to 0.924). Good reliability was reported in term of interrater reliability (ICC=0.820, 95% CI ranged from 0.027 to 0.980) while excellent reliability was found for the intrarater reliability (ICC=0.985, 95% CI ranged from 0.867 to 0.998).

Table 3.4 Test-retest reliability of the assessment protocol (N=5)

	1st assessment		**2nd assessment**		**95% CI**		**ICC (3,1)**
Item	**Mean**	**SD**	**Mean**	**SD**	**Lower**	**Upper**	
Legibility score	1.40	0.55	1.40	0.55	1.000	1.000	1.000
EVAL							
Tripod pinch	5.61	1.28	5.13	1.14	0.174	0.985	0.864
Power grip	18.57	1.92	17.39	1.98	-0.837	0.783	-0.079
DEM							
Time ratio	1.50	0.27	1.28	0.44	-0.468	0.942	0.554
Vertical adjusted time	59.01	8.76	58.65	6.68	0.408	0.991	0.916
Horizontal adjusted time	88.71	24.52	76.11	32.45	0.112	0.983	0.847
MVPT	28.20	3.19	29.40	2.51	-0.420	0.948	0.594
VMI	15.80	2.17	15.80	3.27	-0.571	0.924	0.448

Table 3.5 Inter-rater reliability of the assessment protocol (N=5)

	1st Rater		2nd Rater		95% CI		ICC
Item	**Mean**	**SD**	**Mean**	**SD**	**Lower**	**Upper**	**(2,1)**
Legibility score	1.40	0.55	1.20	0.84	-0.032	0.977	0.800
DEM							
Vertical adjusted time	49.60	8.47	49.80	9.04	0.790	0.997	0.976
Horizontal adjusted time	70.48	13.84	71.09	13.51	0.965	1.000	0.996
Time ratio	1.42	0.08	1.42	0.07	-0.151	0.971	0.753
MVPT	31.20	4.09	31.20	4.09	1.000	1.000	1.000
VMI	19.60	2.70	18.00	2.35	0.027	0.980	0.820

Table 3.6 Intra-rater reliability of the assessment protocol (N=5)

	1st Rating		2nd Rating		95% CI		ICC
Item	**Mean**	**SD**	**Mean**	**SD**	**Lower**	**Upper**	**(3,1)**
Legibility score	1.80	0.45	1.40	0.89	-0.258	0.964	0.700
DEM							
Vertical adjusted time	56.45	7.34	56.65	6.91	0.810	0.998	0.978
Horizontal adjusted time	71.72	20.94	76.11	32.45	0.328	0.989	0.900
Time ratio	1.31	0.40	1.28	0.44	0.888	0.999	0.988
MVPT	29.40	2.51	29.40	2.51	1.000	1.000	1.000
VMI	16.20	3.11	15.80	3.27	0.867	0.998	0.985

Table 3.7 Summary of the ICC scores of reliability tests

	Test-retest reliability ICC(3,1); n=5	**Inter-rater reliability** ICC (2,1); n=5	**Intra-rater reliability** ICC (3,1); n=5	**Internal consistency** Cronbach Alpha n=10
POET Time Speed Pressure	0.993 (range from 0.971 to 1.000) (Chen, 2005)	NA	NA	Overall: 0.642 6 words: 0.485 20 words: 0.650
Legibility rating (Likert scale)	1.000	0.800	1.000	NA
EVAL Tripod pinch Grip	0.864 -0.079	NA	NA	Overall: 0.470
DEM				Adjusted time: 0.570 Adjusted time with ratio: 0.422
Time ratio	0.554	0.753	0.988	
Vertical adjusted time	0.916	0.976	0.978	
Horizontal adjusted time	0.847	0.996	0.900	
MVPT	0.594	1.000	1.000	NA
VMI	0.448	0.820	0.985	NA

3.4.3 Construct validity of the assessment protocol

3.4.3.1 Penmanship Objective Evaluation Tool (POET)

Results of the Mann Whitney U Test were shown in the last two columns of Table 3.8. Significant difference was showed in legibility (Z(2, 8)=-2.154, p=0.031). This might suggest the consistency of teachers to use legibility as an indicator for identifying children as good or poor handwriters. Moreover, significant difference was also found in the mean of speed (Z(2, 8)=-1.984, p=0.047) between the two groups. This might imply that while used for observing children's level of handwriting performance, speed was also one of the factors in teachers' perception.

Table 3.8 Comparison of Chinese handwriting performance between good and poor handwriters

	All (N=10)		**Good handwriters** (n=5)		**Poor handwriters** (n=5)		***Z***	***p value****
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
Time (s)								
Pen in air	66.98	23.03	67.69	9.94	66.28	33.07	-0.313	0.754
Time ratio (ground: air)	0.94	0.33	0.97	0.10	0.91	0.49	-0.313	0.754
Speed (mm/s)								
Mean	38.62	16.75	29.25	6.23	47.99	19.32	-1.984	**0.047**
Variability	26.39	12.90	18.88	4.62	33.91	14.55	-1.776	0.076
Pressure (N)								
Mean	2.86	0.15	2.88	0.14	2.83	0.16	-0.731	0.465
Variability	0.50	0.09	0.51	0.09	0.49	0.11	-0.522	0.602
Legibility	1.10	0.74	1.60	0.55	0.60	0.55	-2.154	**0.031**

* Statistically significant different, i.e. $p \leq 0.05$

Table 3.9 showed the structure matrix of each discriminating variable while Table 3.10 was a reorganized table showing the order of variables being taken out in the analysis. Three variables, in descending order of the matrix value: the legibility, speed variability, and speed mean, were identified with the correlation coefficient higher than 0.40. It might indicate that teachers' perception of poor and good handwriters was affected, and predicted by these three variables. According to the mean comparison table, children in good handwriters group wrote in significantly better legibility, significantly lower speed, and also non-significantly less variability in speed during writing.

Tables 3.11 and 3.12 showed the centroids value and the canonical correlation functions of the three variables: legibility, speed variability and speed mean. From the classification table (Table 3.13), 90% accuracy was reported for the prediction using the discriminant functions of these three variables in discriminating children as good and poor handwriters. In other words, performance in legibility, speed variability and speed mean of the child was highly accurate in predicting the grouping of good and poor handwriters based on teachers' perceptions. However, the results need further verification before application. Figure 3.2 showed a graphical presentation of the discriminating ability of the factors.

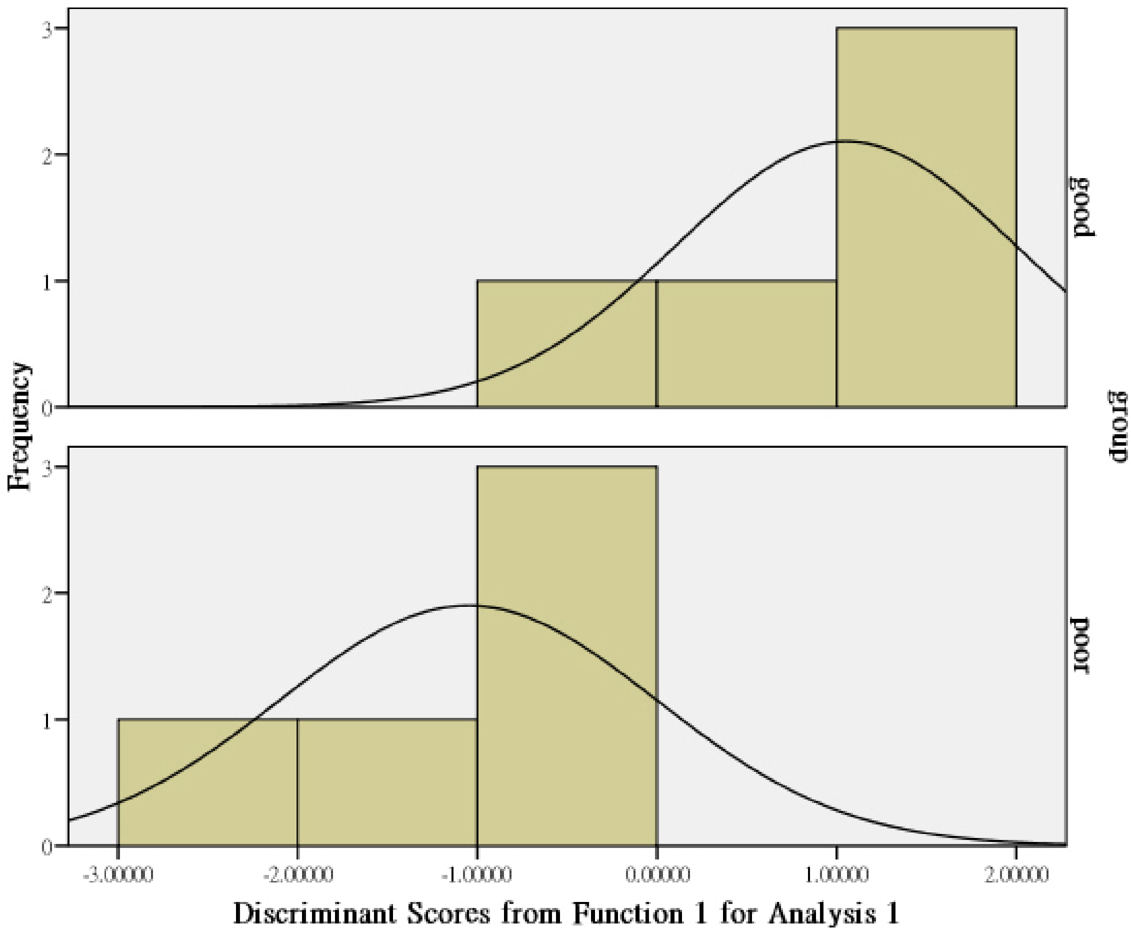

Figure 3.2 Graphical presentation on differentiation of groups by the discriminant scores of the three variables: legibility, speed variability, and speed mean.

Table 3.9 Structure matrix of handwriting performance in discriminating good and poor handwriters

	Matrix				
Pen in air time	.008				
Ground to air time ratio	.025	.025			
Speed mean	-.188	-.190	-.217	-.408	**-.621***
Speed variability	-.200	-.203	-.232	-.435	**-.662***
Pressure mean	.047	.047	.054	.102	
Pressure variability	.025	.025	.029		
Legibility	.263	.266	.304	.571	**.868***

* Correlations between discriminating variables and standardized canonical discriminant functions ≥ 0.40

Table 3.10 Table for structure matrix (in descending order) of handwriting performance in discriminating children into good and poor handwriter groups.

	Matrix				
Legibility	.263	.266	.304	.571	**.868***
Speed variability	-.200	-.203	-.232	-.435	**-.662***
Speed mean	-.188	-.190	-.217	-.408	**-.621***
Pressure mean	.047	.047	.054	.102	
Pressure variability	.025	.025	.029		
Ground to air time ratio	.025	.025			
Pen in air time	.008				

* Correlations between discriminating variables and standardized canonical discriminant functions ≥ 0.40

Table 3.11 Mean Scores on discriminant Functions for the grouping of good and poor handwriters (centroids) by handwriting legibility, speed variability, and speed mean

Legibility score	**Function 1**
Good	1.051
Poor	-1.051
Wilk's Lamda	0.420
Chi Square	5.639
Sig.	0.131
Eigenvalue	1.381
Canonical Correlation	.762

Table 3.12 Standardized Canonical Discriminant function coefficients of handwriting legibility, speed variability and speed mean in discriminating good and poor handwriters

Factors	Function 1
Speed mean	.863
Speed variability	-1.321
Legibility	.761
(Constant)	

Table 3.13 Classification of children in terms of good and poor handwriters using discriminant analysis on handwriting legibility, speed variability, and speed mean

	Group	**Predicted Group Membership**		**Total**
		Good handwriters	Poor handwriters	
Original* Count (%)	Good	4 (80%)	1 (20%)	5 (100%)
	Poor	0 (0%)	5 (100%)	5 (100%)
Cross-validated** Count (%)	Good	3 (60%)	2 (40%)	5 (100%)
	Poor	3 (60%)	2 (40%)	5 (100%)

*90.0% of original grouped cases correctly classified.
**50.0% of cross-validated grouped cases correctly classified.

3.4.3.2 Tools for performance components

As shown in Table 3.14, children with good handwriting in general scored better in MVPT (mean=32.80, SD=2.17), and VMI (mean=19.40, SD=2.88) than those with poor handwriting (MVPT: mean=26.20, SD=2.28; VMI: mean=14.20, SD=3.56). Despite of the small sample size, statistically significant difference was found in MVPT (Z(2,8)=4.690, p=0.002) and VMI (Z(2,8)=2.537, p=0.035) between the two groups of children.

Table 3.14 Comparison of characteristics in performance components between good and poor handwriters

	All (N=10)		**Good handwriters** (n=5)		**Poor handwriters** (n=5)		***Z***	***p value****
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
EVAL (dominant hand)								
Tripod pinch	5.00	1.57	5.70	0.51	4.29	2.01	1.526	0.194
Grip	18.36	5.33	21.01	4.47	15.70	5.13	1.743	0.119
DEM								
Vertical adjusted time	60.90	22.52	51.08	10.68	70.72	28.03	-1.359	0.211
Horizontal adjusted time	112.27	103.25	69.85	13.51	154.69	138.94	-1.359	0.211
Ratio	1.35	0.41	1.38	0.17	1.33	0.58	0.187	0.856
MVPT	29.50	4.06	32.80	2.17	26.20	2.28	4.690	**0.002**
VMI	16.80	4.10	19.40	2.88	14.20	3.56	2.537	**0.035**

* Statistically significant different, i.e. $p \leq 0.05$

The structure matrix among demographic factors and the performance components were showed in Tables 3.15 and 3.16. Children's performance in MVPT-R and VMI was found as the discriminating factors for the grouping of good and poor handwriters. Correlation between discriminating variables and the standardized canonical discriminant functions was .999 and .541 respectively. According to the mean comparison table, children in good handwriters group had significantly higher scores in MVPT-R and VMI, implying that children identified as good handwriters might have better visual perceptual skills and visual motor integration.

Tables 3.17 and 3.18 showed the centroids value and the canonical correlation functions of the two variables: MVPT-R and VMI. From the classification table (Table 3.19), 100% accuracy was reported for the prediction using the discriminant functions of the MVPT-R and VMI in discriminating children as good and poor handwriters. In other words, performance in an overall estimation of visual perceptual skills and visual motor integration was highly accurate in predicting the grouping of the good and poor hndwriters based on teachers' perceptions. However, same as the results found in handwriting performance, further verification is needed before application. Hence, it would be further verified and used for analysis in the main study of this thesis. Figure 3.3 showed a graphical presentation of the discriminating ability of the factors.

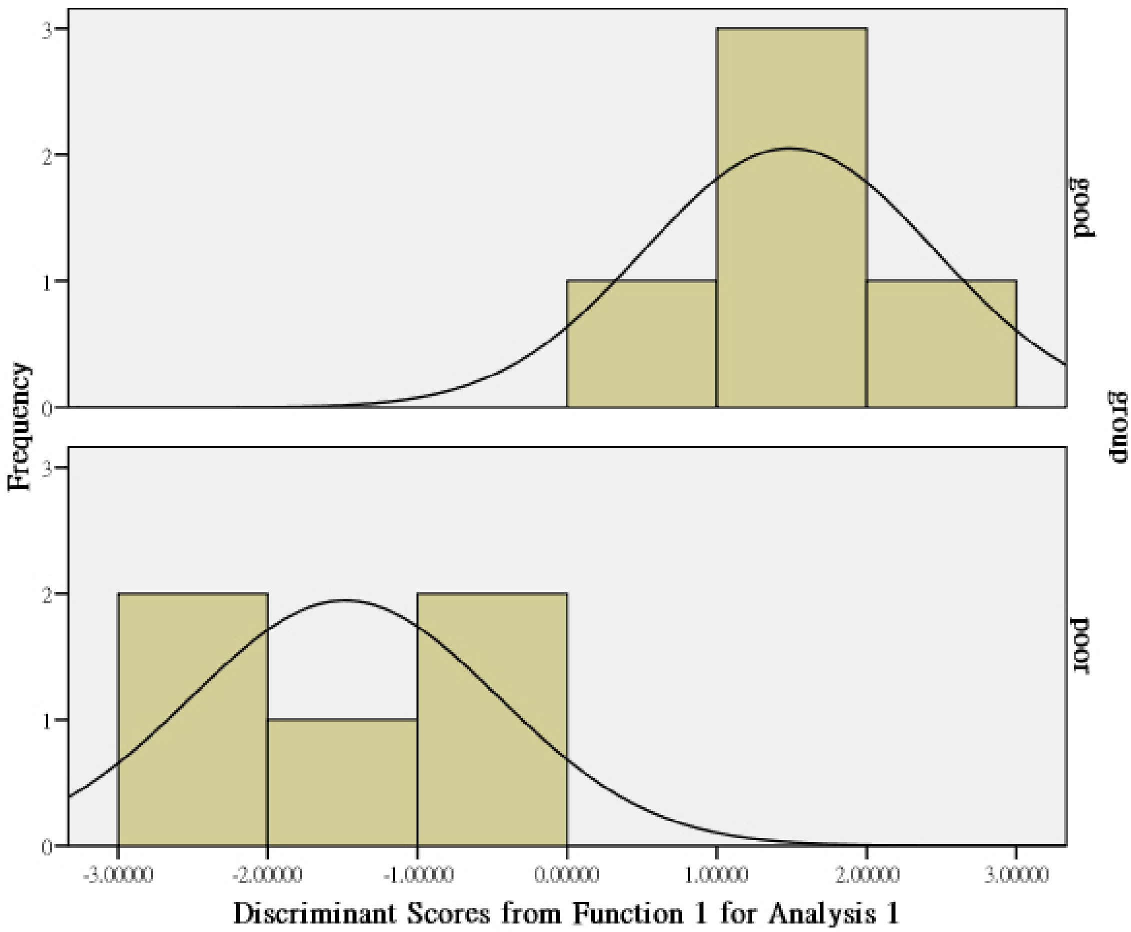

Figure 3.3 Graphical presentation on differentiation of groups by the discriminant scores of the MVPT-R and VMI.

Table 3.15 Structure matrix of demographic factors and performance components in discriminating good and poor handwriters

	Matrix							
Gender	-.121	-.141	-.143					
Age	.326	.031						
Power grip	.166	.194	.197	.198	.272	.326	.371	
Tripod pinch	.145	.170	.172	.173	.238	.285		
DEM vertical time	-.140	-.163	-.165	-.166	-.229			
DEM horizontal time	-.129	-.152	-.153	-.154				
DEM time ratio	.018							
MVPT-R	.447	.523	.529	.533	.732	.877	.998	**.999***
VMI	.242	.283	.286	.288	.396	.474	.540	**.541***

* Correlations between discriminating variables and standardized canonical discriminant functions ≥ 0.40

Table 3.16 Table for structure matrix (in descending order) of demographic factors and performance components in discriminating children into good and poor handwriter groups.

	Matrix							
MVPT-R	.447	.523	.529	.533	.732	.877	.998	**.999***
VMI	.242	.283	.286	.288	.396	.474	.540	**.541***
Grip strength	.166	.194	.197	.198	.272	.326	.371	
Tripod pinch strength	.145	.170	.172	.173	.238	.285		
DEM vertical time	-.140	-.163	-.165	-.166	-.229			
DEM horizontal time	-.129	-.152	-.153	-.154				
Gender	-.121	-.141	-.143					
Age	.326	.031						
DEM time ratio	.018							

* Correlations between discriminating variables and standardized canonical discriminant functions ≥ 0.40

Table 3.17 Mean Scores on discriminant Functions for the grouping of good and poor handwriters (centroids) by MVPT-R and VMI

Legibility score	**Function 1**
Good	1.481
Poor	-1.481
Wilk's Lamda	.266
Chi Square	9.261
Sig.	.010
Eigenvalue	2.754
Canonical Correlation	.857

Table 3.18 Standardized Canonical Discriminant function coefficients of MVPT-R and VMI in discriminating good and poor handwriters

Factors	Function 1
MVPT-R	.976
VMI	.047
(Constant)	

Table 3.19 Classification of children in terms of good and poor handwriters using discriminant analysis on the MVPT-R and VMI

	Group	**Predicted Group Membership**		**Total**
		Good handwriters	Poor handwriters	
Original* Count (%)	Good	5 (100%)	0 (0%)	5 (100%)
	Poor	0 (0%)	5 (100%)	5 (100%)
Cross-validated** Count (%)	Good	5 (100%)	0 (0%)	5 (100%)
	Poor	0 (0%)	5 (100%)	5 (100%)

*100.0% of original grouped cases correctly classified.
**100.0% of cross-validated grouped cases correctly classified.

3.5 Discussion

The reliability and construct validity of the assessment protocol were discussed according to the findings in this study. Feedback was gained in advance from the teachers and occupational therapists who conducted the assessments in this phase of the study to evaluate the usability and to provide comments for the modification of the protocol in phase II.

3.5.1 Reliability of the assessment protocol

3.5.1.1 Evaluation on Chinese handwriting performance

The computerized evaluation for handwriting process showed little impact of rater bias. The study by Chan (2005) has reported a good to excellent test-retest reliability among children in writing Chinese characters. The tool was shown to be reliable for assessing the process of Chinese handwriting including the parameters of handwriting time, handwriting speed and its variability, and the pressure and its variability. Although the internal consistency indicated by the cronbach's alpha was below the level of 0.80, it did not reflect poor content in the tool. Instead, it might reflect heterogeneity among the measurements of the POET. It also suggested a multi-construct characteristic in the process of the handwriting.

Legibility rating by teachers was used as an indicator of performance in product of handwriting. The results presented a good to excellent consistency on repeated measure and repeated rating by the same rater for the legibility rating. However, a relatively low consistency was showed for the consistency between raters. The statistically lower reliability score for legibility rating might be due to its subjectivity. Teachers might bear different definition or standard of the legibility. They usually compared the handwriting product among the children and rated the score comparatively. A teacher who used to rate a group of children with generally good legibility might have a different standard on legibility compared with another teacher who used to rate the children as poor handwriters. Hence, as suggested by Portney and Watkins (2000), one way to increase the rater reliability was to develop objective grading criteria. With a clear and objective guideline, teachers can rate with reference to the given definition and rating criteria so as to enhance the consistency between raters.

Considering the construct validity of the POET in discriminating good and poor handwriters, three variables in handwriting performance including legibility, speed variability and mean speed were analyzed with discriminant functions equal to 0.868, -0.662 and -0.621 respectively. These variables were identified as discriminant factors for predicting teachers' perceptions of good and poor handwriters. While legibility and speed had a long history of being indicators in children's handwriting evaluation (Schwellnus & Lockhart, 2002; Amundson, 1995; Ziviani & Elkins, 1984; Bonney, 1992; Quant, 1946; Chow, Choy & Mui, 2003), it might be interesting to find out that variability in speed was also an important indicator in discriminating children's handwriting performance.

Li, Haddad and Hamill (2005) stated that variability in motor control indicated different levels of motor learning. A significantly lower variability in the handwriting speed of good handwriters might indicate a better master of the handwriting skills. Also, by the high discriminant function as shown in the findings, it might be worthwhile for therapists to use this as an indicator for handwriting evaluation in advance to the legibility and speed.

3.5.1.2 Evaluation on the performance components

Rater bias was not shown in a great extent among instruments for the four performance components, including the power grip and tripod pinch strength, the ocular motor skills, the visual perceptual skills and the visual-motor integration skill. All tools showed a satisfactory range of ICC value with inter-rater reliability ranging from 0.753 to 1.000 and the intra-rater reliability ranging from 0.648 to 1.000. Such high rater reliability could be explained by the standardized characteristic of the assessment tools. The results might also suggest that the computerized and standardized measurement allowed accuracy of data with rater difference. The assessment instruments with standardized instruction and grading criteria were chosen in the study, thus raters could refer to the printed guidelines for instructions and rating. Therefore, the subjectivity in clinical reasoning could be reduced as much as possible.

However, good test-retest reliability was only obtained in the items of tripod pinch and DEM adjusted time (ICC over 0.80) and the reliability was moderate for MVPT-R and VMI (ICC= .597 and .448). The ICC value in measurements of grip was as low as -0.079. As suggested by the literature, such a low reliability in repeated measures might be attributed to two main factors. They were the measurement errors and the carryover effects. The measurement error was a systematic error occurred in the measuring tool or the rater while the carryover effect was also known as the testing or learning effects in repeated tests.

In the measurement of power grip, rater bias was eliminated in the record of reading. However, it was suggested that the positioning, verbal instruction given in the process of assessment, and the environment would also affect a child's performance. For example, one assessor might provide more verbal prompt than the other. This act might produce a rater bias in which would further affect the performance of the child. Hence, to ensure better reliability in grip measurement, standardized instruction was restricted in phase II of the study.

Among the performance components, MVPT-R and VMI were found to have the highest construct validity in discriminating children with good and poor handwriting. In fact, VP and VMI had been consistently found as crucial factors, or predictors, in handwriting performance (Kwok, 2000; Longcamp et al., 2003; Goldstand, Koslowe & Parush, 2005).

3.5.2 Modifications for Phase II of the study

3.5.2.1 Extension of the legibility scale

Subjective feedback from teachers commented on the limited scale with three levels of scores in legibility rating. They suggested that commonly used 5-point likert scale be adopted in the study such that wider scale of performance could be indicated. Also, they commented that the score of '0' was seldom given since it indicated an extremely bad performance with no marks. Hence, with the suggestions given by the teachers, the rating scale would be extended to a 5-point Likert scale with levels of 1 to 5 in the phase II of the study.

3.5.2.2 Addition of the fine motor skills in performance components evaluation

The motor skills used in the study analysis included the grip and tripod pinch strength, and ocular motor skills. Test for fine motor skills was not included in the assessment protocol in phase I of the study. Based on further literature review, fine motor skill was in fact indicated as one of the main factors in performance of handwriting. Although controversial findings have been reported on the correlation between fine motor skills and handwriting performance, it appeared that handwriting was a motor task thus the role of fine motor skills in handwriting deserved research attention.

Adding the fine motor skills evaluation into the assessment protocol would help give a comprehensive analysis including visual perceptual skills, fine motor skills, and the visual motor integration.

3.5.3 Logistic arrangement

3.5.3.1 Length of assessment session

The assessment protocol in this study included instruments for handwriting process plus a total of five performance components. Total time required for each assessment session for each child was about forty minutes.

During the assessment session, fatigue was not observed among children. No children had complained of being tired or refused to perform the assessment. This might be due to the multi-features of different assessment tools for different performance components. For example, the handwriting process evaluation and visual motor integration required children performance in paper and pencil task, the assessment on grip and pich strength was more like a competition on motor strength, the ocular motor task was more on reading, and finally, the visual perceptual and non-verbal intelligence test was more likely a picture recognition task. The multi-features of the instrument could arouse children's motivation and interest in participating in the assessment. Also, the approximate time needed to complete each assessment was about ten to fifteen minutes. This range of time was within the attention span among children at similar age. A shift of task between each assessment allowed children to rest and get prepared for another task. Hence, the forty-minute-long assessment session with mini-breaks was applicable for the children.

3.5.3.2 Environment set up

The assessment was planned to be conducted in quiet rooms in the children's school. However, due to limited accessibility of space in school, especially after school time while rooms were arranged for extra curriculum activities. School could only provide one classroom for the assessment. Hence, stations for assessment were arranged separately in corners inside the classrooms.

Since some of the tests such as the visual perceptual skills and ocular motor tests required children to speak out the answer, children performing the handwriting tasks might be disturbed. Separation between the stations with certain distance or separator could be arranged to prevent children from being disturbed.

3.6 Conclusion

The aim and objectives were achieved in this study.

In conclusion, reliability in terms of test-retest, interrater, and intrarater was generally acceptable and supported among the instruments for handwriting and performance components evaluation. The whole assessment protocol would be adopted in the phase II and phase III of the study. However, several modifications should be made by extending the legibility scale, adding the evaluation on fine motor skills, and considering the hand dominance. Also, suggestion on better logistic arrangement was given. Construct validity in discriminating good and poor handwriters was good in legibility measure, speed mean and variability in POET, MVPT-R and VMI.

Although the results of this phase of study were limited by a small sample size, it provided a valuable clinical trial for implementing the assessment protocol with recommendations on modifications for phase II of the study.

Chapter 4 Phase II of the study

4.1 Introduction

Previous researchers have stated that handwriting demanded a child's cognitive and executive function, neuromuscular control, kinesthetic and tactile sensitivities, visual motor co-ordination and visual perceptual skills (Feder, 2005; Rosenblum, Weiss & Parush, 2003; Ziviani & Watson-Will, 1998). Many studies have provided evidence for the association between these factors and handwriting skills in children. Chinese words were presented with different writing patterns and required different origin for processing (Siok et al., 2004; Peng et al., 2003; Chow, Choy & Mui, 2000; Chow, 2000; Law, Chung & Lam, 1998). It was also suggested that writing Chinese was different from writing other alphabetically based languages such as English, Italian and Hebrew (Tan et al., 2000, 2001; Chow, Choy & Mui, 2000; Rosenblum, Weiss & Parush, 2003).

This study aimed to find out various factors affecting handwriting and the inter-relationships of these factors in affecting the handwriting pause time, speed, pressure and legibility.

4.2 Objectives of the study

a) To investigate the characteristics of children performance in Chinese handwriting among Hong Kong school-aged children;

b) To study the relationships between the intrinsic factors including performance components (grip and pinch strength, fine motor skills, ocular motor skills, visual perceptual skills, and visual motor integration) and the Chinese handwriting performance;

c) To identify the main factors affecting Chinese handwriting performance.

4.3 Methodology

4.3.1 Sampling method

Two hundred and forty children studying Primary 1 (aged 6-8) in whole-day mainstream schools in Hong Kong were recruited by stratified sampling method. The number of children selected was in proportion to the total student number. Schools were selected from the list of whole-day mainstream primary schools in Hong Kong printed in the Yellow Page according to the geographical location (Kowloon, Hong Kong Island, and New Territories) using a dice. For example, if number 5 was shown on the dice, every 5th primary school in the list would be selected. The principals of these schools were then contacted by phone for agreement to participate in the study. If the school drawn was unable to participate, the reasons for refusal were noted and a replacement school in the same geographical area was drawn. Once verbal agreement had been obtained, consent forms with a cover letter explaining the purpose and details of the study were sent to teachers and were distributed to parents of all the Primary one children in the school. Those who returned a signed consent form were recruited as subjects in this phase of the study.

4.3.2 Selection criteria

4.3.2.1 The inclusion criteria

Children who were recruited in the study should:

a) be six to eight years of age (correct to nearest year of age);
b) be studying primary one in the mainstream school in Hong Kong;
c) use Traditional Chinese and Cantonese as the primary language in written and spoken communication.

4.3.2.2 The exclusion criteria

Children should not:

a) have any known cognitive, motor, visual and hearing impairment;
b) be observed to have behavioral and emotional problems at home, school, or during the assessment session.

4.3.3 The assessment protocol

The assessment protocol presented in phase I of the study was modified and adopted. Referring to Section 2.4, the assessment protocol included a digitizer tool, the Penmanship Objective Evaluation Tool (POET) for evaluation of handwriting performance in terms of time, speed, pressure. Also, the legibility of the handwriting product was given to teachers for their rating on the legibility score. In addition, standardized instruments including EVAL hand evaluation system, the Developmental Eye Movement Test (DEM), the Motor-free Visual Perceptual Test (MVPT), and the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI) were used for recording the children's performance components skills.

As discussed in Section 3.5.2, following modifications were made on the assessment protocol in Phase I of the study. First, the fine motor subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-FM) was added into the protocol in this phase of study to assess the fine motor abilities of the children (Refer to Section 2.3.1.1.1). The sub-items and psychometric properties of the modified assessment protocol were showed in Table 4.1 below.

Second, the legibility rating scale was expanded from a 3 point Likert scale (0=poor, 1=average, 2=good) to a five point Likert scale (1=worst, 5=best) according to the teachers' comments given in phase I of the study.

Table 4.1 The assessment protocol used in Phase II of the study

Component in the **Modified Conceptual Model of Handwriting Performance** (Section 1.2.3)	Instrument	Test items
Chinese Handwriting performance	Penmanship Objective Evaluation Tool (POET) Teacher legibility rating (5 point likert scale)	20 Chinese words - pen in air time - speed and its variability - pressure and its variability - legibility
Grip and pinch strength	EVAL hand evaluation system	- Tripod pinch - Power grip
Ocular motor skills	Developmental Eye Movement Test (DEM)	- Time ratio (horizontal to vertical) - Vertical adjusted time - Horizontal adjusted time
Visual motor integration	The Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI)	VMI score (Total=27)
Visual perceptual skills	Motor-free Visual Perceptual Test – Revised (MVPT-R)	MVPT score (Total=40)
Fine motor skills	Bruininks-Oseretsky Test of Motor Proficiency Fine Motor subtest (BOTMP-FM)	Fine motor subtest score

4.3.4 Procedure

This phase of the study was a cross-sectional study in which assessment was only conducted once. Subjects were arranged to perform the assessment based on the evaluation described in Section 2.4. Similar assessment procedure was adopted as in phase I of the study (Section 3.3.4). In view of the relatively low interrater reliability obtained in the pilot study, the guidelines on legibility rating were given to teachers as reference. A score of 1 represents the poorest and a score of 5 represents the best.

Figure 4.1 shows the flow chart of this phase of the study.

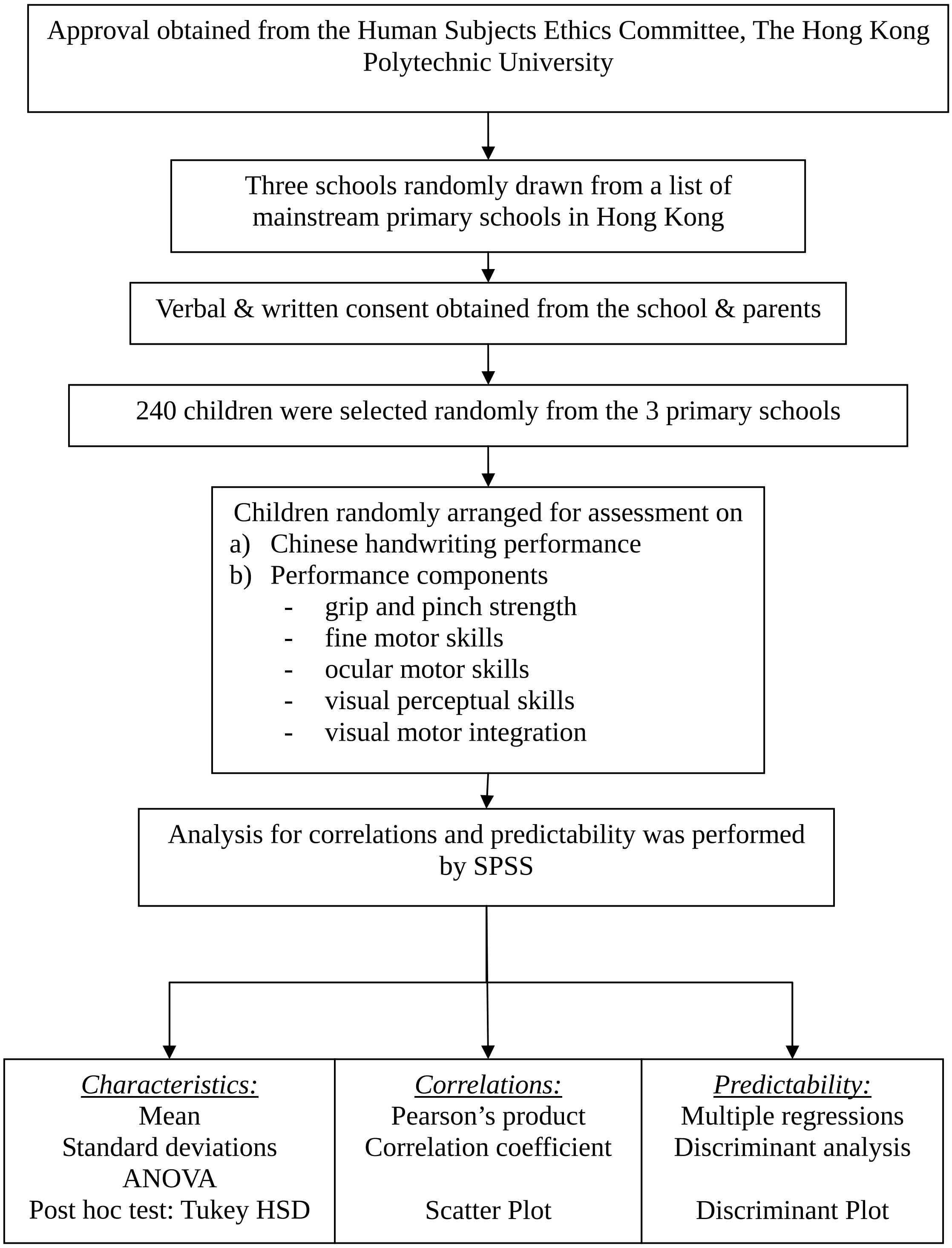

Figure 4.1 The flow of study in Phase II: Factors affecting Chinese handwriting performance among school-aged children in Hong Kong

4.3.5 Data analysis

Data analysis was conducted using the Statistical Package SPSS, version 12.0 for Windows (SPSS Inc., Chicago, IL, USA).

Characteristics of children's performance were compared according to i) the legibility grouping, ii) gender, and iii) hand dominance. Descriptive and inferential analyses were conducted. Mean and standard deviation of the children performance in terms of levels of legibility were presented in tables for descriptive analysis. The profile of children handwriting performance was produced based on the writing of 20 Chinese words. The independent t-test was used for between groups comparison ($\alpha = 0.05$). For comparison among more than two groups, one way ANOVA was performed. With Bonferroni's adjustment, statistical significance was defined with a p value lower than 0.017 to account for the multiple t-test analyses.

The Pearson's product correlation coefficient (r) was performed to study the associations between the factors and children's performance in writing Chinese. Investigations were conducted for the associations for all factors. A coefficient valued higher than 0.75 was considered as good to excellent relationship. A value between 0.50 and 0.75 was considered as having moderate to good association (Portney and Watkins, 2000).

Multiple regression analysis was used to examine the predictability of the factors to different constructs of the handwriting performance including time, speed, and pressure in which the data was captured as continuous data. All variables were input into the regression analysis using the backward model to examine the predictability with consideration of the inter-item correlation as indicated by the tolerance. The value of tolerance ranged from 0.000 to 1.000. The higher the value, the greater the inter items covariance. These variables which failed in the tolerance test was automatically excluded in the regression analysis. Moreover, outliers were screened out with standard deviation of residual greater than 3 using the Casewise diagnostics analysis.

R-square (R^2) was reported to represent the degree of which the variability of dependent variable could be explained by the independent variable entered for analysis. The standardized correlation coefficient, beta (β), was employed to indicate the strength of correlation. Similar as the Pearson's r, correlation would be considered as good to excellent with a coefficient value higher than 0.75; moderate to good with a correlation coefficient between 0.50 and 0.75. Moreover, the significance of correlation was shown in terms of p-value with p-value smaller than 0.05 regarded as being significant.

On the other hand, predictability of factors to the handwriting legibility was performed with the discriminant analysis. The discriminant analysis is a test showing the correlation between variables and a categorical variable. The eigenvalue, which was scaled from 0.000 to 1.000, was reported to indicate the degree to which the variance of dependent variables could be explained by the independent variable. It was interpreted as the same as for the R-square of the regression analysis. Correlations between the discriminating variables and the standardized canonical discriminant functions were reported as the indicator for strength of association. Definition of degree of association was the same for the standardized coefficient correlation (β).

4.4 Results

4.4.1 Demographic data of the subjects

As show in Table 4.2, two hundred and forty children, including 122 (50.8%) boys and 118 (49.2%) girls, were assessed in this study. Their age ranged from 5.9 to 8.3 years old (mean= 6.5 years, SD= 0.4). 95.8% (n=230) of the participants showed a preference of using the right hand for writing, while there were only 4.2% (n= 10) of the children had a preference of left hand in writing (Table 4.2). Among the ten left handers, half were boys and half were girls.

Table 4.3 summarized the characteristics of children among the three groups of legibility. Demographic data showed that a higher percentage of boys had a moderate score of 3 for the legibility (56.7%) while more girls had a score of 4 or 5 (66.7%). This indicated that there is a tendency for girls to write better (Figure 4.2).

Table 4.2 Demographic characteristics of the children participating in the study (N=240)

Characteristics		(N=240)
Age in years	Mean (SD)	6.5 (0.4)
	Max	8.3
	Min	5.9
Gender N (%)	Boys	122 (50.8%)
	Girls	118 (49.2%)
Hand dominance N (%)	Right	230 (95.8%)
	Left	10 (4.2%)
Geographic region of the School N (%)	Hong Kong Island	21 (8.8%)
	Kowloon	153 (63.8%)
	New Territories	66 (27.5%)
Legibility Score N (%)	1	3 (1.3%)
	2	30 (12.5%)
	3	120 (50%)
	4	81 (33.8%)
	5	6 (2.5%)

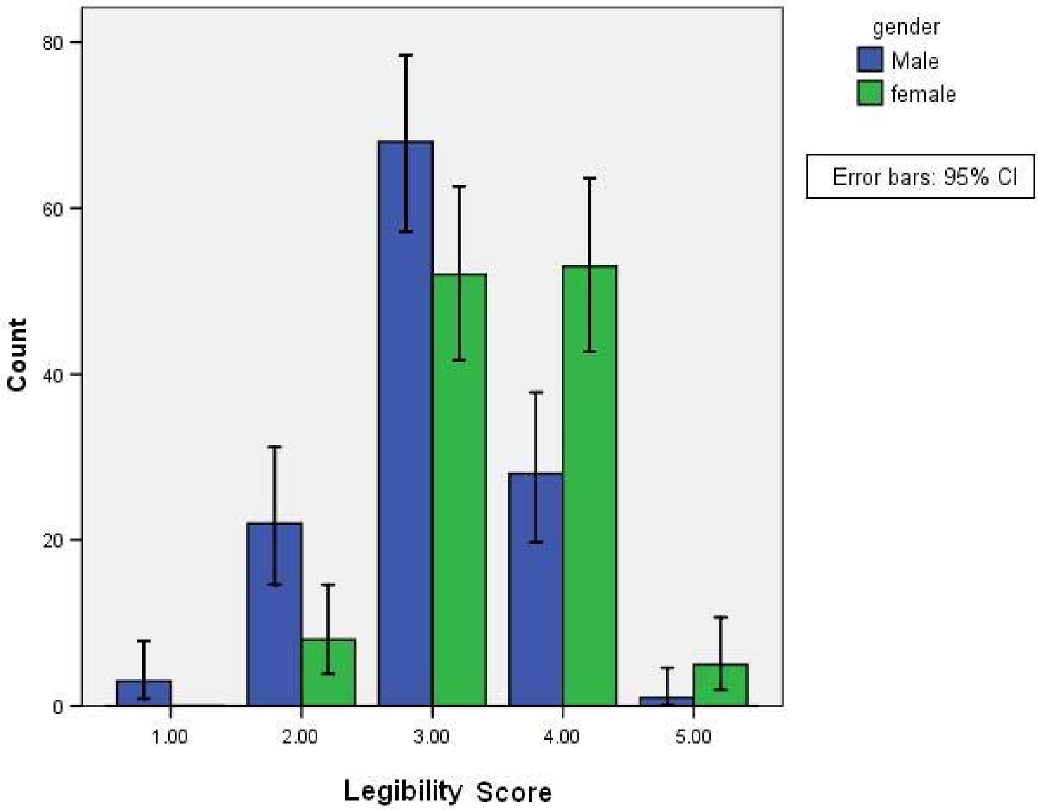

Figure 4.2 Gender distributions in each group of children according to their legibility score on Chinese handwriting (Scale ranged from 1 to 5; '1' for the poor, '5' for the good).

Table 4.3 Demographic data of the children participants according to their legibility score

Item	Poor legibility (scored 1 or 2 / 5)	Average legibility (scored 3 / 5)	Good legibility (scored 4 or 5 / 5)
N (%)	33 (13.8%)	120 (50%)	87 (36.3%)
Mean age (SD) in years	6.4 (0.38)	6.5 (0.39)	6.5 (0.44)
Gender			
Male	25 (75.8%)	68 (56.7%)	29 (33.3%)
Female	8 (24.2%)	52 (43.3%)	58 (66.7%)
Hand Dominance			
Left	3 (9.1%)	6 (5%)	1 (1.1%)
Right	30 (90.9%)	114 (95%)	86 (98.9%)

4.4.2 Characteristics of children performance in performance components

Children's performance components were compared according to their legibility scores, gender, and hand dominance (Tables 4.4 to 4.6). Result showed that children who had better performance in handwriting legibility performed better in VMI, MVPT-R, DEM, and BOTMP.

4.4.2.1 Grip and pinch strength

According to Table 4.5, boys generally showed a greater strength in tripod pinch and power grip as compared to girls. Statistically significant difference was observed in power grip between boys and girls ($F(2, 238)=2.046$, $p=0.042$), which means, boys had a significantly greater grip force as compared to the girls.

Descriptive data in Table 4.6 showed that children with right hand dominance tended to have greater strength in pinch and grip. However, due to the very small sample size in the left handers, the comparison should be interpreted with caution and further studies are needed to verify the results.

4.4.2.2 Ocular motor and fine motor skills

In all comparisons, no statistically significant difference was shown among children in terms of their performance in the DEM tasks as well as the BOTMP-FM. However, it was interesting to note that children with poor legibility generally performed with a longer (over-average) DEM time and poorer (under-average)

BOTMP score in fine motor subtest as compared to the other two groups.

4.4.2.3 Visual perceptual skills

According to the result of ANOVA shown in Table 4.4, significant differences among children with different legibility scores were only shown in the MVPT score ($F(2, 237)=3.354$, $p=0.001$) and VMI score ($F(2, 237)=12.086$, $p=0.000$). Post Hoc test using Tukey HSD found that the significant difference in MVPT score was accounted by the mean difference between children with good and poor legibility ($p=0.001$). With a total score of 40, the mean score of MVPT among children with good legibility (scored 4 or 5 in the scale of 5) was 28.51 with a standard deviation of 4.40 which was significantly higher than that of children with poor legibility (scored 1 or 2 in the scale of 5) with a mean MVPT score of 25.15 (SD=4.76).

4.4.2.4 Visual motor integration

Similar to the result in MVPT, post hoc investigation on comparison of the VMI score among groups found significant difference between the children with good (mean=18.51, SD=2.59) and poor legibility (mean= 15.97, SD=2.83, $p=0.000$). In addition, the performance of the children with good legibility was also significantly different from those with average legibility (mean=17.21, SD=2.73, $p=0.002$). An upward trend of the mean VMI score was found in which children with poor legibility were reported to have a lowest mean of VMI score and verse versa.

Table 4.4 Comparison of children's performance components on legibility score

	All (N=240)		**Poor** (mode of legibility score=1 or 2) (n=33)		**Average** (mode of legibility score=3) (n=120)		**Good** (mode of legibility score=4 or 5) (n=87)		F	p value*
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)		
EVAL (dominant hand)										
Tripod pinch (lb)	5.17	1.53	5.32	1.52	5.15	1.52	5.15	1.55	0.188	0.829
Power Grip (lb)	17.53	3.99	17.47	4.50	17.87	3.90	17.07	3.90	1.010	0.366
DEM Ratio	1.47	0.47	1.50	0.45	1.47	0.48	1.45	0.48	0.127	0.881
Vertical adj. time (s)	58.69	17.32	60.91	18.13	58.86	18.18	57.60	15.80	0.446	0.641
Horizontal adj. time (s)	94.21	48.19	95.07	25.68	97.75	60.75	89.18	33.21	0.773	0.463
MVPT	27.34	4.63	25.15	4.76	27.10	4.53	28.51	4.40	6.354	0.001
VMI	17.51	2.82	15.97	2.83	17.21	2.73	18.51	2.59	12.086	0.000
BOTMP -FM	56.25	7.64	52.91	10.62	56.45	6.53	57.23	7.47	4.014	0.019

* Statistically significant difference found with Bonferroni's adjustment, i.e. $p<0.017$

Table 4.5 Comparison on children's performance components between genders

	All (N=240)		Male (n=122)		Female (n=118)		t	p value*
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
EVAL (dominant hand)								
Tripod pinch	5.17	1.53	5.24	1.59	5.11	1.45	0.645	0.520
Grip	17.53	3.99	18.05	3.90	17.00	4.02	2.046	0.042
DEM								
Ratio	1.47	0.47	1.46	0.40	1.48	0.54	-0.248	0.805
Vertical adj. time	58.69	17.32	58.08	17.04	59.32	17.65	-0.554	0.580
Horizontal adj. time	94.21	48.19	89.84	31.04	98.68	60.81	-1.380	0.169
MVPT	27.34	4.63	26.90	4.83	27.79	4.39	-1.487	0.138
VMI	17.51	2.82	17.23	2.77	17.80	2.84	-1.564	0.119
BOTMP -FM	56.25	7.64	56.60	7.54	55.88	7.75	0.726	0.468

* Statistically significant difference, i.e. $p<0.05$

Table 4.6 Comparison of performance components on hand dominance

	All (N=240)		Left (n=10)		Right (n=230)		t	p value*
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
EVAL (dominant hand)								
Tripod pinch	5.17	1.53	4.58	1.15	5.20	1.54	-1.265	0.207
Grip	17.53	3.99	16.71	2.58	17.57	4.04	-0.667	0.505
DEM								
Ratio	1.47	0.47	1.43	0.53	1.47	0.47	-0.231	0.818
Vertical adj. time	58.69	17.32	68.49	24.36	58.26	16.89	1.314	0.220
Horizontal adj. time	94.21	48.19	144.66	186.92	92.38	34.62	0.791	0.455
MVPT	27.34	4.63	26.90	6.40	27.36	4.55	-0.305	0.761
VMI	17.51	2.82	17.40	3.06	17.51	2.81	-0.124	0.901
BOTMP -FM	56.25	7.64	56.30	6.90	56.24	7.68	0.023	0.982

*Statistically significant difference, i.e. $p<0.05$

4.4.3 Characteristics of children performance in Chinese handwriting

The performance of handwriting was measured in terms of pen in air time, speed and the pressure exerted on the writing surface during handwriting. Tables 4.7 to 4.9 reported the comparison of children's handwriting performance by their legibility scores, gender and hand dominance respectively.

4.4.3.1 Pen in air time

Results showed there was statistically significant difference among children with different legibility score in the time ratio (pen on ground to pen in-air) ($F(2, 237)=9.419$, $p=.000$). According to the post hoc test, significant differences were found between the children with good handwriting legibility (mean=0.69s, SD=0.19) and those with average (mean=0.59s, SD=0.18, $p=.000$) or poor handwriting legibility (mean=0.63, SD=0.19, $p=.003$). However, no statistical significance was revealed in the difference of pen in air time between children with poor legibility and average legibility of Chinese handwriting.

Regarding the gender difference, the pen in air time spent during writing was slightly longer in boys. However, the difference did not show any statistical significance. On the other hand, significant difference was reported in ground to air time ratio between genders. Females demonstrated a higher value of the time ratio (mean=0.66, SD=0.21; ranging from 0.26 to 1.48) while a smaller value for males was found (mean=0.60, SD=0.16; ranging from 0.26 to 1.22). A significantly lower value among males indicated that they spent more time of pen in air than the time on ground. Table 4.9 showed that pen in air was not significantly different between children with left and right hand dominance.

4.4.3.2 Speed and its variability

The results showed that children with good legibility scores had statistically significant differences in both the mean handwriting speed and its variability compared with those with lower legibility scores (mean speed: F(2, 237)=23.965, p=.000; speed variability: F(2, 237)=24.589, p=.000).

In terms of the mean speed in handwriting, post hoc testing indicated that the mean speed for the children with good legibility (mean= 30.45 mm/s, SD=8.00) was significantly different from that of the average (mean= 36.77 mm/s, SD=8.08, p=.000) and the poor handwriters (mean= 41.10 mm/s, SD=10.56, p=.000). However, the mean speed between those with average and poor legibility did not differ significantly from each other (p=0.029) when taking into account the Bonferroni adjustment.

Surprisingly and interestingly, the boys exhibited a faster handwriting speed (mean=36.70mm/s, SD=9.00, ranging from 18.53 to 61.00) while the girls wrote at a slower speed of 33.39mm/s (SD=9.14, ranging from 12.97 to 59.22). However, the variability in speed which indicates the inconsistency in writing efficiency was also revealed to be greater in boys (mean=27.09mm/s, SD=5.10, ranging from 15.15 to 40.63).

Statistical analysis using independent t-test revealed that statistically significant differences existed in speed (t(238)=2.823, p=.005) and speed variability in handwriting (t(238)=3.235, p=.001) between genders. This might indicate that boys may generally perform faster but more unsteadily during writing the Chinese characters compared with girls. Table 4.9 showed that speed mean and variability were not significantly different between children with left and right hand dominance.

4.4.3.3 Pressure and its variability

The pressure data (in non-scale unit) was converted into force scale in Newton by the equation *POET pressure scale = 45.43 + 301.30* force* (Cheung & Li-Tsang, 2006).

A slightly higher pressure (mean= 1.89, SD=0.56) and smaller pressure variability (mean= 0.57, SD=0.14) was found in children with good handwriting legibility according to the comparison of the mean in Table 4.7. However, the ANOVA showed that no statistical significance could be found in the mean pressure exerted on the writing surface (F(2, 237)=0.044, p=.957) and its variability (F(2, 237)=2.127, p=.122) among the children with poor, satisfactory, and good legibility.

Moreover, greater pressure was found exerted by the girls on the writing surface during the process of writing (mean=1.94N, SD=0.53, range from 0.61 to 2.97). However, the difference was not statistically significant (Table 4.8).

On the other hand, Table 4.9 showed significant difference in the pressure mean and variability between left and right handers (t(2, 237)=1.985, p=.048).

4.4.3.4 Legibility

Regarding the legibility rated by teachers, girls had a mean score of 3.50 (n=114, SD=.62, ranged from 2.00 to 5.00) while boys had a mean score of 3.06 (n=117, SD=.71, ranged from 1.33 to 4.67). The difference was found statistically significant (t(229)=-5.053, p=.000).

Table 4.7 Comparison of performance components among children with different level of legibility

	All (N=240)		Poor (mode of legibility score=1 or 2) (n=33)		Average (mode of legibility score=3) (n=120)		Good (mode of legibility score=4 or 5) (n=87)		F	p value*
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)		
Time (s)										
Pen in air	104.29	(35.85)	103.21	(35.60)	101.21	(34.41)	108.96	(37.77)	1.199	.303
g/a time ratio	0.63	(0.19)	0.57	(0.18)	0.59	(0.18)	0.69	(0.19)	9.419	.000
Speed	**(mm/s)**									
mean	167.55	(55.39)	41.10	(10.56)	36.77	(8.08)	30.45	(8.00)	23.965	.000
variability	63.26	(25.64)	29.55	(6.20)	27.00	(4.45)	23.34	(4.77)	24.589	.000
Pressure	**(N)**									
mean	1.87	(0.52)	1.87	(0.55)	1.87	(0.47)	1.89	(0.56)	0.044	.957
variability	0.60	(0.13)	0.61	(0.12)	0.61	(0.12)	0.57	(0.14)	2.127	.122

* Statistically significant different found with Bonferroni's adjustment, i.e. p<0.017

Table 4.8 Comparison of Chinese handwriting performance between genders

	All (N=240)		**Male** (n=122)		**Female** (n=118)		*t*	*p value**
	Mean	SD	Mean	SD	Mean	SD		
Time (s)								
pen in air	104.29	(35.85)	104.74	(34.05)	103.83	(37.76)	0.195	.846
g/a time ratio	0.63	(0.19)	0.60	(0.16)	0.66	(0.21)	-2.334	.020
Speed	**(mm/s)**							
mean	35.07	(9.20)	36.70	(9.00)	33.39	(9.14)	2.823	.005
variability	26.02	(5.29)	27.09	(5.10)	24.91	(5.28)	3.253	.001
Pressure	**(N)**							
mean	1.87	(0.52)	1.81	(0.49)	1.94	(0.53)	-1.918	.056
variability	0.60	(0.13)	0.59	(0.13)	0.61	(0.13)	-1.316	.189
Legibility	3.28	(0.70)	3.06	(0.71)	3.50	(0.62)	-6.194	.000

* Statistically significant difference found, $p \leq 0.05$

Table 4.9 Comparison of Chinese handwriting performance on hand dominance

	All (N=240)		**Left** (n=10)		**Right** (n=230)		*t*	*p value**
	Mean	SD	Mean	SD	Mean	SD		
Time (s)								
pen in air	104.29	(35.85)	96.64	(40.56)	104.62	(35.70)	-0.688	.492
g/a time ratio	0.63	(0.19)	0.66	(0.25)	0.63	(0.19)	0.476	.635
Speed	**(mm/s)**							
mean	35.07	(9.20)	34.46	(10.46)	35.10	(9.17)	-0.215	.830
variability	26.02	(5.29)	25.22	(4.92)	26.06	(5.31)	-0.490	.624
Pressure	**(N)**							
mean	1.87	(0.52)	2.19	(0.46)	1.86	(0.51)	1.985	.048
variability	0.60	(0.13)	0.63	(0.12)	0.60	(0.13)	0.949	.344
Legibility	3.28	(0.70)	2.93	(0.60)	3.29	(0.70)	-1.902	.111

* Statistically significant difference, $p \leq 0.05$

4.4.4 Correlations of age, performance components and Chinese handwriting performance

4.4.4.1 Correlations among age and performance components

As showen in Table 4.10, age was found to be significantly correlated to tripod pinch strength (p=0.000) and maximum grip strength (p=0.001). Strength of associations was fair (│r│ ranged from 0.212 to 0.279). The positive value indicated that the strength in pinch and grip increased with age. Moreover, significant associations with age were also reported positive in VMI and fine motor subtest of BOTMP, and negative in DEM time. However, the strength of the associations was only fair (│r│ ranged from 0.163 to 259, p ranged from 0.000 to 0.014).

It was found that performance components, strength of tripod pinch and strength of power grip measured by EVAL hand assessment system were significantly correlated with each other with a moderate association (│r│ ranged from 0.414 to 0.592, p=0.000).

The strength of association between DEM adjusted time in vertical and horizontal tasks was moderate with an r of 0.527 (p=0.000). Moreover, MVPT, VMI and fine motor subtest of BOTMP were significantly correlated with the measurement of grip and pinch strength. However, the significance was weak with r value ranging from 0.135 to 0.274 and p value varying from 0.0000 to 0.038. A moderate positive association was found between the MVPT score and the VMI score (r= 0.439 0.279, p=0.000), indicating the inter-relationship of these visual processing skills. For the fine motor skills, BOMTP-FM was associated with all other performance components including pinch and grip strength, DEM time, MVPT, and VMI. The associations were positive in BOTMP-FM with grip and pinch strength, visual perception, and visual motor integration. This might indicate a better performance in fine motor skills would have better performance in these areas. Similarly, the negative value of r between BOTMP-FM and DEM time might indicate a shorter time in DEM as the BOTMP-FM scored higher. However, the strength was only fair to moderate (│r│ ranged from 0.155 to 0.349, p ranged from 0.000 to 0.017)

Table 4.10 Correlation among children's age and performance components

r (p-value*)	Age	Tripod pinch	Max grip	DEM vertical	DEM horizontal	DEM time ratio	MVPT	VMI	BOTMP-FM
Age	1.000	0.279	0.212	-0.102	-0.163	0.003	0.101	0.183	0.259
		0.000	0.001	0.115	0.014	0.959	0.120	0.004	0.000
Tripod pinch		1.000	0.592	-0.052	0.026	0.081	0.171	0.248	0.173
			0.000	0.428	0.692	0.223	0.008	0.000	0.008
Max grip			1.000	-0.116	-0.034	0.012	0.127	0.078	0.274
				0.076	0.608	0.858	0.050	0.233	0.000
DEM vertical adj. time				1.000	0.527	-0.141	-0.115	-0.143	-0.228
					0.000	0.033	0.076	0.027	0.000
DEM horizontal adj. time					1.000	0.366	-0.047	-0.072	-0.187
						0.000	0.479	0.277	0.005
DEM time ratio						1.000	0.086	0.001	-0.067
							0.194	0.989	0.313
MVPT							1.000	0.439	0.349
								0.000	0.000
VMI								1.000	0.268
									0.000

* Statistically significant correlation with $p<0.05$;

4.4.4.2 Correlations among the constructs of Chinese handwriting performance

According to the results (Table 4.11), there were many correlations among the constructs of Chinese handwriting performance measured by the POET.

The speed (mm/s) was calculated by dividing the length in writing (mm) by the time spent (s), while, the in air time was a subcomponent of the total writing time in which the time of pen on ground was eliminated. It was not surprising to report a significant correlation between pen in air time and speed ($|r|$ ranged from 0.471 to 0.499, p=0.000). Similarly high correlations between mean speed and its variability (r=0.937, p=0.000), as well as pressure and its variability (r=0.714, p=0.000) were obtained.

Finally, the legibility in Chinese handwriting according to the teacher rating was moderately correlated to speed mean and its variability. The negative value might reflect an inverse relationship (r= -0.420 and -0.417, p=0.000), that is, the better the legibility, the slower the speed. The result echoed the findings in phase I of the study. According to the results in phase I, the speed mean and speed variability were the two crucial discriminant factors between good and poor handwriters.

Table 4.11 Correlation among the contructs of the Chinese handwriting performance

r (p-value*)	In air time (s)	g/a time ratio	Speed mean (mm/s)	Speed variability (mm/s)	Pressure mean (N)	Pressure variability (N)	Legibility score
In air time	1.000	-0.314 (.000)	-0.499 (.000)	-0.471 (.000)	0.045 (.489)	-0.069 (.288)	0.082 (.204)
g/a ratio		1.000	-0.418 (.000)	-0.379 (.000)	0.336 (.000)	0.131 (.043)	0.269 (.000)
Speed mean			1.000	0.937 (.000)	-0.239 (.000)	0.006 (.922)	-0.420 (.000)
Speed variability				1.000	-0.191 (.003)	0.069 (.290)	-0.417 (.000)
Pressure mean					1.000	0.714 (.000)	0.049 (.454)
Pressure variability						1.000	-0.095 (.141)

* Statistically significant correlation with p<0.05,

4.4.4.3 Correlations between age and the Chinese handwriting performance

Among the demographic data, only age is a continuous data. Thus, only age was included in this section for correlation analysis (Table 4.12).

A positive significant correlation was found between age and the time ratio (r=0.150, p=0.000). A higher ratio of ground to air time indicated a larger proportion of time spent on writing when compared to the time spent in the air. However, the association was very weak in strength.

In contrast, age was negatively correlated to speed mean, and variability of pressure. The relationship was only fair (│r│ ranged from 0.133 to 0.193, p ranged from 0.003 to 0.039).

Table 4.12 The Pearson's product correlation coefficient (r) between age and the Chinese handwriting performance

R (p value*)	Air time	Time ratio	Speed mean	Speed variability	Pressure mean	Pressure variability	Legibility
Age	-0.056 0.386	0.150 0.020	-0.133 0.039	-0.116 0.072	-0.121 0.061	-0.193 0.003	0.088 0.173

* Significant correlation found in p level <0.05

** Significant correlation found in p level <0.01

4.4.4.4 Correlations between performance components and Chinese handwriting performance

Table 4.13 summarized the Pearson's Product Moment correlation coefficient (r) between the performance components and the parameters in Chinese handwriting evaluation.

For the correlation between grip and pinch strength and handwriting performance, a significant correlation was only indicated between the tripod pinch and pressure exerted on writing surface (r=0.130, p=0.046).

Among the items in DEM, significant relationships were found between the vertical and horizontal time and the pressure mean and its variability (p ranged from 0.009 to 0.023). The associations were positive with r value ranging from 0.150 to 0.171. Hence, the strength of associations was only fair.

Table 4.13 The Pearson's product correlation coefficient (r) between performance components and the Chinese handwriting performance

r (p value*)	Air time	Time ratio	Speed mean	Speed variability	Pressure mean	Pressure variability	Legibility
EVAL							
Tripod	-0.005	0.062	-0.061	-0.024	0.130	0.011	0.018
	0.940	0.341	0.346	0.719	0.046	0.871	0.786
Grip	-0.027	-0.047	0.010	0.034	0.038	0.040	-0.039
	0.680	0.469	0.875	0.605	0.565	0.540	0.550
DEM							
Ratio	-0.059	-0.051	0.082	0.117	-0.082	-0.009	-0.095
	0.377	0.442	0.218	0.077	0.218	0.890	0.151
Vertical Adj. time	0.128	0.051	-0.120	-0.142	0.164	0.154	0.143
	0.048	0.430	0.064	0.028	0.011	0.017	0.027
Horizontal Adj. time	0.022	0.099	-0.120	-0.101	0.150	0.171	0.014
	0.742	0.136	0.071	0.127	0.023	0.009	0.838
VMI	-0.059	-0.051	0.082	0.117	-0.082	-0.009	-0.095
	0.377	0.442	0.218	0.077	0.218	0.890	0.151
MVPT	-0.165	0.140	-0.002	-0.022	0.010	-0.067	-0.123
	0.010	0.030	0.972	0.737	0.876	0.302	0.057
BOTMP-FM	-0.180	0.003	0.085	0.092	-0.084	-0.081	-0.164
	0.005	0.968	0.190	0.157	0.197	0.210	0.011

* Significant correlation found at p level <0.05

4.4.5 Factors affecting Chinese handwriting performance

The investigation on factors affecting Chinese handwriting performance relied on results of the multiple regressions. The handwriting performance was put in as the dependent variable, and the independent variables included the power grip and tripod pinch strength, DEM time in vertical and horizontal tasks, the DEM time ratio, MVPT, VMI and BOTMP-FM scores.

The effect of age, which was the only continuous data among demographic factors, was considered being controlled by the inclusion criteria.

4.4.5.1 Pen in air time

Results of the multiple regressions showed BOTMP-FM was the significant predictor for pen in air time in Chinese handwriting. As showed in Table 4.13, the association indicated by the beta value was only fair in strength (β= -.180, p=.005). The R-square was .032 which indicated that 3.2% of the variance in pen in air time was accounted by the BOTMP-FM (p=.005). On the other hand, MVPT was found as the predictive factor for the time ratio (pen on ground to pen in air). The association between MVPT and time ratio was fair with a beta value of 0.140 and p value of 0.030. The factor accounted for only 3.0% of the variance in pen in air time (R^2 =0.020, p=0.030).

4.4.5.2 Speed and its variability

For predicting the performance in mean speed, 6.9% variance was found explained by three factors including the DEM horizontal time, DEM ratio and VMI (R-Square=0.069, p=0.001). The associations indicated by the beta value of each item were fair in strength. All beta values were negative, indicating a negative relationship between the factors and the speed. The magnitude of the standardized correlation coefficient (beta) ranged from 0.149 to 0.194, with a significance level of 0.002 to 0.029 (Table 4.13).

Similar result was found in the variability of speed. In addition to the three variables: DEM horizontal time, DEM ratio and VMI, BOTMP-FM was also found as one of the significant predictors with an R-square of 0.098 (p=0.000). That means a 9.8% of variance in the speed variability was accounted by these factors. The standardized correlation coefficient ranged from 0.141 to 0.246 in the magnitude.

4.4.5.3 Pressure and its variability

Three factors were found significant in predicting the pressure exerted during handwriting according to the Table 4.13. They included DEM horizontal time (β=0.204, p=0.003), DEM ratio (β=-0.166, p=0.016), and the tripod pinch measured by the EVAL hand evaluation system (β=0.136, p=0.032). R-square was 0.061 which means 6.1% of the variance in pressure mean was explained by the three factors listed above (p=0.002).

On the other hand, the pressure variability was significantly predicted by the DEM time of the horizontal task and the VMI. However, having an R-square of 0.045 (p=0.004), only 4.5% of the variance was explained by the DEM horizontal time.

4.4.5.4 Legibility

The analysis of predictability of factors to the performance in handwriting legibility was conducted by the discriminant analysis (Table 4.14). Two discriminant functions were derived with respect to the three levels of legibility scores (poor=scores 1 and 2, average=score 3, and good=scores 4 and 5). However, according to the structure matrix shown in Table 4.15, a function 1, i.e. difference between children with poor and average legibility, was derived by the SPSS analysis. This might indicate that the difference in children with average and good legibility was very small and insignificant.

In the discriminant analysis for function 1 (poor v.s. average legibility), VMI and MVPT were found as the discriminant factors. The canonical correlation structure matrix was reported with a value higher than 0.40 (1.000 for VMI and 0.400 for MVPT). As shown in Table 4.14, discriminant function 1 (poor to average legibility) yielded a Wilks' Lambda of 0.925 and a Chi Square of 17.337 (p= 0.000).

Table 4.16 showed the classification results based on the discriminant function 1. The number of cases showed in diagonal boxes indicates the correct number (count and percentage) of children who were correctly classified according to the discriminant analysis. As shown, the discriminant functions partly classified the children into groups. The percentage of correct classification was 37.1% (N=240).

Table 4.14 Mean Scores on discriminant Function for the legibility score (centroids)

Legibility score	Function 1*
Poor (score 1 or 2/5)	-.497
Average (score 3/5)	-.105
Good (score 4 or 5/5)	.333
Wilk's Lamda	.925
Chi Square	17.337
Sig.	.000
Eigenvalue	.081
Canonical Correlation	.273

* Discriminant function between children with poor and average legibility

Table 4.15 Canonical correlation structure matrix between the factors and the legibility score

Factors	Function 1*
VMI	1.000
MVPT	.400
Tripod pinch	.281
BOTMP-FM	.232
DEM vertical adjusted time	-.103
Max grip	.089
DEM horizontal adjusted time	-.051
DEM time ratio	.009

* Discriminant function between children with poor and average legibility

Table 4.16 Classification of children in terms of the legibility scores by discriminant analysis on the performance components

	Legibility	Predicted Group Membership			Total
		0 (poor)	1 (average)	2 (good)	
Original* Count (%)	Poor (score 1 or 2/5)	18 (54.5%)	7 (21.2%)	8 (24.2%)	33 (100%)
	Average (score 3/5)	50 (41.7%)	16 (13.3%)	54 (45.0%)	120 (100 %)
	Good (score 4 or 5/5)	23 (26.4%)	9 (10.3%)	55 (63.2%)	87 (100%)
Cross-validated** Count (%)	Poor (score 1 or 2/5)	18 (54.5%)	7 (21.2%)	8 (24.2%)	33 (100%)
	Average (score 3/5)	50 (41.7%)	16 (13.3%)	54 (45.0%)	120 (100 %)
	Good (score 4 or 5/5)	23 (26.4%)	9 (10.3%)	55 (63.2%)	87 (100%)

*37.1% of originally grouped cases correctly classified.
**37.1% of cross-validated grouped cases correctly classified.

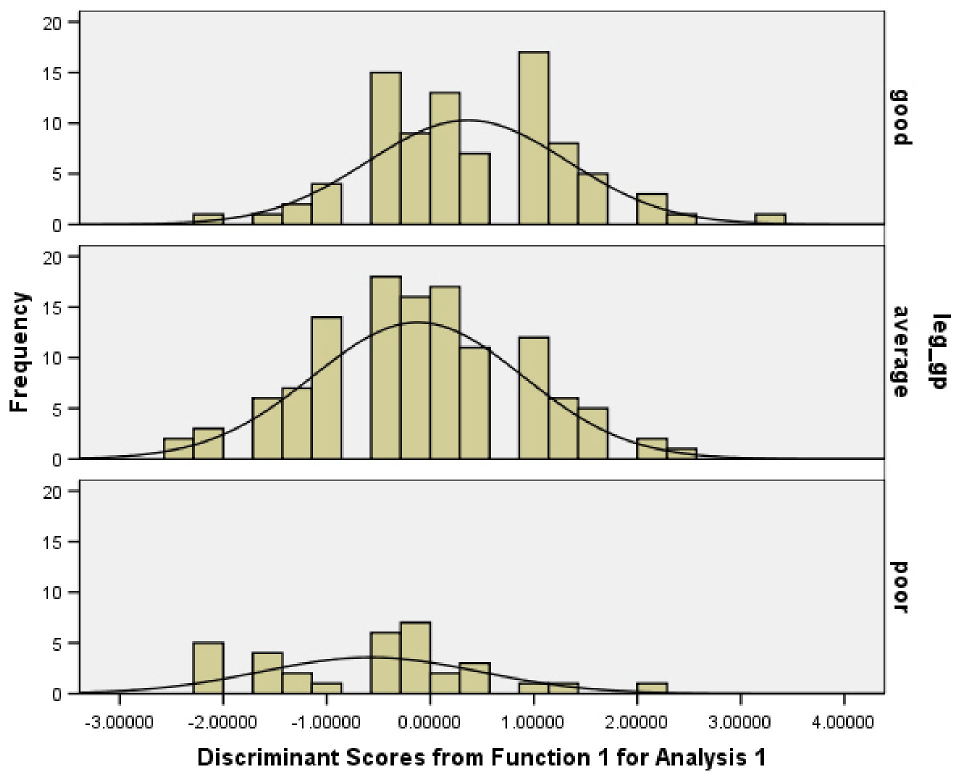

Figure 4.3 Distribution of children in relation to the discriminant scores for the discriminant functions (legibility) according to legibility levels: Poor (top) =score of “1 & 2”; Average (middle)= score of “3”; and, Good (bottom) =score of “4 or 5”.

4.5 Discussion

4.5.1 Factors affecting Chinese handwriting performance

According to the results of this study, various factors were found affecting different constructs of the Chinese handwriting performance.

Figure 4.4 showed the significant associations between the factors and Chinese handwriting performance.

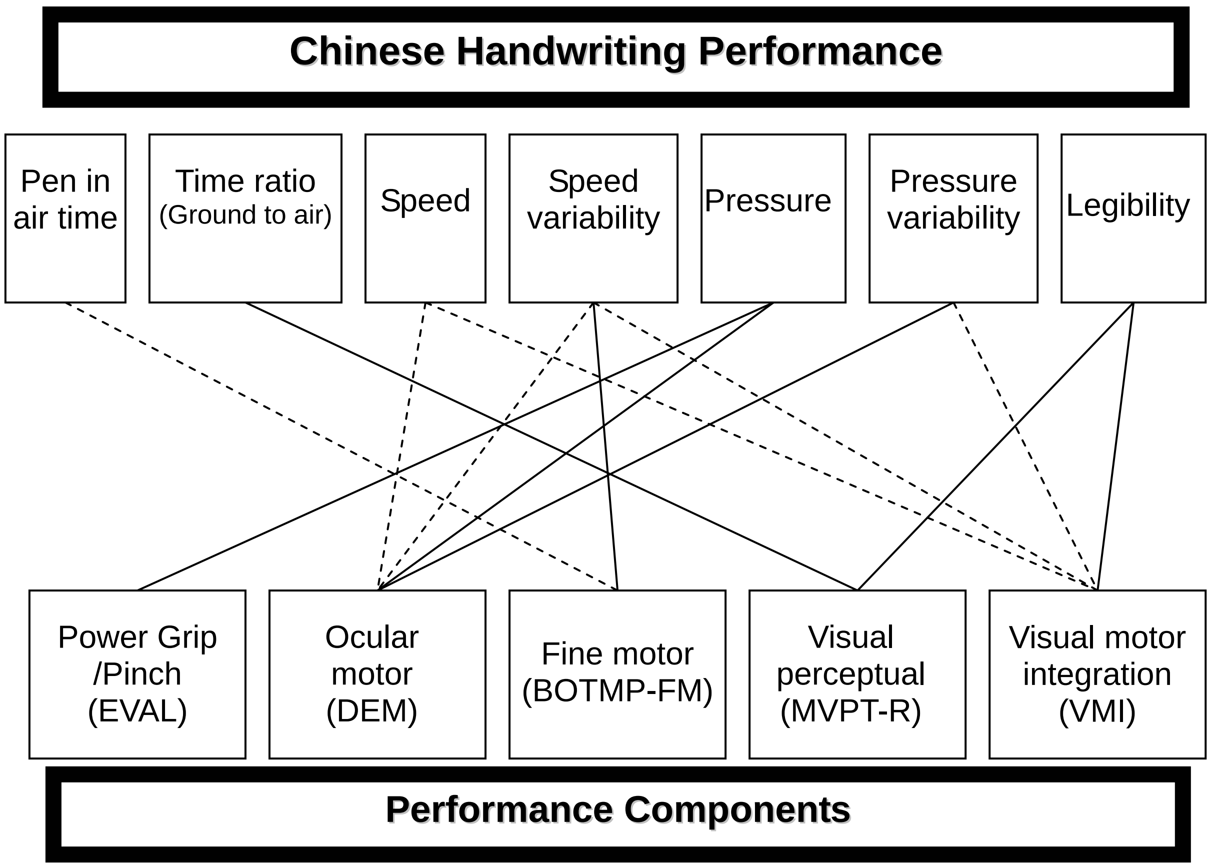

Figure 4.4 Significant associations between the factors (performance components) and Chinese handwriting performance, in which, positive relationship was indicated by solid lines and negative relationship by dashed lines.

Linear relationships were shown between Chinese handwriting performance and the performance components including tripod pinch, ocular motor skills, visual perceptual skills, and visual motor integration. With reference to Figure 4.4, different constructs in the Chinese handwriting performance were shown to be attributed by different factors in various degrees of association. The strength of the correlation ranged from weak to fair. In fact, none of the correlations indicated by the multiple regressions had a correlation coefficient greater than 0.40.

Among all the factors, the visuo-motor control including the ocular motor skills, visual perceptual skills, and visual motor integration appeared to be the main factors affecting the Chinese handwriting performance among children in Hong Kong.

The important role of visual perceptual skills and visual motor integration in Chinese handwriting performance was demonstrated in this study. According to the current results, better visual perceptual skills were correlated with better legibility and higher time ratio of pen on ground to pen in air.

This finding was supported by the study of Orliaguet, Kandel and Boe (1997) who found that visual perceptual skills enabled a child to perceive the words to be written and predict their motor movement accurately. Thus, the motor anticipation of the hand movement might facilitate a better legibility and shorter pause time in handwriting.

Similar to visual perceptual skills, better visual motor integration was also showed to relate with better legibility. However, it was surprising to note that it was also found related with a slower speed in handwriting. This might suggest that children wrote more slowly for a better construction of forms and hence, resulting a better legibility.

This might explain the phenomenon as shown in the results of relationship between visual motor integration and handwriting speed as well as legibility.

Moreover, better ocular motor skills, in specific the automaticity and eye teaming skills (Pang, 2004), indicated by a short time in performing the DEM tasks were associated with a faster speed and lighter pressure in handwriting. As coordinated and smooth ocular movement was essential to allow input of correct inter-strokes visual tracking and visual feedback, children with better ocular motor skills might spend less time in tracking the information and thus are able to perform faster. The important role of ocular motor skills in handwriting as indicated in the results echoed the findings in previous studies (Longcamp et al., 2003; Goldstand, Koslowe & Parush, 2005; Kulp and Schmidt, 1996; Cubelli & Lupi, 1999). The current study further demonstrated their role in writing Chinese words which are composed of discrete intricate strokes (Chow, Choy & Mui, 2000; Tan et al., 2001; Law, Chung & Lam, 1998).

Besides the visuo-motor control, impact of fine motor skills in handwriting was also demonstrated via the performance in fine motor subtest of the BOTMP. The linkage of pause in writing and the fine motor skills as well as the visual perceptual skills indicated that these skills might play a role in processing and motion control during the process of writing. However, the role of fine motor skills in handwriting performance was unclear. Controversial findings on the significant correlations were reported in previous studies (Yochman & Parush, 1998; Ziviani, Hayes & Chart, 1990). Further verifications on the relationship between fine motor skills and writing Chinese words are needed.

4.5.2 Other factors affecting Chinese handwriting performance

Referring to the demographic distribution of this study, it is interesting to note that ratio of boy to girl was the highest among those with legibility scores of 1 or 2 categorized as poor legibility, while the ratio was the lowest among the children with good legibility (i.e. legibility scores at 4 or 5). Yochman and Parush (1998) found that in both the dictation and copy tasks, girls were reported to have significantly better performance than boys which further echoed the difference between boys and girls in daily handwriting tasks.

Indeed, the difference in handwriting performance between genders was also reported in terms of speed in the literature (MaCarthy et al., 2001;Ziviani & Elkins, 1984; Groff, 1961; Summers & catarro, 2003; Ziviani & Watson-Will, 1998; Tseng & Hsueh, 1997). Girls were generally found to spend more time in handwriting for a better legibility, and thus result a lower speed.

However, controversial findings have been reported in studies of English versus Chinese handwriting. Ziviani and Watson-Will (1998) compared handwriting speed across several age ranges and found that boys wrote faster at ages 11 to 12 years, while girls generally wrote a little faster at ages 7 to 10 years. The result of a study in Chinese population by Tseng and Hsueh (1997) revealed that Chinese girls wrote faster than boys in grades 3 to 6 (mean age ranging from 8.55 to 11.53 years) while boys studying in grade 2 (mean age =7.61 years) wrote faster than girls.

The discrepancy in the results might be attributed by the fact that children's handwriting skills were taught in different levels of the development in different countries. Also, different expectation throughout the learning experience might create different impacts on the maturation of the handwriting skills. Furthermore, this might also reflect the difference in writing Chinese and English languages along different stages of development among children. According to Tseng (1998), Chinese characters were composed of strokes which required more pen lifts and sharp turns during writing. While in English, the pattern is more continuous and smooth. Hence, the requirement on fine motor skills was different and affected the handwriting performance, e.g. speed, of the children.

4.5.3 Strengths of the study

The study has several strengths in investigating the factors affecting Chinese handwriting performance.

First, the Modified Conceptual Model for Handwriting Performance (Section 1.2.3) proposed in this study provided a structured framework for the clear direction and organization throughout the study. With reference to the two models, the Occupational Performance Model and the Conceptual Model of Handwriting Performance, the Modified Conceptual Model for Handwriting Performance put forward the ideas of dynamics between factors and the handwriting performance.

Second, with reference to the Modified Conceptual Model for Handwriting Performance, various factors in stead of single indicator were considered in the study. As quoted from the paper of Cornhill and Case-Smith (1996), they suggested that ‘An appreciation of the multiple factors that contribute to handwriting acquisition is important to providing effective remediation.’ Three types of factors have been considered in the model. Inter-factor correlations were also taken into account. The model also provided a comprehensive view on the constructs of handwriting including the elements of the product and the process. In addition to the evaluation on the end product of handwriting in terms of legibility, researchers suggested that the writing process was an important indicator to find out the problems of handwriting (Longstaff & Heath, 1997; Rosenblum, Weiss & Parush, 2003). This study reported associations between the factors and both the product and process of the handwriting. This information might be helpful in the specific identification of handwriting difficulties.

Third, the evaluation of performance in Chinese handwriting and performance components was conducted using validated standardized assessment tool. The use of the standardized tools allowed standardized instructions and marking criteria. Supported by the results in phase I of the study, these tools owned a high reliability in repeated measures and rater difference in which accurate and reliable information was encouraged.

Fourth, this study had a large sample pool sufficient for analysis for an exploratory study. A common rule of thumb was that the ratio of number of variables in analysis to the number of subjects to be included should be about 1:10. Taking into account the various factors investigated in the study, 240 subjects were sufficient to meet the criteria.

Fifth, the study was conducted under an organized procedure for subject sampling with blindness of the evaluators. Using a draw lots method, schools were randomly selected for participation in the study. Also, selection for schools was based on the geographical distribution while the selection for number of children in the school was with reference to the total number of students in that grade. The coding procedure as described in the methodology reduced the bias in rating the children performance.

4.5.4 Limitations of the study

Despite the strengths of the study, the study had several limitations.

First, the evaluation on overall legibility relied heavily on subjective judgment of the teachers which might give concerns to the rater bias and systematic error in the measurement. Although a moderate to good rater and test-retest reliability was obtained in the phase I of the study, objective measurements on different aspects of legibility such as spacing, alignment and errors are recommended for further investigation.

Second, effects of cognitive skills of the children were not considered in the conceptual model. Study on the effect of cognitive skills including attention, memory, and language processing was beyond the scope of the design. However, implication of the cognitive skills in handwriting and reading performance has been reported in previous studies (Levine, Oberklaid & Meltzer, 1981; Graham & Weintraub, 1996; Rosenblum, Weiss & Parush, 2003). To address this point, subjects were recruited from the mainstream schools in Hong Kong and it was assumed that all the subjects had normal intelligence.

Third, the study was not able to control the effect of socioeconomic status of the children. It was suggested that children's academic as well as handwriting performance was affected by their socioeconomic status development context (Marr, Windsor & Cermak, 2001; Lee-Corbin & Evans, 1996). Out of the 240 subjects in the study, over 50% were recruited from a school located in Kowloon. The dominant sample size of children living in Kowloon might have an impact on the study results. Thus the results obtained in the study may not be able to successfully apply to children in Hong Kong Island, or New Territories. Moreover, confounding factors such as parenting were not controlled. Future studies may take into account these factors and address the possible impact of family background to the children's handwriting performance.

Finally, this study remained as an exploratory study in which no conclusion on cause and effect relationship could be formulated. The associations observed in the study only indicated the comparative relationship between the factors and Chinese handwriting performance. The direct effect of the factors on that particular performance outcome of Chinese handwriting needs further justification.

Therefore, phase III of this study would evaluate the direct effect of the visuo-motor control on Chinese handwriting performance using a randomized-control trial design. This was to verify the effect of performance of the factors on the Chinese handwriting performance.

4.6 Conclusion

This phase of the study assessed 240 Hong Kong children for their handwriting performance in terms of time, speed and pressure with the use of a digitized device for comparison among legibility levels. It gave a general idea for the researchers and clinicians on the characteristics in writing Chinese characters among children in Hong Kong. By analysis, the parameters in process of handwriting were found to have different degrees of importance in the handwriting performance. Thus, teachers and therapists might take into account these elements, especially the time ratio and the variability of speed while helping children to enhance their legibility.

The study found that the visuo-motor skills, which included ocular motor skills, visual perceptual skills and visual motor integration, appeared to be the main factors affecting Chinese handwriting performance. Ocular motor skills, in specific the automaticity and eye teaming skills reflected by the DEM, might be an important factor affecting the control of movement in writing Chinese characters. While the importance of perceptual-motor skills was frequently reported in previous literature, the finding on ocular motor skills may indicate the unique need of eye fixation and tracking in writing Chinese.

In phase III of this study, training protocols based on these factors would be developed and evaluated.

Chapter 5 Phase III of the study

5.1 Introduction

According to the results of phase II of the study, integration of gross motor, fine motor, and ocular motor skills, namely visual-perceptual-motor components (Kephart, 1971, as cited in Erhardt & Meade, 2005) were the crucial factors affecting handwriting performance.

This study aimed to evaluate the effectiveness of visuo-motor training program to enhance children's handwriting performance. Two intervention protocols, namely the training for visual perception and visual motor integration; and the basic ocular motor training, were prepared for children with handwriting difficulties. The effectiveness of these two programs was assessed through evaluation of children's performance pre-, post-training, and one month after the training and compared between the training and non-training groups.

5.2 Objectives of the study

a) To evaluate the effect of VP/VMI training, and ocular motor training on performance components including visual perceptual skills, visual motor integration, and ocular motor skills;

b) To evaluate the effect of VP/VMI training, and ocular motor training on Chinese handwriting performance including pen in air time, speed and its variability, pressure and its variability, and legibility.

5.3 Methodology

Limited by the timeframe and sample size, this phase of the study aimed to act as a pilot study to find out if the ocular motor training and VP/VMI training would have a positive effect on children with handwriting difficulties using a matched group design. Children were recruited using convenience sampling method and they were divided into three groups as follows:

i) the VP/VMI training group,
ii) ocular motor training group, and
iii) control group.

Assessment of handwriting performance would be conducted before, after and one-month after the training to evaluate the effectiveness of the training protocols.

5.3.1 Participants

5.3.1.1 Sampling method

Participants were recruited by convenience sampling and then matched with age and gender. The parents and children were provided information about the aim and content of the project through an association for children with special learning difficulties. Recruited children were then selected based on the inclusive and exclusive criteria and were matched and assigned into groups. Thirty participants were planned to be recruited in this pilot study. The proposed sample size was based on our previous study on validation of POET. While the statistical power was set at 0.5 with effect size at 0.8 (alpha level at 0.05), the sample size was estimated to be 10 for each group (Portney & Watkins, 2000).

5.3.1.2 Inclusion and exclusion criteria

Children who would be recruited in the study should be:

a) 7 to 11 years of age (correct to nearest year of age);

b) studying in Hong Kong mainstream primary school;

c) using Chinese and Cantonese as their primary written and spoken language;

d) identified as experiencing ocular motor dysfunction (in terms of fixation, motility) as shown by the Visagraph III assessment and intervention system;

e) having a clinical diagnosis of Specific learning difficulties with handwriting difficulties by the psychologists.

Children with reported or observed attention deficits or behavioral problems, neuromuscular disabilities and visual impairment would be excluded.

5.3.2 Instruments

5.3.2.1 Visagraph III assessment and intervention system

The Visagraph III system was demonstrated in Figure 5.1. It is an objective assessment tool for evaluation of visual efficiency including fixation, duration of fixation, number of regression, etc. as well as the reading efficiency (fluency) through visual tracking. The reading characteristics that determine fluency are visual/functional proficiency, perceptual accuracy and information processing competency. These characteristics directly affect the ease and comfort with which we read and comprehend and are termed as the fundamental reading process. Through the use of infra-red sensors, the ocular motor activity of the children would be recorded while reading with the Visagraph III goggles. Eye movement characteristics would then be automatically analyzed. After that, detailed reports that could provide insight as to "how" the individual read would be generated. Following the reading, a brief series of questions were asked to determine whether or not the children read with reasonable comprehension.

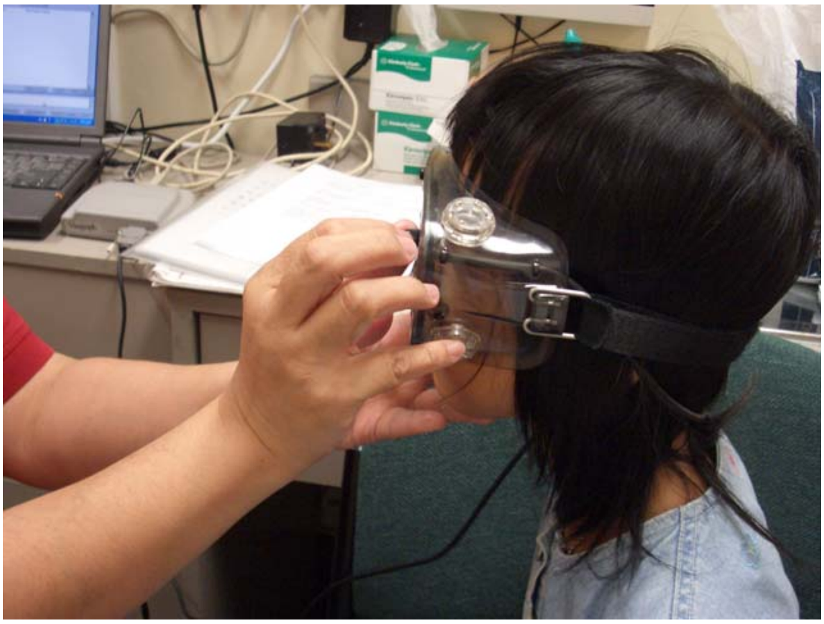

Figure 5.1 The Visagraph III assessment and intervention system.

5.3.2.2 Assessment protocol

POET, legibility rating (5-point likert scale), MVPT-R and VMI were conducted to evaluate children's performance in handwriting and performance components. The procedure in conducting the assessment for handwriting performance and performance components was the same as in phases I & II of the study (Sections 3.3.4 and 4.3.4)

5.3.3 Procedure

Ethics approval was granted from the Human Subjects Ethics Committee, The Hong Kong Polytechnic University. Written consents were obtained from the parents of the recruited children. Children selected for the study would be screened using the Visagraph III system. Those who did not have difficulties in ocular motor movement were excluded. Specialized training on the administration of the instrument was provided by a Registered Optometrist.

Children were then divided into three groups by matched group design with age and gender matched. Two groups would receive training for ocular motor control and VP/VMI respectively while one group was for control. They were assessed before and after the training program and at one month follow up session. All the data were analyzed and processed with the subject code using the SPSS.

5.3.4 Treatment protocol

The whole training program lasted for 5 weeks, twice per week, with a total of 10 individual treatment sessions. Each session lasted for 30 minutes. Home assignment was given to both the VP/VMI training group and ocular motor training group. They were instructed to have practice for 15 -20 minutes per day at home. Appendix B attached the protocol given for home program. Children in the control group were not given with any training during the research period.

5.3.4.1 The VP/VMI training group

Children in VP/VMI training group received training on visual perceptual skills and visual motor integration using computer games. The training was divided into two parts in each session. In part I, training was given on subcomponents of visual perceptual skills including form perception, visual closure, figure-ground, spatial relationship, visual memory and sequential memory (Figure 5.2). In part II, training was on the visual motor integration with use of a digitized device (Figure 5.3). The time allocation for each session in this training group was shown in Table 5.1.

Table 5.1 Time allocation for each session in VP/VMI training group

Time allocation	Session content
5 mins	Greeting & warm-up
10 mins	Part I: visual perceptual skills
10 mins	Part II: visual motor integration
5 mins	Round up

Figure 5.2 The VP/VMI training: Part I-Visual perceptual skills

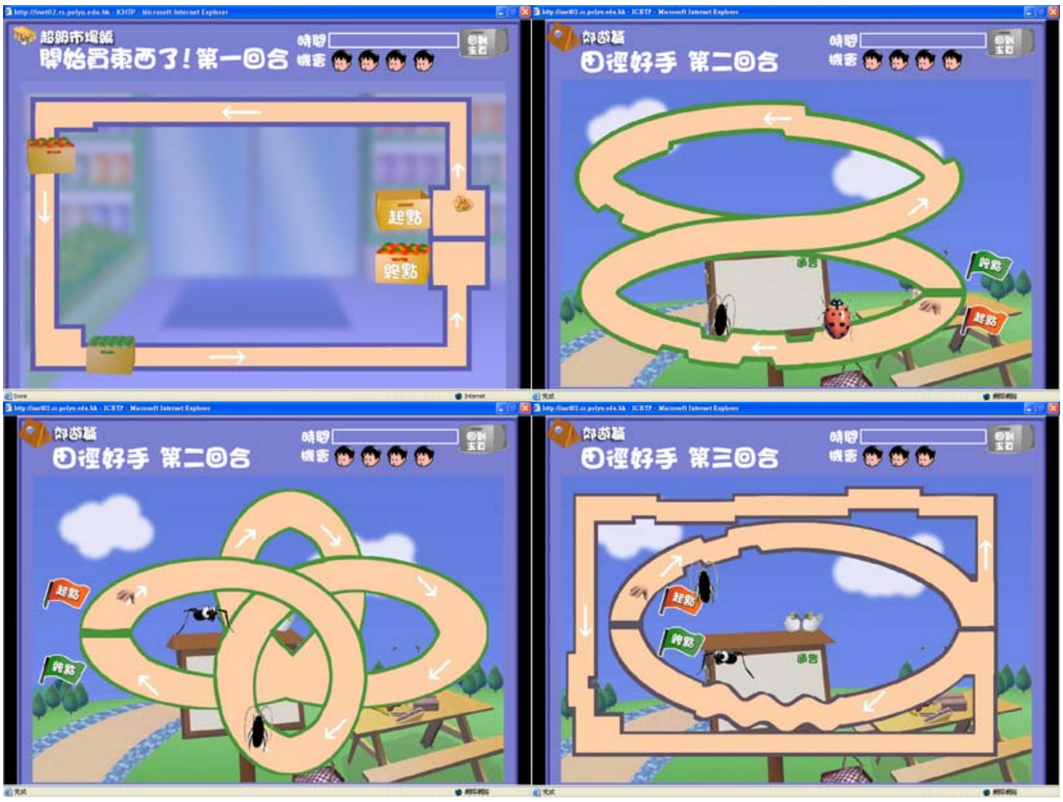

Figure 5.3 The VP/VMI training: Part II-Visual motor integration

5.3.4.2 The ocular motor training group

Table 5.2 and Figure 5.4 showed the training content of the 10-session ocular motor training. The training was divided into three stages which aimed for three levels of skills including basic visual skills such as fixation, motility such as saccadic movement, and their integration by use of exercise, activities, and on-paper tasks. Overlapping of the training stages exist between two stages aiming to provide a progression of training according to the children's ability, performance and individual needs before they were upgraded to another level of training.

Table 5.2 Training content in the 10-session ocular motor training

Stage I: (Session 1-3)	Basic visual skills	• *Eye muscle exercise* • *Fixation* • *Accommodation/ Quick Localization*
Stage II: (Session 3-6)	Ocular motor skills	• *Smooth pursuit* • *Saccades*
Stage III: (Session 6-10)	On paper exercise	• *Visual tracking* • *Visual searching* • *Skimming and Scanning*

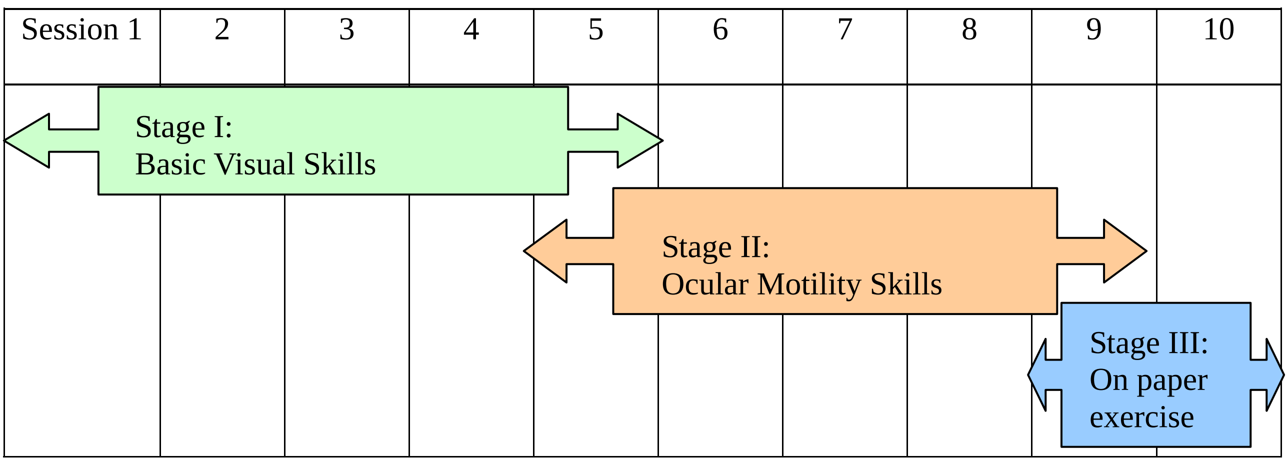

Figure 5.4: The three stages of training for the ocular motor training group

Time arrangement for each session was showed in Table 5.3. In each session, eye muscle relaxation exercise was arranged for the children before and after the training activities so as to prevent eye fatigue.

Table 5.3 Time allocated for each session in the ocular motor training group

Time allocation	Session content
5 mins	Greeting & warm-up Eye muscle relaxation exercise
20 mins	Training activities
5 mins	Round up Eye muscle relaxation exercise

5.3.5 Data analysis

Data analysis was conducted using the Statistical Package SPSS, version 12.0 for Windows (SPSS Inc., Chicago, IL, USA). The characteristics of handwriting performance, ocular motor skills, visual perceptual skills and visual motor integration were presented in descriptive statistics as well as in tables and figures.

For the analysis of the within group effect and between group effect, ANOVA under the general linear model was conducted. Line graph showing the trend in mean scores of children performance was also used.

5.4 Results

5.4.1 Demographic data of the subjects

34 children were recruited. 29 of them were identified with ocular motor dysfunction by the standardized screening tool, the Visagraph III assessment/ intervention system. Among the 29 children, 20 (69.0%) were boys and 9 (31.0%) were girls. Their age ranged from 6.8 to 10.0 years, with a mean age of 9.0 years (S.D.=1.2).

The 29 children were assigned into three groups for i) VP/VMI training, ii) ocular motor training, and iii) no training (control group). As discussed earlier, age and gender were found to have certain impact on development and performance of the children. In the sample of subjects, as there was a wide range of age, children were matched and assigned into the groups according to their gender and age so as to reduce the effect of these two confounding factors.

As shown in Table 5.4, there were 9 participants in the ocular motor training group and 10 in the other two groups. The mean age was a little bit lower for the VP/VMI group compared with the other two groups (8.5 v.s. 9.3 years). There were more boys than girls in the sampled subjects.

Table 5.4 Demographic characteristics of the children participating in the study (N=29)

Characteristics		All (N=29)	VP/VMI training group (n=10)	Ocular motor training group (n=9)	Non training group (n=10)
Age in years	Mean	9.0	8.5	9.3	9.3
	(SD)	(1.2)	(1.5)	(0.9)	(1.1)
	Max	10.9	10.9	10.8	10.8
	Min	6.8	6.8	8.3	7.0
Gender N (%)	Boys	20 (69.0%)	7 (70%)	6 (66.7%)	7 (70%)
	Girls	9 (31.0%)	3 (30%)	3 (33.3%)	3 (30%)
Hand dominance N (%)	Right	27 (93.1%)	10 (100%)	8 (88.9%)	9 (90%)
	Left	2 (6.9%)	0 (0%)	1 (11.1%)	1 (10%)

5.4.2 Within group comparison

As shown in Table 5.5, significant differences were observed in handwriting performance including the pen in air time, speed mean, speed variability, and pressure mean in the ocular motor training group across the three time-points of evaluation, i.e. the pre, post, and 1 month post training. The F statistics for these items ranged from 6.085 to 13.055 (p ranged from 0.001 to 0.015), with an observed power ranging from 0.789 to 0.985.

The line graphs (Figure 5.5) indicated children who received ocular motor training had a significant decrease in pen in air time during handwriting (F= 13.055, p=0.001). A significant decrease in speed mean and increase in speed variability was also noted together with a significant increase of pressure exerted during writing for the ocular motor training group.

5.4.3 Between group comparison

According to Table 5.6, significant differences were not found among ocular motor control training group, VP/VMI training group and control group in all aspects of handwriting performance and performance components.

The legibility scores in pre, post and follow up assessment indicated a greater improvement in legibility among children who received ocular motor training when compared to those in VP/VMI training group and control group (Figure 5.6). This might suggest ocular motor training had positive effect on handwriting performance including pen in air time, speed, pressure and legibility despite the insignificant result in statistical analysis.

Table 5.5 Within group effect (time: pre, post & follow up) of the VP/VMI training group (n=10) and ocular motor control training group (n=9)

	VP/VMI training			Ocular motor training		
Handwriting performance	F	P value	Observed power	F	P value	Observed power
Pen in air time	0.398	0.688	0.089	13.055	0.001*	0.985
Speed mean	0.576	0.591	0.108	6.085	0.015*	0.789
Speed variability	0.271	0.772	0.076	11.183	0.002*	0.967
Pressure mean	0.141	0.871	0.064	9.345	0.004*	0.934
Pressure variability	3.096	0.119	0.391	0.795	0.474	0.155
Legibility	1.701	0.214	0.305	0.207	0.816	0.076
Visuo-motor skills						
MVPT	1.378	0.306	0.217	0.026	0.975	0.053
VMI	1.293	0.326	0.206	2.318	0.141	0.379
DEM						
Time ratio	1.269	0.332	0.203	6.727	0.029	0.711
Vert. adj. time (s)	1.469	0.286	0.229	1.936	0.195	0.309
Hori. Adj. time (s)	0.912	0.440	0.157	3.036	0.093	0.459
Visagraph						
Average duration of fixation (s)	0.246	0.787	0.077	0.354	0.710	0.092
Fixation/100 numbers	0.119	0.889	0.063	0.157	0.856	0.069
Regression/100 numbers	0.169	0.848	0.068	0.300	0.747	0.087
Mean Saccade Size	3.014	0.106	0.427	0.471	0.635	0.110
Excursion	0.056	0.945	0.056	0.981	0.387	0.203

*Significant difference with Bonferroni correction, i.e. p<0.017

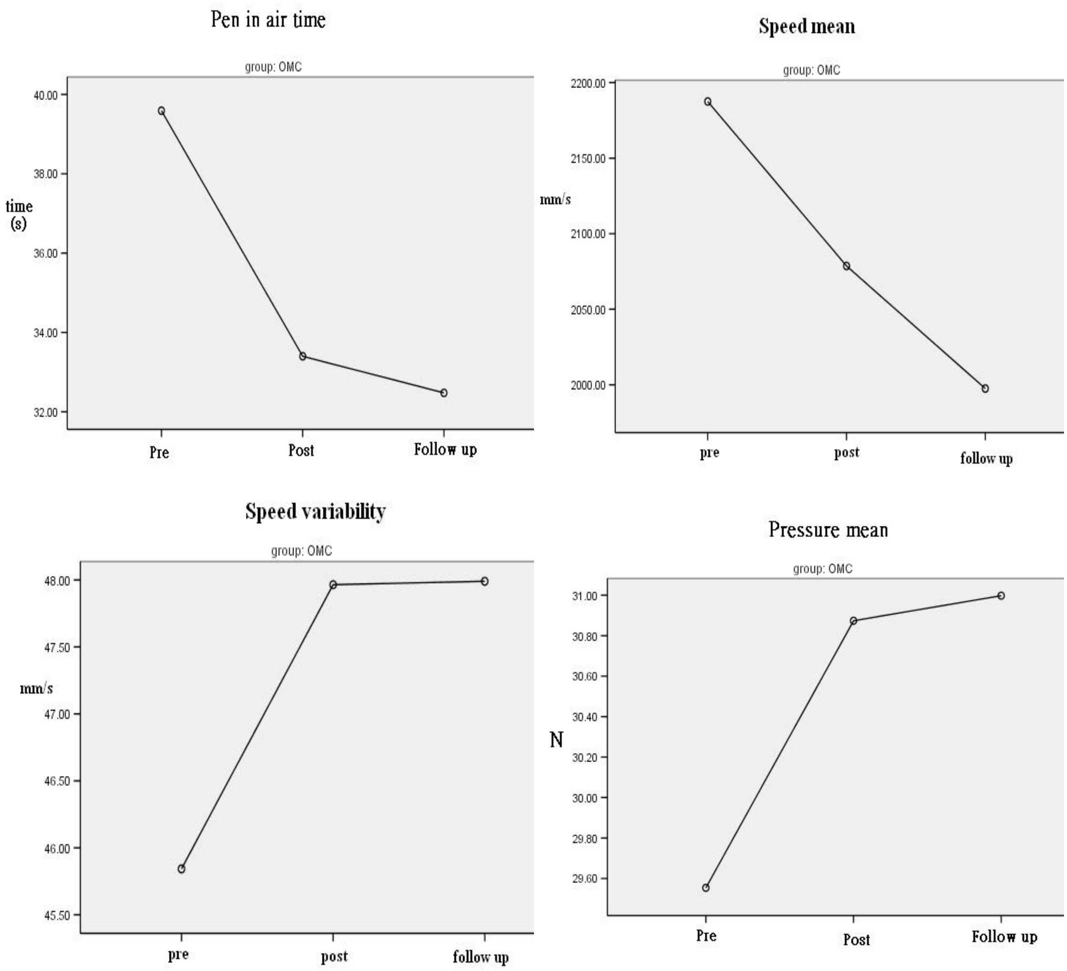

Figure 5.5 Line graph showing the handwriting performance of children in ocular motor training group across the pre, post and follow up assessment.

Table 5.6 Between group effect of handwriting performance using General linear model (group* time effect)

Handwriting performance

	F	P value	Observed power
Pen in air time	0.029	0.971	0.054
Speed mean	0.167	0.848	0.072
Speed variability	0.027	0.974	0.054
Pressure mean	0.502	0.615	0.118
Pressure variability	0.295	0.749	0.089
Legibility	0.392	0.536	0.093

Visuo-motor skills

	F	P value	Observed power
MVPT	4.131	0.037	0.638
VMI	1.570	0.238	0.284
DEM			
Time ratio	1.466	0.267	0.257
Vert. adj. time (s)	0.551	0.587	0.126
Hori. Adj. time (s)	0.582	0.569	0.131
Visagraph			
Average duration of fixation (s)	1.860	0.195	0.317
Fixation/100 numbers	1.306	0.304	0.233
Regression/100 numbers	2.751	0.101	0.448
Mean Saccade Size	0.500	0.630	0.100
Excursion	0.047	0.954	0.056

*Significant difference with Bonferroni correction, i.e. $p<0.017$

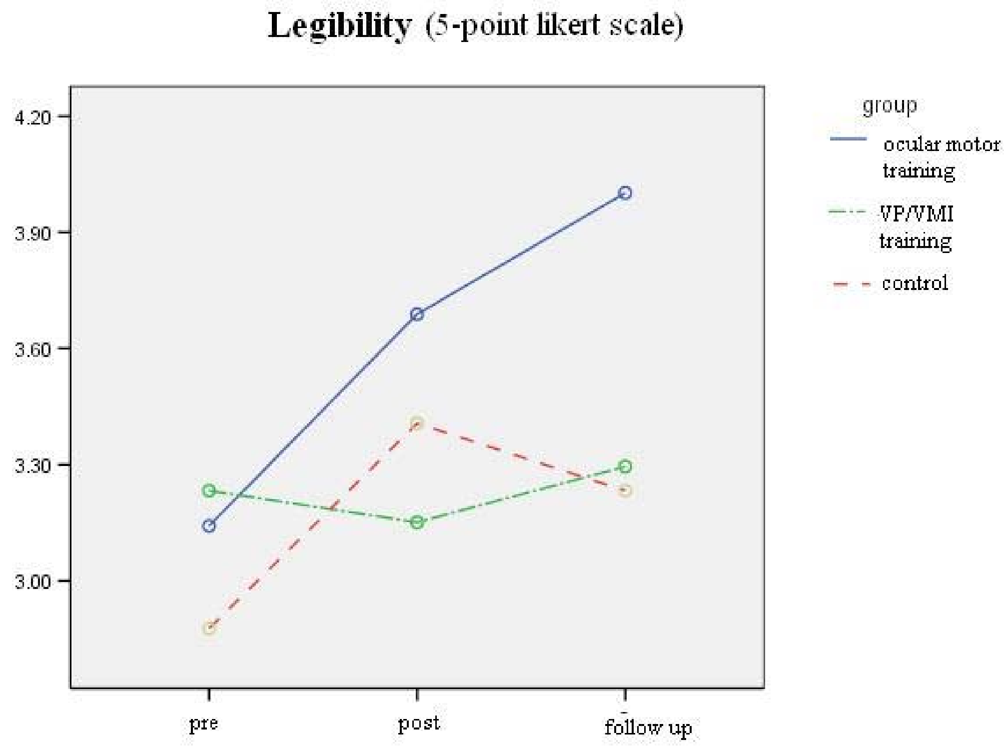

Figure 5.6 Line graph showing mean legibility scores of the groups in pre, post and follow up assessment.

5.5 Discussion

5.5.1 Training effect on handwriting performance and visuo-motor skills

The study was conducted on 29 children with handwriting difficulties and ocular motor dysfunction. Positive within group effect of the ocular motor training on handwriting performance in terms of pen in air time, speed mean and variability, pressure mean and legibility were found. However, when compared with control group, the between group effects were insignificant.

Handwriting is a complex skill which needs integration of the fundamental skills in advance to the competence of the individual components. In this study, both training group did not included repeated training of actual handwriting tasks which might have learning effect to the assessment tools. The VP/VMI training program included focused and repeated training on children's visual perceptual and visual motor integration skills. The ocular motor training protocol was incorporated with some on paper visual tracking and searching task in the later stage of the training sessions. This might be able to facilitate skills integration and generalization for handwriting skills from basic ocular motor and fine motor control. Denton, Cope and Moser (1996) compared the effectiveness of a sensorimotor components training and therapeutic practice. They found that therapeutic practice had greater effects on improvement of handwriting performance. They explained that children selected for sensorimotor intervention were experiencing sensorimotor impairment which might limit the impact of intervention. In our study, ocular motor training which involved paper and pencil practice might facilitate the training effect as compared with the VP/VMI training which mainly focus on training of components.

On the other hand, the effect of the training might be limited by the poor compliance with the home program among the participants. Due to the limited timeframe, the trainings were delivered in an intensive mode. Time for treatment sessions was short, hence, children were highly expected to have practice on the home program. However, parents and children had reported that they were not able to comply with the practice as they had to deal with the schoolwork prior to the practice. In Hong Kong, schoolwork was generally regarded as having a higher priority by parents, thus, children might be affected by their parents' attitude as well as the culture of high academic expectation. Also, it was considered that children surviving with handwriting difficulties as well as ocular motor dysfunction would experience difficulties in handwriting. They were usually commented as writing poorly with a low speed. Hence, considering the longer time for them to spend on school work and revision, they might not have sufficient time for extra practice. In further study, more consideration on control of compliance on home program should be taken to facilitate the treatment effect.

5.5.2 Significance of the study

This pilot study gave an insight of effects of the ocular motor training on handwriting performance among children with specific learning disabilities. Also, the results suggested the role and importance of skills integration and generalization in the training protocol. Furthermore, same as the phase II of the study, the evaluation on children's performance took the advantage of the standardized assessment tools for Chinese handwriting performance and the visuo-motor skills. The use of standardized tools can enable good reliability and validity of the data to be collected.

Thus, with this reliable outcome measure, the power of the study analysis was enhanced.

This study made use of the matched design for comparing the training effects on children. According to results in previous phases, it appeared that gender and age had certain impact on the performance of children in terms of Chinese handwriting as well as the performance components. This might be attributed by their effect on the development and maturation of fundamental skills for achieving a higher degree of performance, or the occupational performance, which was defined as the Chinese handwriting performance in this study.

Another significance of this study was the evaluation on long term effect of the training. The follow up assessment after one month of the treatment allowed the comparison on children's performance while no training was provided after the training period.

In future research, the training and assessment protocol in this study could be applied to a larger size of sample with higher homogeneity.

5.5.3 Limitations of the study

It should be noted that there was a rather high drop-out rate during the follow up assessment. Among the 29 subjects, 7 of them did not show up for the 1 month follow up assessment, one was from the ocular motor training group, three from the VP/VMI training group, and another three from the non-training group. This resulted in great discrepancy of sample size among the groups and might create the "intention-to-treat" bias on the results of the analysis. Children were explicitly matched with each other in group assignment, the drop out would terminate the matching result and thus affect the analysis with ignorance of the covariates being controlled. To address this issue in future studies, commitment to the participation in the study should be greatly encouraged among the subjects.

5.6 Conclusion

This phase of the study tested 29 children with ocular motor dysfunction for the effect of visuo-motor control training on their Chinese handwriting performance. Effects of ocular motor training were indicated in children's handwriting performance for shorter pen in air time and better legibility after training. However, they also presented with a slower mean of speed, higher speed variability and greater pressure exerted during writing.

Training on the performance components might form part of the intervention strategies. Other means of training to enhance the higher order integrative skills such as handwriting may be needed. Further study on this aspect is recommended with a larger sample size, higher commitment from the subjects to follow up assessment, and matched design. Also, investigation on effect of skill-integrated training deserves attention.

Chapter 6 Concluding Remarks

Referring to The Modified Conceptual Model for Handwriting Performance proposed in this study, the handwriting performance was affected by various factors including the performance components, the demographic factors and the environmental factors.

This study attempted to examine the effects of various performance components on the Chinese handwriting. The demographic and environmental factors were either being controlled by selection criteria or being analyzed as covariates in the analysis (Figure 6.1).

Among the performance components, five were studied including the pinch and grip strength, fine motor skills, ocular motor skills, visual perceptual skills and visual motor integration. Evaluation of these performance components as well as the Chinese handwriting performance of children relied on the assessment protocols including standardized tests and digitized tools.

In phase I of the study, the reliability of the assessment protocol was tested. It was found that there was moderate to good reliability for the inter-rater, intra-rater and test-retest reliability. Despite various reliability values obtained among the tools, the results supported use of the assessment protocol in the later phases of study. Thus, in phase II, the assessment protocol was adopted to evaluate the variables so as to gather information for correlations and regressions analysis.

The main results of the phase II study were that visuomotor skills, including visual perceptual skills, visual motor integration and ocular motor skills, were found highly correlated with the speed, pressure, and legibility of Chinese handwriting performance. Also, different constructs in handwriting were found correlated with different performance components in various extents. The results further demonstrated the importance of visuomotor skills in performing handwriting. While previous researches have reported the predictive role of visual perceptual skills and visual motor integration, little has been done on the relationship of ocular motor skills and handwriting skills. Thus, the results of this study may shed light on influence of ocular motor skills on children's occupational performance such as handwriting.

In phase III, the research findings obtained in the previous two phases were used for clinical evaluation of the treatment protocol on visuomotor skills including visual perceptual skills, visual motor integration and the ocular motor skills for the handwriting enhancement. Significantly shorter pen in air time, higher legibility score, slower speed, higher speed variability and greater pressure were indicated among children with the ocular motor control training. However, these effects were found insignificant when compared with the control group. The short training time, poor compliance and high drop out rate might limit the observable effects in the performance of handwriting as well as the performance components.

Furthermore, handwriting was suggested being a complex activity that requires integration of various skills. Thus, training in the performance components may not directly enhance the handwriting performance, especially for those children with difficulties in generalizing skills into functional performance (Figure 6.2).

To conclude, this study has sampled 240 children studying the first year of primary school in Hong Kong which gave a valuable profile on their performance in Chinese handwriting as well as the performance components. The correlation and regressions analysis echoed previous findings on the role of visuomotor skills in handwriting performance. Furthermore, the study found that besides visual perceptual skills and visual motor integration, ocular motor skills also played a role in the Chinese handwriting performance. However, clinical evaluation did not show any significant improvement in the performance after the performance components-based training. Further study could focus on the integration process and effect of integration of skills on the handwriting performance. Also, investigation on what ocular motor skills and how they may influence handwriting performance would be valuable in research.

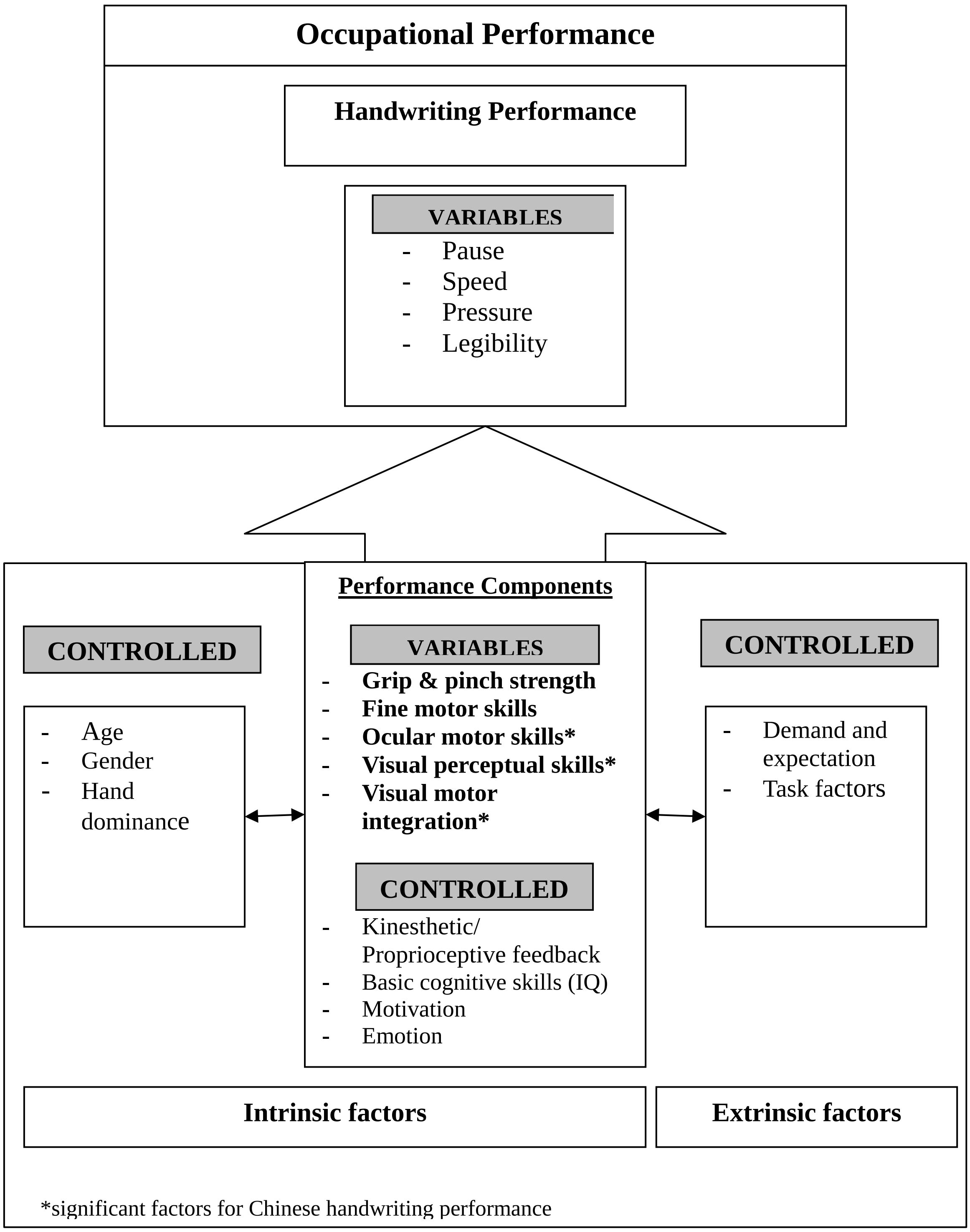

Figure 6.1 The variables and controlled factors of the study with reference to The Modified Conceptual Model for Handwriting Performance

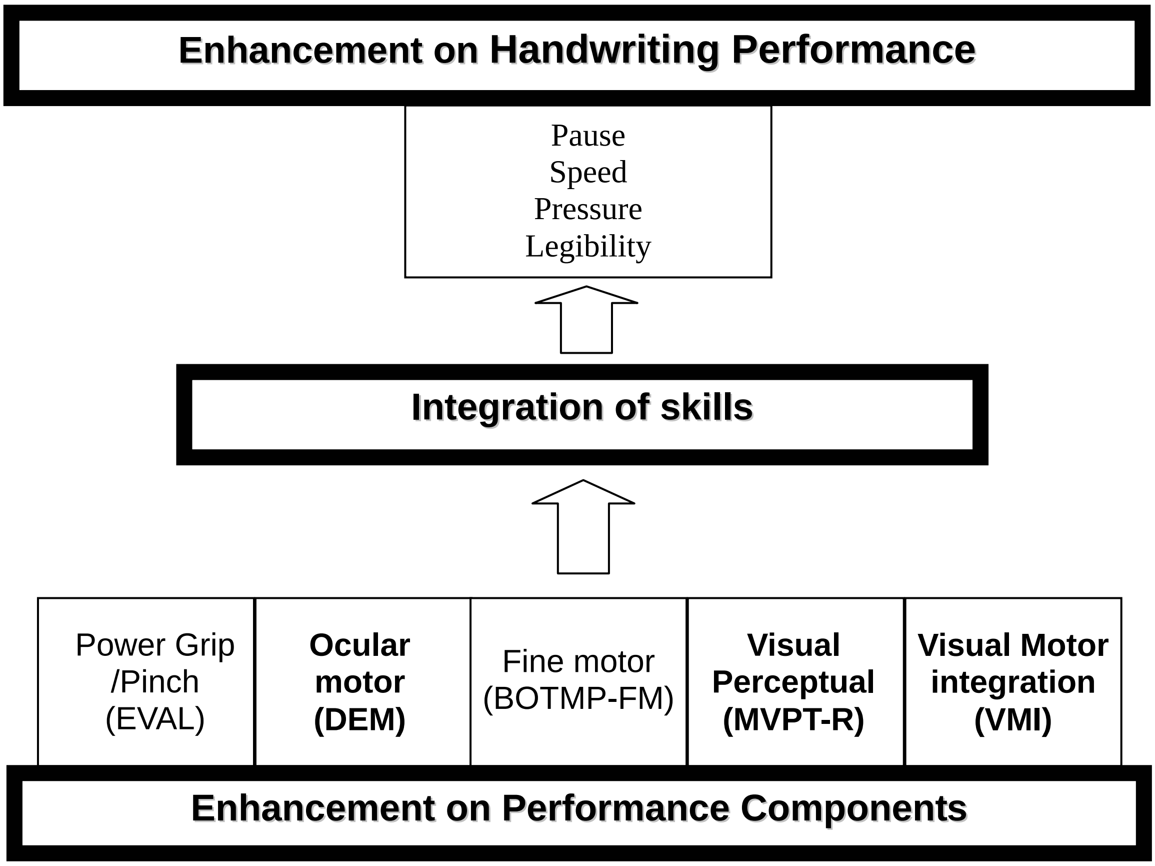

Figure 6.2 Integration of skills in enhancement of handwriting performance

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List of Appendices

Appendix A: Consent forms and ethical approval letters

Appendix B: Chinese handwriting templates (6 words and 20 words)

Appendix C: Protocol of home program of ocular motor training

Appendix A:

The Hong Kong Polytechnic University
Department of Rehabilitation Sciences

Research Project Informed Consent Form

Project title:
Study on the Chinese handwriting performance

Investigator(s):
Dr. Cecilia Li, PhD, Associate Professor, Department of Rehabilitation Sciences
Ms. Candice Cheung Wai Shan

Project information:

Handwriting has been used as a tool to show a child's performance in learning. In Hong Kong, there was 5-10% of the Hong Kong school-aged population reported to have reading and writing difficulties. It was found that poor handwriting may lead to problems of social participation and integration of the child and this will last until their adulthood.

Through analysis of the performance components, handwriting demands a child's cognitive and executive function, neuromuscular control, kinesthetic and tactile sensitivities, visual motor co-ordination and visual perceptual skills. Past researches were mainly conducted on phonetic-based language such as English and Hebrew. Being categorized as a morphemic language, research on Chinese handwriting performance is needed.

This study aims to find out the crucial factors that relate to the Chinese handwriting performance. Children who participate in this study have to perform a 40-minute occupational therapy assessment on Chinese handwriting performance, visual perception, visual-motor integration, fine motor skills, grip strength and visual scanning function. The handwriting performance of each child will be rated by their teachers with the 'Chinese Teachers' Questionnaire of Chinese Handwriting Performance'.

Benefits

This study can equip occupational therapists, teachers and parents with better understanding on which factors correlated with the Chinese handwriting performance. Therapists and teachers can also use the study findings in designing therapy or teaching materials for helping those children surviving with handwriting difficulties.

Consent:

I, ____________________________, have been explained the details of this study. I voluntarily consent to participate in this study. I understand that I can withdraw from this study at any time without giving reasons, and my withdrawal will not lead to any punishment or prejudice against me. I am aware of any potential risk in joining this study. I also understand that my personal information will not be disclosed to people who are not related to this study and my name or photograph will not appear on any publications resulted from this study.

I can contact Ms Candice Cheung at telephone 2766 7094 or the chief investigator, Dr Cecilia Li at 2766 6715 for any questions about this study. If I have complaints related to the investigator(s), I can contact Mrs Michelle Leung, secretary of Departmental Research Committee, at 2766 5397. I know I will be given a signed copy of this consent form.

Signature (subject): _____________________ Date: _____________________________

Signature (witness): _____________________ Date: _____________________________

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學
Department of Rehabilitation Sciences

敬啓者：

參與《眼球控制與中文書寫能力之研究》邀請書

閱讀及書寫能力是學習過程中重要的一環，書寫更需要多方面的基本功能的協調才可有效地完成。文獻指出，學童的眼球活動能力與閱讀及書寫能力有密切關係。職業治療師及視光師會透過各種治療性活動去訓練學童書寫及閱讀的基本功能，從而幫助他們提昇讀寫的效率及表現。因此探討一般學童眼球活動能力，並找出其中與書寫相關的眼球基本功能，有助設計合適的治療，及幫助他們提昇讀寫能力。

此計劃旨在研究眼球控制能力與中文書寫能力的關係。參與學童將於香港理工大學眼科視光學診所接受屈光及視力檢查、雙眼協調能力、視覺認知能力、眼球控制能力及書寫能力的測試，須時約四十五分鐘。我們會與　貴家長電話預約日期及時間。被選拔之學童將會安排參與眼球控制及視覺訓練，以幫助他們提昇書寫能力。現誠邀　貴子女參與此計劃。

閣下如有任何查詢，可致電 2766 7094 聯絡職業治療師李小姐或張小姐。此計劃的成功有賴　貴家長的積極參與和支持，謹致予衷心感謝。

謹附上香港理工大學眼科視光學診所之地圖及同意書一份，懇請　貴家長幫忙簽署並交回負責老師。

此致

家長或監護人

香港理工大學康復治療科學系
職業治療學部副教授
李曾慧平博士謹啓

二零零六年十一月四日

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學
Department of Rehabilitation Sciences

研究眼球控制與中文書寫能力之關係

參與同意書

負責人：李曾慧平博士，香港理工大學康復治療學系副教授
林小燕博士，香港理工大學眼科視光學系副教授

張瑋珊姑娘（註冊職業治療師）
李偉瑜姑娘（註冊職業治療師）
梁美寶小姐（註冊眼科視光師）

計劃內容：

此計劃旨在研究眼球控制能力與中文書寫能力的關係。參與學童需在香港理工大學眼科視光學診所接受屈光及視力檢查、雙眼協調能力、視覺認知能力，眼球控制能力及書寫能力的測試，需時約四十五分鐘。被選拔之學童將會安排參與寫字、眼球控制及視覺訓練項目。

對項目參與人士和社會的益處：

此研究

潛在危險性： 這計劃沒有直接或潛在的危險性。

同意書：

本人__________________(聯絡電話：________________，子女姓名：_______________) 已瞭解此次研究的具體情況。本人 * **願意/不願意** 敝子女參加此次研究，本人有權在任何時候、無任何原因放棄參與此次研究，而此舉不會導致我受到任何懲罰或不公平對待。本人明白參加此研究課題的潛在危險性以及本人的資料將不會洩露給與此研究無關的人員，我的名字或相片不會出現在任何出版物上。

本人可以致電 2766 4329 聯繫 林小姐，或2766 6715聯絡此次研究課題負責人李曾慧平博士。若本人對此研究人員有任何投訴，可以聯繫梁女士（部門科研委員會秘書），電話：27665397。本人亦明白，參與此研究課題需要本人簽署一份同意書。

____________________	____________________
家長簽署	見證人簽署
____________________	____________________
日期	日期

* 請刪除不適用選項

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

MEMO

To : TSANG Wai Ping Cecilia, Department of Rehabilitation Sciences
From : NG Yin Fat, Chairman, Departmental Research Committee, Department of Rehabilitation Sciences

Ethical Review of Research Project Involving Human Subjects

I write to inform you that approval has been given to your application for human subjects ethics review of the following research project for a period from 29/08/2005 to 28/02/2007:

Project Title : Factors affecting the Chinese handwriting performance of children in Hong Kong

Department : Department of Rehabilitation Sciences

Principal Investigator : TSANG Wai Ping Cecilia

Please note that you will be held responsible for the ethical approval granted for the project and the ethical conduct of the research personnel involved in the project. In the case the Co-PI has also obtained ethical approval for the project, the Co-PI will also assume the responsibility in respect of the ethical approval (in relation to the areas of expertise of respective Co-PI in accordance with the stipulations given by the approving authority).

You are responsible for informing the Departmental Research Committee Department of Rehabilitation Sciences in advance of any changes in the research proposal or procedures which may affect the validity of this ethical approval.

You will receive separate notification should you be required to obtain fresh approval.

NG Yin Fat
Chairman
Departmental Research Committee
Department of Rehabilitation Sciences

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

MEMO

To : TSANG Wai Ping Cecilia, Department of Rehabilitation Sciences
From : NG Yin Fat, Chairman, Departmental Research Committee, Department of Rehabilitation Sciences

Ethical Review of Research Project Involving Human Subjects

I write to inform you that approval has been given to your application for human subjects ethics review of the following research project for a period from 10/07/2006 to 30/06/2007:

Project Title : Profile on ocular motor control and its relationship with Chinese handwriting performance among Hong Kong school-aged children

Department : Department of Rehabilitation Sciences

Principal Investigator : TSANG Wai Ping Cecilia

Please note that you will be held responsible for the ethical approval granted for the project and the ethical conduct of the research personnel involved in the project. In the case the Co-PI has also obtained ethical approval for the project, the Co-PI will also assume the responsibility in respect of the ethical approval (in relation to the areas of expertise of respective Co-PI in accordance with the stipulations given by the approving authority).

You are responsible for informing the Departmental Research Committee Department of Rehabilitation Sciences in advance of any changes in the research proposal or procedures which may affect the validity of this ethical approval.

You will receive separate notification should you be required to obtain fresh approval.

NG Yin Fat
Chairman
Departmental Research Committee
Department of Rehabilitation Sciences

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

MEMO

To : TSANG Wai Ping Cecilia, Department of Rehabilitation Sciences
From : NG Yin Fat, Chairman, Departmental Research Committee, Department of Rehabilitation Sciences

Ethical Review of Research Project Involving Human Subjects

I write to inform you that approval has been given to your application for human subjects ethics review of the following research project for a period from 02/05/2006 to 31/12/2007:

Project Title : An Interactive Computerized Handwriting Training Program (ICHTP) for Improving and Enhancing Handwriting Function

Department : Department of Rehabilitation Sciences

Principal Investigator : TSANG Wai Ping Cecilia

Please note that you will be held responsible for the ethical approval granted for the project and the ethical conduct of the research personnel involved in the project. In the case the Co-PI has also obtained ethical approval for the project, the Co-PI will also assume the responsibility in respect of the ethical approval (in relation to the areas of expertise of respective Co-PI in accordance with the stipulations given by the approving authority).

You are responsible for informing the Departmental Research Committee Department of Rehabilitation Sciences in advance of any changes in the research proposal or procedures which may affect the validity of this ethical approval.

You will receive separate notification should you be required to obtain fresh approval.

NG Yin Fat
Chairman
Departmental Research Committee
Department of Rehabilitation Sciences

Appendix B:

<u>6 words template</u>

上	天	日
大	山	水

<u>20 words template</u>

池	子	石	玩
形	青	雨	米
全	友	陽	回
布	車	花	魚
夏	朵	開	媽

Appendix C:

THE HONG KONG
POLYTECHNIC UNIVERSITY

Department of Rehabilitation Sciences

香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

香港理工大學康復治療科學系

眼球活動能力訓練

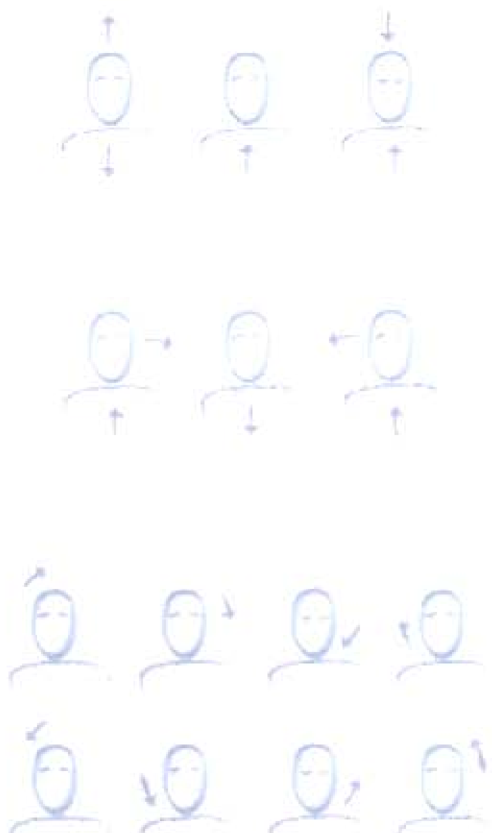
家中訓練

>>>

第一課練習

眼球活動練習：

- 頭向前
- 眼望向上維持五秒
- 眼望前休息一會
- 眼望向不同方向(下、左、右、打圈) 重複練習



如有查詢，請聯絡職業治療師張姑娘：2766 7094 (rscandic@

>>

第二課練習

『木頭公仔』：

- 家長和小孩一起說：『木頭公仔唔準郁，望上面』
- 家長手指向上，指示小孩望上面
- 注意頭要向前，不可轉動
- 數五秒
- 在不同方向(下、左、右、斜) 重覆練習

如有查詢，請聯絡職業治療部張姑娘：2766 7094 (rscandic@

Department of Rehabilitation Sciences

香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

「叻叻手指公」

- 小孩雙手向前伸直，雙手豎起手指公(作讚人「叻」狀)
- 當左手手指動，望向左手
- 相反則望向右手
- 重覆要小孩練習能協調眼和手的活動

- 拉遠雙手距離，加大眼球活動的幅度

如有查詢，請聯絡職業治療師張姑娘：2766 7094 (rscandic@

THE HONG KONG
POLYTECHNIC UNIVERSITY

Department of Rehabilitation Sciences

香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

>>>

第三課練習

『木頭公仔』(請參第二課練習)

『叻叻手指公』(請參第二課練習)

『追蹤太空船』

- 小孩一隻手向前伸直，豎起手指公
- 整隻手貼向身體，眼望手指公
- 整隻手慢慢向外展開，眼一直望著手指
- 重覆相反方向



- 重覆由上向下及下向上



THE HONG KONG
POLYTECHNIC UNIVERSITY

Department of Rehabilitation Sciences

香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

>>>
第四課練習

遊戲一 (超級市場篇)：
http://inet02.rs.polyu.edu.hk/ichtp/super_game2-1.swf

遊戲二 (學校篇)：
http://inet02.rs.polyu.edu.hk/ichtp/school/school_game2-1.swf

請進入並完成。

>>>
第五課練習

遊戲三 (家庭篇)：
http://inet02.rs.polyu.edu.hk/ichtp/home/home_game2-1.swf

遊戲四 (運動篇)：
http://inet02.rs.polyu.edu.hk/ichtp/sports/sports _game2-1.swf

請進入並完成。

>>>
第六課練習

遊戲五 (餐廳篇)：
http://inet02.rs.polyu.edu.hk/ichtp/resta/resta_game2-1.swf

遊戲六 (郊遊篇)：
http://inet02.rs.polyu.edu.hk/ichtp/picnic/picnic_game2-1.swf

請進入並完成。

>>>
第七課練習

遊戲七 (職業篇)：
http://inet02.rs.polyu.edu.hk/ichtp/occupation/occupation_game2-1.swf

遊戲八(遊樂場篇)：
http://inet02.rs.polyu.edu.hk/ichtp/playground/playground_game2-1.swf

請進入並完成。

如有查詢，請聯絡職業治療師張姑娘：2766 7094 (rscandic@

THE HONG KONG
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Department of Rehabilitation Sciences
香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

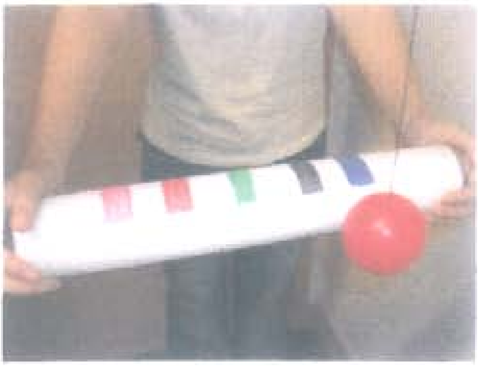
>>

第八、九、十課練習

『幻彩碰碰球』

- 小孩雙手拿著棒 (可用長型膠水樽代替)
- 用繩吊著一個球，放於小孩前方

- 家長說出棒上其中一隻顏色，小孩須把棒上的顏色對準並揮向吊於前方的球
- 家長再說出另一隻顏色，如此類推，以訓練手眼協調。



如有查詢，請聯絡職業治療師張姑娘：2766 7094 (rscandic@

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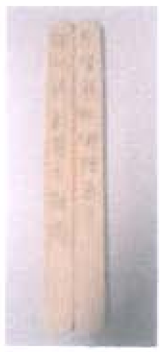
Department of Rehabilitation Sciences

香港 九龍 紅磡
Hung Hom Kowloon Hong Kong

「左望望右望望」

- 準備兩支雪條棒 (可用間尺貼上白紙/lable 紙代替)
- 輪流在兩支棒上寫上一串數字 (可寫上英文字或一句中文句子以加深難度)



- 小孩一手向前伸直，拿著其中一支棒
- 另一支棒由家長拿著，位置約在小孩手拿的棒後的一尺距離

- 小孩望向棒一，再望向棒二，順序讀出寫於棒上的數字/句子。
- 拉開棒與棒之間的距離(前後及左右)以加深難度

-完-

如有查詢，請聯絡職業治療師張姑娘：2766 7094 (rscandic@