國立臺灣大學醫學院職能治療學系

碩士論文

School of Occupational Therapy

College of Medicine

National Taiwan University

Master Thesis

自閉症兒童中文書寫介入方案療效：隨機交叉型試驗

Effectiveness of Chinese Handwriting Intervention Program for Children with ASD: A Randomized Crossover Trial

馮家樂

Jia-Le Pong

指導教授: 王湉妮 博士

Advisor: Tien-Ni Wang, Ph.D.

中華民國 113 年 1 月

January, 2024

doi:10.6342/NTU202400330

致謝

尊敬的指導教授、評審委員以及所有支持我完成碩士論文的各位：

在這段學術旅程的過程中，我深感榮幸並由衷地表達我最誠摯的謝意。

首先，我要感謝我的指導教授王湉妮教授，您的悉心指導和寶貴建議是我論文進展的重要動力。您不僅在學術上給予我深厚的啟發，更在人生和事業規劃上給予我寶貴的建議，讓我獲益良多。

感謝評審委員陳顥齡教授、吳亭芳教授、何自欣副教授以及黃雅淑助理教授，您們的寶貴意見和建議使我的論文更加完善。在審查過程中提供的專業見解對我的研究有著深遠的影響，我感到十分感激。

感謝我的同窗承毅，從一開始完全研究主題的不相關，到最後被我拖入自閉症的苦海裡，感謝你在研究所期間的互相包容和扶持。感謝我的好麻吉品蓁，不同實驗室的我們因為碩一開始的合作讓我們到現在不只是酒肉朋友，還可以掏心掏肺，研究所期間我們都經歷了痛苦的一段時間，但更多的是美好的人事物等著我們慢慢回味，願在未來的路上，還可以相互陪伴，一起努力。我還要感謝凱傑學長、文峰學長、采瑜學姐、淨維學長、芷琦、亭予、艾融、彤與在這段研究所期間給與的協助和寶貴建議，你們的陪伴和支持使整個研究過程充滿了歡笑和挑戰。

最後，我要感謝身邊對我來說非常重要的家人朋友，感謝你們一直以來的支持和鼓勵。你們的愛和理解是我不斷努力的最大動力。

謹以最誠摯的心，向以上各位表達我最深切的謝意。

敬祝 安康

馮家樂

doi:10.6342/NTU202400330

中文摘要

書寫技巧對於學齡孩童是一項非常重要的功能性技巧，它與孩童的學業及社交參與是息息相關的。剛入學的孩童常常面對書寫相關的問題且書寫對於自閉症類群障礙症孩童更具挑戰。然而，目前仍沒有針對自閉症兒童中文書寫介入的相關研究。因此，研究者藉由中文書寫的視覺空間特性，設計一套針對自閉症兒童的書寫介入方案，來改善自閉症孩童的中文書寫問題。本研究的目的為驗證此方案的有效性。

本方案設計採用多個書寫介入相關理論如心理幾何理論、動作學習理論和認知訓練理論，以確保有效方案的建立。本方案包含 36 個活動，納入與書寫習習相關的基礎能力，如視知覺、精細動作及視動整合的訓練，並將中文書寫之特性整合入活動中。本研究為交叉型試驗設計，共招募了 20 名國小一年級和二年級的自閉症孩童，並且隨機分配到直接治療組和等待控制組。治療方案為期 4 週，每週 2 堂，共 12 小時。所有受試者將會進行三次評估。主要成效評估包含書寫易讀性和書寫速度，次要成效評估包含視知覺、精細動作和視動整合。孩童及照顧者對於方案的滿意度使用本團隊開發之問卷進行調查。在確定治療成效無延續效應(carryover effect)後，治療成效使用成對樣本 T 檢定進行治療和控制期之比較分析，方案滿意度則會以平均值和標準差來呈現。

研究結果中，本方案於主要成效（整體書寫易讀性、字體大小、部件大小、部件空間及筆畫正確性）以及次要成效（視知覺和手眼協調能力）都在治療期達到顯著更大的進步。然而，在其餘的主要（近端遠端抄寫速度）及次要成效（視動整合和動作協調）則未達到顯著更大的進步。此外，本方案也得到參與者及照顧者的高度評價及滿意度。參與者對方案表達高度接受度和動機，

doi:10.6342/NTU202400330

並認為方案對他們是重要且有幫助的；照顧者則對方案高度滿意，並表示願意推薦此方案。

本研究驗證了此方案為有效且照顧者及孩童友善的。此研究的發現提供臨床證據，支持整合中文書寫特性，書寫基礎能力訓練及認知策略，能有效加強自閉症兒童的書寫表現。本研究也提供關於自閉症兒童增進書寫表現的系統性方法，對臨床實踐具有重要意義。

關鍵字：書寫表現、神經發展性疾患、視知覺技巧、精細動作技巧、視動整合技巧

doi:10.6342/NTU202400330

Abstract

Handwriting is crucial for academic and social engagement in children, but those with Autism Spectrum Disorder (ASD) face additional challenges. Previous studies have explored interventions combining sensorimotor and cognitive approaches for alphabetic handwriting in children with ASD, but there is a lack of programs specifically targeting Chinese handwriting. Chinese handwriting poses unique challenges due to differences from English handwriting and weak central coherence in individuals with ASD. This study aims to evaluate the effectiveness of the "Go Go Handwriting-ASD version" intervention program, which combines the mentioned aspects and focuses on the visual-spatial features of Chinese handwriting to enhance handwriting skills in children with ASD.

The intervention program for improving handwriting in children with ASD incorporated psycho-geometric theory, motor learning theory, and cognitive training theories. A total of 36 activities targeting visual perception, fine motor skills, and visual-motor integration were designed to align with the unique properties of the Chinese writing system. The program was delivered over eight sessions within four weeks, totaling 12 hours of intervention. For the study, 20 first and second-grade children with ASD were recruited and randomly assigned to either the sequence A: treatment first or the sequence B: control first in a crossover-designed study. Baseline, assessment 1, and assessment 2 were conducted to evaluate handwriting performance, including legibility and speed, as well as fundamental skills such as visual perception, fine motor skills, and visual-motor integration, using six standardized assessments. Participants' and caregivers' acceptance and satisfaction were assessed using a self-developed questionnaire. The effectiveness of the intervention program was analyzed through paired t-tests, comparing the changes during treatment and control phases after the

doi:10.6342/NTU202400330

carryover effects were tested. Descriptive statistics were analyzed to present the acceptability and satisfaction levels.

The intervention program demonstrated significantly greater improvements in the treatment phase for the primary outcomes (overall handwriting legibility, size of character, radical proportion, radical position, and stroke correctness) as well as secondary outcomes (visual perception and eye-hand coordination) However, there are no significant greater improvements in the remaining primary (near and far copy speed) and secondary outcomes (visual motor integration and manual coordination). In addition, the program received high appraisal and satisfaction from participants and caregivers. Participants expressed high acceptance and motivation for the program, rating it as important and helpful. Caregivers reported high satisfaction and willingness to recommend the program to others.

The study indicated the program to be an effective caregiver and child-friendly program. These findings provide valuable clinical evidence supporting the integration of Chinese writing features, handwriting-related fundamental skills training, and cognitive approach to improve the handwriting performance of children with ASD. This study offers an alternative and systematic method to enhance handwriting performance in this population, which has important implications for clinical practice.

Key words: handwriting performance, neurodevelopmental disorder, visual perceptual skills, fine motor skills, visual motor integration skills

doi:10.6342/NTU202400330

Table of Contents

doi:10.6342/NTU202400330

doi:10.6342/NTU202400330

List of Figures and Tables

doi:10.6342/NTU202400330

Chapter 1 Introduction

Handwriting skill is an essential functional skill for school-aged children that is related to their academic success, socio-communicative development, and the building of self-esteem. Children who turn school-aged and enter elementary school often struggle with handwriting problems. This often becomes more challenging for children with Autism Spectrum Disorder (ASD), as claimed in previous studies. In this chapter, we will review and discuss the importance of handwriting, handwriting problems in children with ASD, and the previous handwriting intervention program.

1.1 Importance of handwriting

Handwriting performance is vital in the development of children. First, handwriting is an essential functional skill for academic success. It supports majority academic tasks during elementary school. A child with poor handwriting performance may be unable to engage in the occupational role of a "student" (Cartmill et al., 2009). Furthermore, studies also found that children with poor handwriting legibility and/or speed can bring consequences to academic performance. This is probably caused by the trouble appearing when they encounter the challenge to keep going with the class sessions. This may lead to an increment in fatigue during class or school work and a decrease in academic performance if the problem is left without intervening (Gargot et al., 2020). Hence, it was clear that handwriting difficulties such as poor legibility and slow handwriting speed can overshadow a child's capabilities and make their success at school less easily attainable (Feder & Majnemer, 2007).

Second, poor handwriting skills negatively affect a child's social and communicative development (Cornhill & Case-Smith, 1996). In fact, it is expected that children with poor handwriting often being labeled as lazy, disobedient, or lacking motivation (Feder & Majnemer, 2007). A previous study also showed that improving handwriting quality in

doi:10.6342/NTU202400330

children could also improve their written expression and compositional fluency, enhancing their communicative development (Cartmill et al., 2009). Therefore, the mislabeled of conduct problems, weaker expression, and weaker compositional fluency caused by the poor performance of handwriting may also influence the engagement of the child in group activities, which may further a barrier to communicative and social interactive skill development.

Third, previous studies have also shown that handwriting skill is associated with the development of one's self-esteem (Feder & Majnemer, 2007). Poor performance in handwriting may induce negative comparison among peers and self-criticizing, which may eventually affect the self-esteem of the children (Gargot et al., 2020). As a student, school-aged children spend most of their daily time in school activities, the poor handwriting performance consequences of being labeled with negative perspectives, such as laziness, disobedience, or lacking motivation, will definitely influence their building of self-esteem.

1.2 Handwriting problems in children with ASD

Handwriting is a complex task that requires skills in several domains to be mastered to write proficiently. Due to its complexity, a number of school-aged children struggled to develop proficient handwriting, estimating a prevalence of writing problems ranging from 5% to 25% of the school population (Taverna et al., 2020; Tse & Li-Tsang, 2018). However, based on clinical observation, producing a quality handwriting performance often becomes relatively more challenging in children with neurodevelopmental disorders such as autism spectrum disorder (ASD), attention deficit hyperactive disorder (ADHD), and developmental coordination disorder (DCD). According to an Australian survey, a high number of children with ASD are referred to occupational therapists working in the education system in Queensland. 86% of them referred for assistance with fine motor or

doi:10.6342/NTU202400330

handwriting problems (Cartmill et al., 2009). These data indicate the importance of investigating this issue.

Several current studies have discussed the handwriting of children with ASD. The handwriting problems of children with ASD can be categorized into handwriting performance and fundamental skills. The handwriting performance refers to handwriting speed and legibility, while the fundamental skills of handwriting were referred to visual perception, fine motor skills, and visual motor integration skills. The following section will review and discuss the characteristic of handwriting performances in children with ASD.

1.3 Handwriting performances in children with ASD

Handwriting performance is often assessed in terms of two dimensions in the literature, which are legibility and speed. The handwriting legibility refers to the proper formation, size, orientation and space of the components in a character, while the handwriting speed is often assessed with the number of characters or words written in a minute. A number of studies indicated a significantly weaker performance of children with ASD in these two dimensions compared to children with typical development. Children with ASD tend to write more illegible and slower in speed than children with typical development (Grace et al., 2018; Li-Tsang et al., 2018; van den Bos et al., 2022).

1.3.1 Handwriting legibility in children with ASD

The written word of children with ASD was sloppy and had low readability in overall. Previous studies indicated the handwriting of children with ASD exist problems in the dimension of formation and sizing of their written words.

First, the children with ASD tend to write with less proper formation of words. Previous studies comparing the handwriting formation between school-aged children with ASD and typically developing children indicated significantly less proper letter

doi:10.6342/NTU202400330

formation in children with ASD when measuring using Minnesota Handwriting Assessment (MHA) (Cartmill et al., 2009; Fuentes et al., 2009). The appropriate formation of letters or words refer to the overall quality of the written letter. A correct letter formation represents no gaps, no extension, no extra line, and the proper appearance of both pointed and curved segments (Reisman, 1999).

Besides, the sizing problem of written words in children with ASD was also reported in several studies (Beversdorf et al., 2001; Johnson et al., 2013). The letter-sizing problems performed in ASD children with the phenomenon of macrographia were found in their handwriting which their written letters are atypically enlarged. Studies comparing the average vertical and longitudinal size of written words between both children and adults with ASD and without ASD claimed that macrographia was observed among those with ASD.

The handwriting legibility problems in children with ASD including formation and size might correlate with deficiency in handwriting fundamental skill. The handwriting fundamental skill refers to visual perceptual, fine motor and visual motor integration skills (Biotteau et al., 2019; Klein et al., 2011). Therefore, the deficiency of these skills in children with ASD should be considered to address the handwriting problems in this population.

1.3.2 Handwriting speed in children with ASD

Handwriting speed is also one of the aspects which usually considered when assessing one's handwriting performance. The handwriting speed problems in children with ASD have also been reported in previous studies (Cartmill et al., 2009; Li-Tsang et al., 2018; van den Bos et al., 2022). The handwriting speed problem in children with ASD can be classified into (1) slow handwriting speed and (2) scarifying handwriting quality for faster handwriting speed.

doi:10.6342/NTU202400330

First, the slow handwriting speed in elementary school-age children and adolescents with ASD has been proven in the literature study. A previous study that measures the number of words written per minute in children with and without ASD when producing a free-style handwriting task also reported a significantly slower handwriting speed in children with ASD (van den Bos et al., 2022). Moreover, a study comparing the handwriting speed of adolescents with ASD in English and Traditional Chinese handwriting tasks reported that a significantly slower in handwriting speed in the adolescent with ASD compared to typically developing adolescents in both tasks (Li-Tsang et al., 2018). Besides that, previous studies also reported that a need to sacrifice the quality of their written words for a faster handwriting speed. The poorer legibility of the written words in accuracy, formation, and space were observed in children with ASD to achieve an adequate handwriting speed or when requested to complete a timed handwriting task compared to the non-timed handwriting task (Cartmill et al., 2009; Grace, Rinehart, et al., 2017).

In summary, the children with ASD face a certain degree of difficulties in handwriting speed. The handwriting speed problems as mentioned above might be caused by the lack of automaticity in writing. It is believed correlate with the fine motor impairment in children with ASD (Prunty et al., 2016 & 2014).

After reviewing the handwriting problems observed in children with ASD, the next section will further review and discuss the handwriting fundamental skills performance in children with ASD, which might be the potential causes of their handwriting problems. By understanding their weakness in the handwriting fundamental skills, a program targeting their weakness will be developed to better address the issue of poor handwriting performance in this population.

1.4 Handwriting fundamental skills in children with ASD

doi:10.6342/NTU202400330

Handwriting skill is a complicated process that relies on several skills to enable a writer to write proficiently. Visual perception, fine motor skills, and visual-motor integration skills are viewed as the fundamental developmental skills serving as the base of handwriting skill development. Visual perceptual skills are the ability to understand, interpret or make sense of visual stimuli, which involves the individual's cognitive function and sensory awareness (O'Brien & Kuhaneck, 2019). When completing a Chinese handwriting task, a child with a visual perception deficit may face difficulties in differentiating two similar characters (visual discrimination), unable to understand character formation (visual closure, figure-ground), inappropriate spacing between radicals (visual-spatial relation) or unsmooth characters/sentences copying skill (visual memory, visual sequential memory). Fine motor skills refer to the ability of an individual to plan and control their fine motor movements (finger and hand) smoothly, appropriately, and efficiently for the intended goal. As for handwriting tasks, motor coordination indicates planning hand movement in forming the characters, which are closely related to the kinematics and kinetics components (Hwang et al., 2020; Klein et al., 2011). Moreover, visual-motor integration is the ability to perceive visual stimuli, process the received information, and coordinate a smooth motor response which relates to eye-hand coordination, praxis, visual perceptual skills, and motor coordination (Carsone et al., 2021). These skills are critical for a child's school participation and academic success as it is necessary for academic (handwriting tasks) and nonacademic (drawing tasks) endeavors. A child with poor visual-motor integration might be unable to copy a resemblance character as difficulties appeared during the integration of detected visual stimuli and control of movement.

Previous studies also claimed the correlation between these skills with handwriting performances in children with ASD (Cartmill et al., 2009; Hellinckx et al.,

doi:10.6342/NTU202400330

2013; Li-Tsang et al., 2018). To be specific, the handwriting legibility in children with ASD was reported to be correlated with their visual perception, fine motor skills, and visual-motor integration skills in the literature (Cartmill et al., 2009; Hellinckx et al., 2013; Johnson et al., 2013), whereas their handwriting speed correlated with their performance in fine motor skills or manual dexterity (Hellinckx et al., 2013; Li-Tsang et al., 2018). Particularly, these three fundamental skills, which are essential to handwriting skill development, were found with certain deficiencies in children with ASD.

1.4.1 Visual perceptual skills in children with ASD

The visual perceptual skills in children with ASD have been consistently reported to be poorer than typically developing children in the literature (Cartmill et al., 2009; Chung & Son, 2020; Hellinckx et al., 2013; Wuang et al., 2020). Children with ASD were reported with weaker visual perceptual skills in all subtests in the test of visual perceptual skills (TVPS): visual discrimination, visual memory, visual-spatial relationship, visual form constancy, visual sequential memory, visual figure-ground, and visual closure compared to typically developing children (Cartmill et al., 2009; Hellinckx et al., 2013; Nejati et al., 2021; Wuang et al., 2020). Among the different types of visual perceptual skills, visual discrimination, visual-spatial relationship, and visual memory were believed to correlate with Chinese handwriting performance in children with ASD. The visual discrimination skill refers to the ability to detect minimal differences in and ability to classify objects, symbols, or shapes, whereas the spatial relationship enables an individual to identify the location of an object in relation to each other. In Chinese handwriting, high demand for these skills is needed to discriminate the fine differences between the characters and form a character with an appropriate combination of radicals. The visual memory skill refers to the ability to recall information or objects that have been viewed in the past and is reported as a significant predictor of handwriting speed for the slow

doi:10.6342/NTU202400330

hand writers (Tseng & Chow, 2000). However, the impairment of children with ASD in these critical visual perceptual skills in Chinese handwriting was proven ranging from 57 percent to over 87 percent of the participants in a previous study involving 117 elementary school students with ASD (Wuang et al., 2020).

Besides the deficiency of visual perceptual skills mentioned above in children with ASD, this population also performs unique visual processing patterns called weak central coherence or detail-focused processing patterns (Booth & Happé, 2018; Chung & Son, 2020; Hinojosa & Hsu, 2013). Chung & Son (2020) reviewed the neuroimaging studies relating to the visual perception characteristic of individuals with ASD, reported the over-focusing on local features in ASD's visual processing patterns. According to this review, the characteristic of visual processing in ASD is consistent with the weak central coherence hypothesis. Central coherence is the ability to integrate information and then draw it out into a meaningful whole. An individual with poor central coherence tends to exhibit a defect in integrating local perceptions into a global perception (Booth & Happé, 2018). A previous study assessed the central coherence abilities in children with ASD by asking the participants to complete two drawing copy tests: a house with two elements and a face with ten elements (Hinojosa & Hsu, 2013). This study indicated the detail-focused processing pattern in children with ASD who struggle to copy the complete form of a figure, ending up producing a fragmented final product. This processing style can restrict or hinder their ability to see and copy complete drawings. It is also believed to affect handwriting performance in children with ASD when copying words, especially the Chinese characters. Chinese handwriting as a language characterized by logographic nature featuring with square frame and complicated geometric figuration emphasizes the visual-spatial characteristic, including the appropriate spacing and arrangement of the combination of radicals. Hence, the detail-focused process pattern in children with ASD

doi:10.6342/NTU202400330

might induce the inappropriate combination and spacing between the radicals when writing Chinese characters.

1.4.2 Fine motor skills in children with ASD

Fine motor skill or fine motor coordination, which refers to the ability of an individual to plan and control their fine motor movements, was also found to be a deficiency or impairment in children with ASD when completing handwriting tasks (Grace et al., 2017, 2018; Johnson et al., 2013; Kaur et al., 2018; Weimer et al., 2001). In fact, according to a study in children with Asperger syndrome, which is a milder form of ASD, founded that 58% of children aged between 6 and 11 years had received occupational therapy for assistance in their fine motor problems (Church et al., 2000). Children with ASD demonstrated the problem in planning the handwriting movement with a significantly smaller number of total pen lifts across the entire handwriting task and significantly less planning time when transitioning between the same letters compared to children with typical development. Moreover, previous studies also consistently claimed that a lesser quality of their manual dexterity was found in children with ASD compared to typically developing children when assessing with Movement Assessment Battery for Children, second edition (MABC-2), Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition, (BOT-2) and also Physical and Neurological Examination of Subtle Signs (PANESS) (Fuentes et al., 2009; Grace et al., 2017; Hellinckx et al., 2013; Jansiewicz et al., 2006; Johnson et al., 2013; Li-Tsang et al., 2018).. The clumsy hand movement might further affect their motor regulation and performance during handwriting tasks.

1.4.3 Visual motor integration skills in children with ASD

Visual-motor integration skill, is an essential aspect of handwriting skill development. This skill enables the writer to integrate the visual information input with

doi:10.6342/NTU202400330

the smooth and coordinated motor output to complete the handwriting task efficiently. However, the potential impairment in visual perceptual skills and fine motor skills in children with ASD might contribute to the poorer performance of visual-motor integration skills in this population (Green et al., 2016, 2019; Hellinckx et al., 2013; Miller et al., 2014). Previous studies using the Developmental Test of Visual-Motor Integration (Berry-VMI) to detect the different performance of visual motor integration in children with ASD and typically developing children consistently reported a weaker performance in children with ASD (Green et al., 2016, 2019; Hellinckx et al., 2013; Miller et al., 2014). The weakness in visual motor integration skills in children with ASD might further affect their copying skills and their handwriting performance when completing Chinese character copying, which emphasizes the logographic feathers in naïve writers or beginners.

In summary, the children with ASD showed their weakness in the fundamental handwriting skills: visual perceptual, fine motor, and visual motor integration skills. These skills have been proven to correlate and predict the handwriting performance of children with ASD. Hence, developing a handwriting program emphasizing these three fundamental skills might bring a noticeable improvement in handwriting performance for children with ASD.

1.5 Handwriting intervention studies

Although there are a lot of handwriting problems exist in children with ASD, including their handwriting performance and handwriting fundamental skills, handwriting intervention for children with ASD were relatively scarce. Up to date, there are only four studies reported the effectiveness of English handwriting intervention programs targeting school-aged children with ASD (Ch'ng & Ahmand, 2021; Dessoye et al., 2017; Palsbo & Hood-Szivek, 2012; Panos, 2019). There are no handwriting intervention program study targeting children with ASD in Chinese handwriting which is

doi:10.6342/NTU202400330

distinct from alphabetic writing system. Hence, the Chinese handwriting intervention studies targeting school-aged children with poor handwriting legibility will also reviewed in this session.

1.5.1 Handwriting intervention studies in children with ASD

Palsbo & Hood-Szivek (2012) used a robotic-guided three-dimensional repetitive motion device with a dosage of 25 to 30 minutes per session for 15 to 20 daily sessions on eighteen grade K-5 participants who had impairment from cerebral palsy (CP), autism spectrum disorder (ASD), attention deficit disorder (ADD), and attention deficit hyperactivity disorder (ADHD). The intervention resulted in improved handwriting quality of children with ASD or ADHD who were referred for slow writing speed to be able to increase their handwriting speed without scarifying their handwriting legibility. Another study in 2017 implemented 70 days of 10 to 12 minutes per day of handwriting and visual-motor training using an Ipad application in children ages 5 to 7 years old with a diagnosis of ASD, resulting in a significant improvement in visual motor integration skills after receiving the intervention (Dessoye et al., 2017). Panos (2019) conducted a study involving three elementary students with ASD to examine the effectiveness of the Center on Accelerating Student Learning (CASL) handwriting intervention. The 18 times of 20 minutes of the intervention consisted of alphabetic knowledge activities, explicit instruction in handwriting, timed practice with goal-setting, praise, performance feedback, and self-graphing. The intervention program showed an improvement in participants' handwriting accuracy and handwriting speed after receiving the intervention. Ch'ng & Ahmand (2021) investigated 30 sessions, 80 minutes for each session handwriting program, on eight autistic students aged 12 years and above. The intervention consists of a visual motor workout followed by visual motor activities with visual and verbal cueing from the caregivers. The students improved their handwriting legibility based on

doi:10.6342/NTU202400330

observation from their school teacher between the pre and post-test of handwriting patterns.

To date, there are only a few handwriting studies targeting children with ASD, although this population has been consistently proven with poor handwriting performance and handwriting fundamental skills in the literature. The intervention or training program developed in previous studies examined a certain degree of effectiveness in using sensorimotor approaches and integrating them with cognitive approaches to facilitate the handwriting performance in children with ASD. However, these studies were limited by the lack of support by a high evidence level of study design such as a randomized controlled study.

Furthermore, there is no intervention study to address poor handwriting performance in children with ASD in Chinese handwriting, which differs from alphabetic handwriting such as English handwriting. The alphabetic writing system emphasizes the smoothness and continuity of the simple stroke. In contrast, the logographic writing system, especially Chinese writing, is characterized by a square frame feature with complicated geometric figuration that emphasizes the relative size and space between strokes and radicals. The differences between the logographic writing system (Chinese handwriting) and the alphabetic writing system (English handwriting) might be a different challenge to children with ASD, corresponding to their unique visual processing pattern features and impaired fine motor performance. The writer is expected to retrieve the visual-spatial characteristics of the character and to arrange the radicals within a grid of imaginary square shapes when writing Chinese characters. The unique visual processing pattern in children with ASD might cause the improper combination and spatial arrangement of radicals during the handwriting task, meanwhile, the complicated combination of geometric figuration and strokes in Chinese handwriting will also challenge the weakness

doi:10.6342/NTU202400330

of children with ASD in their fine motor skills. Hence, due to the differences between these two writing systems, we reviewed some Chinese handwriting intervention studies targeting school-aged children with poor Chinese handwriting legibility.

1.5.2 Handwriting intervention studies in Chinese

Unfortunately, studies of Chinese handwriting intervention for children with poor handwriting legibility were also scarce. Three research teams had investigated the effectiveness of Chinese handwriting intervention (Chang & Yu, 2014, 2017; Poon et al., 2010). In this session, the intervention programs and results will be reviewed for further information in the Chinese handwriting intervention program.

Poon et al. (2010) used a computerized visual perception and visual-motor integration training program to intervene in children with handwriting difficulties compared to the control group who received handwriting training from school teachers. Only the experimental group demonstrated improvement in some aspects: visual perception skills, writing speed, and decrement in "on paper" time and "in air" time; however, no significant improvement was found in visual-motor integration and handwriting legibility after receiving the computerized training (Poon et al., 2010). Training programs that lack insufficient treatment hours (6-hour) might be the explanation.

Chang and Yu (2014, 2017) studies expanded the treatment hours to investigate the effectiveness of computer-assisted therapeutic practice and visual-haptic perception training in children with handwriting difficulties. The computer-assisted handwriting program, which gives immediate feedback on speed and accuracy after completing a single writing task, is efficient in handwriting speed and fluency by kinematic and kinetic analyses. Meanwhile, the visual and haptic perception activities significantly improved visual–perceptual skills and handwriting accuracy in the dictation and copy tests (Chang

doi:10.6342/NTU202400330

& Yu, 2014, 2017). These above results have supported the potential effectiveness of Chinese handwriting training using the sensorimotor approach, which emphasizes the training of handwriting-relating fundamental skills (visual perceptual, fine motor, and visual motor integration skills); however, the outcome measures of handwriting legibility have not always been comprehensively addressed which should be considered in future study. In addition, as mentioned earlier, Chinese character has its unique features which emphasize on the complicated geometric figuration and visual-spatial properties. Thus, the characteristics in Chinese handwriting should be considered in the design of intervention program.

To address previous concerns, our team developed a Chinese handwriting intervention program, which integrate sensorimotor training with the unique features of the Chinese handwriting system, such as different type of Chinese character and combination of radicals (李冠儀等人，民國 110 年). The intervention consists of twelve-session course in four units according to the different type of Chinese characters (horizontal, vertical, P/L shaped or enclosed). Each unit included activities of visual perceptual, fine motor and visual motor integration. The participants in the study highly accepted the program, and improvement in handwriting legibility according to subjective comparison by 20 experts also examined the program's effectiveness. This finding supported that emphasizing the unique features of the Chinese handwriting system in the intervention might further improve handwriting performance in participants.

In summary, the studies for Chinese handwriting intervention indicated that training in visual perceptual, fine motor, and visual motor integration skills, which is common in alphabetic handwriting intervention, also showed a certain degree of effectiveness in Chinese handwriting intervention. Furthermore, based on our previous work, including character writing that emphasizes the unique features of the Chinese handwriting system

doi:10.6342/NTU202400330

in the intervention might benefit the program's effectiveness. Although the previous studies in Chinese handwriting intervention provided some helpful information, the results still need to be conclusive owing to the following reasons. First, the need for more reports on Chinese handwriting legibility outcome after receiving the intervention. Second, no study has developed and examined the Chinese handwriting intervention program for children with ASD. The differences between the logographic writing system (Chinese handwriting) and the alphabetic writing system (English handwriting) might be a different challenge to children with ASD, corresponding to their unique visual processing pattern features and impaired fine motor skills. Thus, this current study will plan to develop and examine the effectiveness of the Chinese handwriting intervention program, named "Go Go Handwriting" for children with ASD to address the handwriting problems faced by this population.

The newly developed intervention program designed to target handwriting problems in children with ASD will focus on two strategies. First, the impact of weak central coherence in Chinese handwriting will be emphasized by activities featuring Chinese writing properties. Second, cognitive strategy to facilitate handwriting performance will also implemented in the intervention delivery. The detail of intervention program will be introduced in the method section.

1.6 Research purpose

This study aims to investigate the effectiveness of the newly developed Chinese handwriting intervention program, which integrates unique features of the Chinese writing system, handwriting fundamental skills training with the use of cognitive approach for skill acquisition to address the handwriting problems in school-aged children with ASD, named "Go Go Handwriting - ASD version" for children with ASD. The expected outcome of this study includes the improvement in Chinese handwriting

doi:10.6342/NTU202400330

performance (handwriting legibility and speed) as the primary outcome; meanwhile, the improvement in fundamental skills (visual perceptual skills, fine motor skills, and visual motor integration skills) and acceptability to the program are the secondary outcomes in this study.

doi:10.6342/NTU202400330

Chapter 2 Methodology

2.1 Intervention program

2.1.1 Application of theory

To establish and develop an efficient program, several theories were implemented in the program design. Theories were used to guide the Chinese handwriting intervention program to address the handwriting problems and specific characteristics in children with ASD. The theories emphasized in this intervention program include psycho-geometric theory, motor learning theory, and cognitive training theories to ensure the effectiveness of our program.

2.1.1.1 Psycho-geometric theory

First, the psycho-geometric theory, which is developed on the concept of Chinese geometricity properties, emphasizes the unique visual-spatial features of Chinese characters (Kuo et al., 2015). This theory suggested a high demand for dynamic integration between visual perception and motor coordination abilities when completing a Chinese handwriting task. The writers have to focus on the orthographic information given by the Chinese character to discriminate between the subtle differences in the character (forms, components, and strokes) and also the visual-spatial organization (respective position and size of radicals) to enable proficient writing in Chinese character (Chang & Yu, 2014; Huang et al., 2023; Lau, 2020). Hence, in our study, the visual properties of Chinese characters, such as different types of characters, were emphasized by providing activities that require visual scanning of the whole image to identify the proper combination of radicals to address the weakness of children with ASD in their detail-focused processing pattern or weak central coherence.

2.1.1.2 Motor learning theory

Second, the motor learning theory was also implemented when delivering the

doi:10.6342/NTU202400330

intervention program to the participants. Motor learning is defined as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement" (Schmidt & Lee, 2005). By emphasizing motor learning theory and principles in the study, helpful information on technique will be involved in the learning and teaching process of movement to improve the motor impairment in children with ASD (Zwicker & Harris, 2009). The application of the motor learning principle can be categorized into the type of task, practice, and feedback (Taghizadeh et al., 2022).

In our study, the task will be given with moderate challenge and in a discrete condition to improve the handwriting performance of participants in a motivated and secure condition. All activities were graded with different difficulties and provided the challenge, which is achievable with practice (moderately challenging). The tasks will also be given with a recognizable start and end according to the therapist's instruction at the beginning of the activity (discrete task).

Besides, in the visual motor integration, which required the participants to write the characters, the practice will be given in part practice before the whole practice. For example, the participants were requested to copy or trace part of a character or figure before copying or tracing the whole to enhance a friendly learning process for naïve writers (Zwicker & Harris, 2009). The principle of random practice is also applied by giving practice in the random cycle of visual perception, fine motor skill, and visual motor integration. The purpose of applying the random practice principle in the study is to avoid the blocked practice in order to facilitate the retention of learned skills in participants (Getchell et al., 2018).

For the type of feedback, knowledge of feedback and faded feedback will be implemented in the intervention program. The feedback and instruction are given about the performance (knowledge of performance, KP) at the beginning of the program and

doi:10.6342/NTU202400330

the result (knowledge of result, KR) after the participants perform a certain degree of proficiency regarding the execution of the task. The frequency of feedback gradually reduced based on the capability of the child to independently complete the task to enhance internalization and transfer.

2.1.1.3 Cognitive training theories

Third, cognitive training theories were used to facilitate the progress of learning and acquisition of new skills, which emphasizes assisting the child to identify, develop and use cognitive strategies to perform daily occupations such as handwriting (O'Brien & Kuhaneck, 2019). In this study, the strategies based on cognitive learning theories included: global cognitive strategy (goal-plan-do-check), verbal mnemonic and guidance.

For the global cognitive strategy, the goal (self-interrogation), plan (self-monitor), do (self-observation), and check (self-evaluation or self-reinforcement) proposed by Luria was implemented (Luria, 1962). For example, the participants in the study were requested to visually scan the character to be copied (goal) and identify the radical combination (size and space) of the character (plan) before start copying the character (do); the participants will then use the transparent sheets provided to evaluate the product (check) in terms of size, position, and orientation of character and relative size and space between the radicals.

In the verbal mnemonic strategy, general principles to read a character were taught to provide a visual scanning principle for children with ASD who tend to have detail-focused processing patterns during visual detection. The principles taught included: (1) From left to right, from up to down, and (2) Global first, then local. The examples of the mnemonic are shown in Figure 1.

Lastly, in the guidance strategy, verbal and visual guidance was implemented to look at the method of helping the learner acquire handwriting skills better. In verbal guidance,

doi:10.6342/NTU202400330

the therapist guided the taught strategies (eg. GPDC) and principles (eg. global first, then local). The guidance is then changed to overtly self-talking in participants, eventually followed by internalization into covert. On the other hand, the visual guidance will be given explicitly in the beginning and turned implicit when the participant is capable for the handwriting task. For example, the transparent sheets for self-checking will be eliminated after the child successfully writes the character in the correct combination several times to facilitate self-monitoring without using any assistive tools.

2.1.2 Arrangement of the intervention program

The intervention program was developed and finalized by a group of occupational therapist specialists in the pediatric field. Thirty-six 20-minute activities with twelve activities for each handwriting fundamental skill (visual perceptual skills, fine motor skills, and visual motor integration skills) were designed in this program. The 12 hours intervention program will be delivered in 1.5 hours for each session with two sessions per week and distributed within four weeks.

In the visual perception program, visual perceptual skills that are believed essential to Chinese handwriting were emphasized and were designed with the integration of unique Chinese writing properties. In fine motor skill activities, 12 activities will be divided into pencil tasks and tasks using other tools featuring the unique characteristic of the Chinese handwriting system. In pencil tasks, the Chinese character writing tasks and other pencil-paper tasks such as mazes were designed, while the task using other tools emphasized the fine motor component training, proximal coordination of upper extremities, force regulation, and tools manipulation. Moreover, the visual motor integration activities consisted of twelve Chinese character writing tasks which gradually increase in the demand for Chinese writing ability from copying stokes to radicals and the whole character. In the radicals copying task, the relative proportion and position

doi:10.6342/NTU202400330

between radicals within the character were emphasized, while the character writing task highlighted the character's size, space, and orientation within the box given. The examples of activities are shown in table 1.

All intervention activities were designed based on the characteristic of Chinese characters and included different types of characters (vertical, horizontal, enclosed, P-shaped, and L-shaped). The unique features and characteristics of Chinese handwriting emphasized included (1) the size of characters relative to the writing boxes, (2) the position of characters located in the boxes, (3) the upright orientation of radicals in the characters, (4) the relative size proportion of radicals in the characters and (5) the relative space proportion between the radicals in the characters.

The activities designed also be graded according to the following principle: (1) the similarities between the character given, (2) the complexity of the figure or character in the activities, and (3) the frequency and level of therapist assistance. First, the similarities between the character given. Visual discrimination, spatial relation, and visual memory were emphasized in the visual perceptual skills intervention. The visual discrimination between the Chinese character "打" and "把" is considered easier to discriminate when compared to the fine differences between "自" and "目". Second, the complexity of the figure or character was classified according to the total amount of strokes to be copied or traced. For instance, the copying task of "樹" is considered more difficult than "村". Third, the frequency and level of the therapist's assistance. For example, the therapist can give the children a different type of cueing, such as from extrinsic feedback to intrinsic feedback, to facilitate the self-monitoring in participants.

Furthermore, a playful and interesting intervention context was integrated into the program with the design of the adventure journey of an astronaut to further facilitate the

doi:10.6342/NTU202400330

motivation and participation of the participants in our program. The scenarios for each session were as follows: pre-depart training, on my way to the planet, exploring the planet, storing the food, invite to our open house, party preparation, packing the luggage, and returning to Earth.

2.2 Study Design

2.2.1 Participant

Twenty school-aged students with handwriting problems were recruited for this study. Only those who are (a) diagnosed with ASD, (b) and score at least seven scores in Autism Behavior Checklist Taiwan Version (ABC-T), (c) reported problems with poor handwriting legibility or performed less readable handwriting as claimed by their school teachers or caregivers, and (d) score below 25% percentile ranks in overall legibility dimension or strokes dimension in Chinese Handwriting Legibility Assessment for Children (CHLAC), (e) first or second grader, were included in this study. The exclusion criteria in this study included (a) any physical disability affecting the upper limb, (b) any hearing or visual impairment, (c) intelligence quotient below 70 or previously diagnosed with intellectual disability, and (d) unable to follow the evaluation instruction. All the participants were recruited from several hospitals, clinics, and associations in Taipei and New Taipei regions. Informed consent and a demographic questionnaire were obtained from the parents and participants before participating in the study.

Based on our pilot study involving four children with handwriting problems, the estimated sample size requirement is 20 participants, given a large effect size (f = 1.22), a power of 0.80, and a two-sided type I error of 0.05. Therefore, the present study planned to recruit at least 22 participants after considering the estimated dropout rate of 10%. All participants in this study were randomly assigned into two groups in this study to receive the intervention.

doi:10.6342/NTU202400330

2.2.2 Procedure

This study aimed to examine the effectiveness of our self-developed Chinese handwriting intervention program on school-aged children with ASD, named "Go Go Handwriting". A crossover study design was conducted in this study. The participants randomly assigned into two groups, the sequence A: treatment first and the sequence B: control first, using a research randomizer (https://www.randomizer.org/). Children who are randomly assigned to the sequence A: treatment first received the intervention during the first time period, while the sequence B: control first received the intervention program during the second time period (Figure 2). Baseline and outcome evaluation were accessed at three time points: baseline assessment (1st week), assessment 1-midway (6th week), and assessment 2-final (11th week) in this study. The flowchart of this study is shown in Figure 3.

During the control period, participants were allowed to receive their usual care and school education. In the treatment period, participants received the handwriting intervention program, delivered by a well-trained occupational therapist who is familiar with the program in face-to-face, individual sessions. The 12-hour intervention program was delivered in 1.5-hour sessions twice a week, distributed over four weeks. Activities focusing on visual perception, fine motor skills, and visual-motor integration were given in a random order by the therapist. This study was conducted during the school semester to ensure that the amount of training in school was maintained throughout the entire study.

2.3 Measurement

In this study, handwriting performance and fundamental skills of participants were accessed in the 1st, 6th, and 11th weeks, while motivation and satisfaction were measured every week during the treatment period by children and after received treatment by caregivers, respectively.

doi:10.6342/NTU202400330

The screening measures in this study included: (1) Autism Behavior Checklist Taiwan Version (ABC-T), (2) Raven's Standard Progressive Matrices (RSPM), and (2) Chinese Handwriting Legibility Assessment for Children (CHLAC). Meanwhile, the outcome measures in this study involve three domains: (1) handwriting performance: Chinese Handwriting Legibility Assessment for Children (CHLAC), handwriting speed test in Battery of Chinese Basic Literacy (BCBL), (2) handwriting fundamental skills: Beery-Buktenica Developmental Test of Visual-Motor Integration – Forth Edition (VMI-4), Developmental Test of Visual Perception – Third Edition (DTVP-3), Test of Visual Perceptual Skills – Fourth Edition (TVPS-4) and Bruininks-Oseretsky Test of Motor Proficiency - Second Edition (BOT-2) and (3) motivation: Pediatric Motivation Questionnaire (PMQ) and Satisfaction Questionnaire for the caregiver (SQ) to comprehensively understand the efficacy and acceptance of this program.

2.3.1 Autism Behavioral Checklist- Taiwan Version (ABC-T)

ABC-T is a screening test used for uncovering the potential autism spectrum disorder for children and adolescents aged 3 to 15 years old. This questionnaire consists of 47 items, including the sensory, relating, body and object use, language, social, and self-help subtests. Caregivers or teachers are required to rate yes (one point) or no (zero point) according to the item statement. A score over 7 points indicates the possibility of ASD is suggested in this screening tool. ABC-T demonstrated acceptable to excellent internal consistency reliabilities (Cronbach's alphas = 0.95 for parents; 0.96 for teachers; 0.75-0.87 for subscales), good test-retest reliability (r = 0.89 for parents), and criterion validity has been examined (黃君瑜、吳佑佑，民國 102 年).

2.3.2 Raven's Coloured Progressive Matrices (RCPM)

RCPM is a part of the series of Raven's Progressive Matrices, a multiple-choice test used to assess the intelligence of children and adolescents between the ages of 6 and 16

doi:10.6342/NTU202400330

(Raven, 1998). The test consists of 36 increasingly difficult pattern-matching tasks presented in 3 sets of 12 coloured matrices and takes 20 min to complete. A Taiwan version norm for this test was developed. The test produces a single raw score which can be converted into a percentile score. Participants with a percentile rank below five were ruled out from this study. It also reported excellent internal consistency reliabilities (Cronbach's alphas = 0.87~0.90) and acceptable test-retest reliability (r = 0.73) (陳榮華、陳心怡, 民國 95 年).

2.3.3 Chinese Handwriting Legibility Assessment for Children (CHLAC)

CHLAC is a self-developed assessment tool to measure handwriting legibility. The participants will be requested to copy the printed 10 Chinese characters to 2*2cm squares on the exam sheet. These Chinese characters were selected from three versions of current mandarin textbooks, and those with high-frequency and around-the-average stroke counts were chosen. These chosen characters were then selected to ensure a similar ratio of each character type, including top-down (vertical), left-right (horizontal), P-shaped, L-shaped, and enclosed in the test. A trained examiner scored the character legibility according to handwriting legibility and amounts of incorrect strokes. The handwriting legibility included two domains: character domain and radical domain. These two domains further consisted the subdomain of size and space for character domain, and orientation, radical proportion, and radical position for radical domain. The raw score for handwriting legibility dimensions can be converted into standard scores. The stroke correctness will also be counted for every correct and appropriate appearance of stroke. The incorrect copied character was rated 0 for all subdomain of the character in the test. The higher score in both dimensions indicate the more legible handwriting. Children scoring below the 25th percentile ranks are considered to have handwriting problems and

doi:10.6342/NTU202400330

are included in this study. The CHLAC demonstrated moderate to excellent intra-rater reliability (ICC = 0.90~0.99) and test-retest reliability (r = 0.83). The validities were also examined, including factorial, convergent, and discriminate validity (王姝婷，民國 109 年).

2.3.4 The Battery of Chinese Basic Literacy (BCBL)

The BCBL is a standardized assessment to evaluate Chinese reading and writing skills. It consists of reading and writing tests. Only the copying subtest was administered in this study to measure the handwriting speed of participants. In this test, the participant is requested to correctly and accurately copy 25 Chinese characters printed on the exam sheet (near copy subtest and 25 Chinese characters displayed on a cloth strip (far copy subtest). The number of correct characters written within the prescribed time will be calculated and converted into character copy per minute to represent their handwriting speed. The BCBL was examined with good reliability and validity. The internal consistency reliability of the overall test (Cronbach's alphas = 0.87) and test-retest coefficients of the far-point copying subtests were 0.83 (Hung et al., 2003).

2.3.5 Beery-Buktenica Developmental Test of Visual-Motor Integration –Forth Edition (VMI-4)

Beery-Buktenica Developmental Test of Visual-Motor Integration – Forth Edition (VMI-4) is a standardized, norm-referenced assessment to measure the integration level between visual and motor systems of an individual using geometric figure copying tasks (Beery et al., 2010). Only the full-form test will be administered in our study. The participants were requested to copy the geometric figure printed, and a trained examiner will score the results according to the criteria given in the scoring sheet. A higher raw score on this test will represent a better visual-motor integration skill. The good to

doi:10.6342/NTU202400330

excellent internal consistency on all subtests, good test-retest reliability (r = 0.91), and good to excellent inter-rater reliability (r = 0.96) of the test were reported (劉鴻香、陸莉，民國 86 年).

2.3.6 Developmental Test of Visual Perception – Third Edition (DTVP-3)

The DTVP-3 is a standardized, norm-reference test used to evaluate the visual perception skills of children between 4 and 12 years old (Hammill et al., 2014). The test consists of 5 subscales, including Eye-Hand Coordination (EH), Copying (CO), Figure-Ground (FG), Visual Closure (VC), and Form Constancy (FC). Only the Eye-Hand Coordination (EH) subtest will be assessed in this study to measure the ability of children to integrate the functioning of visual and fine motor control. The Eye-Hand coordination (EH) subtest in DTVP-3 has been examined for good internal consistency reliabilities, excellent inter-rater reliabilities ($r \geq 0.9$), and strong test-retest reliabilities ($r>0.85$) (Brown, 2016).

2.3.7 Test of Visual Perceptual Skills – Fourth Edition (TVPS-4)

TVPS-4 is a motor-free visual perception test for individuals between 4 and 18 years of age. There are seven subtests in TVPS-4, including visual discrimination, visual memory, spatial relationships, form constancy, sequential memory, figure-ground and visual closure. The child is requested to choose the correct answer among 4-5 other plausible options based on the instruction, which is different in every subtest. The test was completed when there were five incorrect answers among seven consecutive questions. The raw score was used to represent the overall test performance. A higher raw score obtained represents a better visual perception skill. The TVPS-4 was examined with excellent reliability and validity. The reliability of internal consistency (coefficient α = 0.94) and test-retest reliability (r = 0.97) have been examined for the overall score. The

doi:10.6342/NTU202400330

validity of the tool was also found acceptable (Brown & Peres, 2018).

2.3.8 Bruininks-Oseretsky Test of Motor Proficiency - Second Edition (BOT-2)

The BOT-2 is a standardized instrument to measure fine motor function in children from 4 to 21 years old. The BOT-2 consists of eight tasks; only two for manual coordination will be measured in this study: a manual dexterity, and an upper-limb coordination task. The raw score was used to represent the fine motor performance of the children. The BOT-2 has reported acceptable and excellent validity and reliability in Manual Coordination (MC) composites with consistency reliability (coefficient $\alpha = 0.89$, test-retest reliability $r = 0.71$, interrater reliability $r = 0.98$) and the construct validity has been established by other studies (Bruininks & Bruininks, 1978).

2.3.9 Pediatric Motivation Questionnaire (PMQ) and Client Satisfaction Questionnaire for the caregiver (CSQ)

Pediatric Motivation Questionnaire (PMQ, Appendix 1) and Client Satisfaction Questionnaire for the caregiver (CSQ, Appendix 2) is our self-developed questionnaire that aims to understand the acceptance of both participants and their caregiver to our program. PMQ and CSQ are both five point-Likert scale questionnaires with 12 and 10 questions, respectively. The questions were designed based on three major domains, which include the degree of internal regulation and extrinsic motivation (value or usefulness, effort or importance), basic psychosocial need (relatedness, competence, autonomy), and degree of intrinsic motivation (interest, enjoyment). A higher average score out of 5 indicates the more acceptance and satisfaction with our program.

2.4 Statistical analysis

All analyses were conducted on an intention-to-treat basis. Descriptive statistics were conducted for all variables (demographic, training outcomes, and measurements of motivation). An independent two-sample t-test and chi-square analysis were

doi:10.6342/NTU202400330

performed to test if there is any significant difference between the two groups on demographic information. The Shapiro–Wilk test was used to assess for normality of the outcome measures.

The washout period was not included in this study because it is unlikely to conduct washout with a non-pharmaceutical therapy intervention as the participant was not assumed to unlearn a motor skill (Werner et al., 2021). Additionally, it seemed unethical to ask children not to do any therapy during a washout period to eradicate progress from the first treatment arm. Instead, participants in wait-list control also received the intervention in the second phase for ethical purposes. Since it is necessary not to mix potential period effects with treatment effects, the carryover effect was tested with an unpaired two-tailed t-test of the sum values of period change scores used with a conservative a=0.10 (Sköld et al., 2011).

The outcome measures were analyzed using paired t-tests for treatment effects between intervention period and control period. The level of significance was set at 0.05. Cohen's d was calculated as a measure of effect size.

doi:10.6342/NTU202400330

Chapter 3 Study Results

In this study, a total of 20 participants were completed the intervention program as shown in the participants' flowchart (Figure 3). In the screening phase, 36 participants were recruited. However, only 22 of them were eligible and 14 of them excluded from the study due to the following reasons: 6 of them did not demonstrated legibility impairment as measured by the CHLAC, 4 were unable to follow the evaluation instructions, and 4 had an intelligence quotient below 70 according to RCPM. All participants were randomly assigned to the sequence A: treatment first and sequence B: control first. After the study began, one participant in sequence A: treatment first and one in the sequence B: control first were unable to complete the study due to personal issues (only completing the baseline assessment). The results of the 20 participants who completed the study were analyzed and reported in this chapter.

3.1 Demographic characteristics

A total of 20 subjects participated in this study, with 10 participants in the sequence A: treatment first (6 boys and 4 girls) and 10 participants in the sequence B: control first (10 boys). Demographic characteristics of the sequence A: treatment first and sequence B: control first were presented in Table 2. No significant differences were found between groups in terms of age in months, intelligent quotient based on RCPM standard scores, and ASD symptoms according to ABC-T scores. Furthermore, there were also no significant pre-existing differences in handedness and comorbidities between the two groups.

3.2 Baseline comparisons

Table 3 demonstrated the baseline measurements of participants in both groups, including primary and secondary outcomes. The analyses show that there are no significant differences between groups in all baseline measurements (primary and

doi:10.6342/NTU202400330

secondary outcomes). Primary outcomes include handwriting legibility and handwriting speed. Handwriting legibility was measured using the Chinese Handwriting Legibility Assessment for Children (CHLAC) which assesses dimensions of legibility as well as stroke correctness, and handwriting speed was measured by the Battery of Chinese Basic Literacy (BCBL) which assesses near and far copy speed. The secondary outcomes included visual perception as measured by the TVPS-4, visual motor integration as measured by the VMI-4, and fine motor skills as measured by the Eye-Hand Coordination subtest in the DTVP-3 and Manual Coordination subtests in the BOT-2.

3.3 Test for carryover effect

The carryover effects were tested using an independent t-test with a conservative alpha of 0.10 to compare the differences in changes during the treatment phase between the sequence A: treatment first and the waitlist control group (Sköld et al., 2011). In this study, the analysis revealed that there were no statistically significant differences in the primary outcomes between the treatment groups during different phases ($ps \geqq 0.35$), indicating that no carryover effect exists in the study. Therefore, the analysis for the treatment effect in the following section will compare the changes of all primary and secondary outcomes during the treatment period with the changes during the control period for all participants (N=20) in the study by using paired t-test.

3.4 Primary outcomes

The primary outcomes in this study included two categories: handwriting legibility and handwriting speed. Handwriting legibility was measured using the Chinese Handwriting Legibility Assessment for Children (CHLAC) which assesses dimensions of legibility as well as stroke correctness, and handwriting speed was measured by the Battery of Chinese Basic Literacy (BCBL) which assesses near and far copy speed. The

doi:10.6342/NTU202400330

following paragraphs will compare the changes in participants' performance during the treatment phase and control phase to further examine the effectiveness of the intervention program on handwriting performance.

According to Table 4, which shows the comparison of changes in CHLAC during the control and treatment phases, significant differences were observed in the total score of legibility as well as the following dimensions and domain: the domain of character, domain of radical, the subdomain of character size, appropriateness of the radical proportion and appropriateness of the radical position. These significant changes also indicated moderate to large effect sizes with reported Cohen's d of 1.13, 0.92, 1.06, 0.60, 0.63 and 0.70, respectively. The remaining subdomains, including space of character within a box, and orientation of character did not show significant differences. Furthermore, the stroke correctness in CHLAC also perform a significant difference when comparing the changes between the treatment phase and the control phase, with an intermediate effect size of Cohen's d of 0.73, as displayed in the table 4.

Table 4 also displayed the changes in handwriting speed during the treatment and control phases, according to the amount of characters written per minute within two minutes of near copy and far copy in BCBL. Significant difference was found in far copy indicating the more changes during control period compared to treatment period.

3.5 Secondary outcomes

In this study, the secondary outcomes were also assessed and analyzed to examine the effectiveness of the program in improving the fundamental skills of handwriting (Table 5). The secondary outcomes included visual perception which was measured by the TVPS-4, visual motor integration measured by the VMI-4, and fine motor skills measured by the Eye-Hand Coordination subtest in the DTVP-3 and Manual Coordination subtests in the BOT-2. The following paragraphs will compare the

doi:10.6342/NTU202400330

changes in participants during the treatment period and control period to further examine the effectiveness.

According to Table 5, the changes in the total score and subdomains of visual perception in TVPS-4 were compared between the treatment and control phases. Significant differences were found in the total score of visual perception, as well as the subtests of sequential memory, visual figure-ground, and visual closure subtests, with moderate effect sizes of Cohen's d 0.96, 0.55, 0.55, and 1.22, respectively. There were no significant differences in the remaining subdomains of visual perception, as shown in Table 5. Furthermore**,** the VMI-4 were also assessed in the study for the detection of visual-motor integration. The results showed that no significant difference was found for the changes in VMI-4 between phases (Table 5). For the fine motor skills, the Eye-Hand Coordination subtest in the DTVP-3 and manual coordination subtests in the BOT-2 were assessed in the study. Based on the paired t-test comparison of changes between the treatment phase and control phase, significant differences were found only in the Eye-Hand coordination subtest in the DTVP-3, with moderate effect sizes of Cohen's d 0.65 (Table 5). However, no significant differences were found in the Manual Coordination subtests in the BOT-2.

3.6. Motivation

In this study, motivation was measured using the Pediatric Motivation Questionnaire (PMQ) for participants and the Client Satisfaction Questionnaire (CSQ) for caregivers. The PMQ was assessed once a week, while the CSQ was filled out once after the completion of the treatment session. Table 6 and 7 displayed the results of the PMQ and CSQ, including total scores and item scores with their corresponding averages and standard deviations.

In PMQ, participants rated an average score of 4.60 (0.58) on the 5-point Likert

doi:10.6342/NTU202400330

scale PMQ, indicating the participants' acceptance of our program (Table 6). The item ratings ranged from 4.35 to 4.80, suggesting a high level of acceptance among the participants. The top three rated items were: "Do you think these activities are important to you?", "Do you think the program helps you?", and "Did you try your best in the program?", with average ratings of 4.75, 4.76, and 4.80, respectively.

Beside the pediatric motivation, caregivers also rated an average total score of 3.91 on the 4-point Likert scale CSQ. The item ratings ranged from 3.65 to 4.00, indicating a high level of acceptance by caregivers towards the program. Three items received full marks of four, including "How do you appraise the program?", "Would you recommend the program to your friend's children with handwriting problems?", and "In overall, what is your satisfaction level to our program?".

doi:10.6342/NTU202400330

Chapter 4 Discussion

This study examined the effectiveness of the newly developed Chinese handwriting intervention program, named "Go Go Handwriting – ASD version" for children with ASD. To the best of our knowledge, this is the first Chinese handwriting intervention program which assesses the effectiveness of program regarding the performance of handwriting legibility (Chang & Yu, 2014, 2017; Poon et al., 2010). In this study, the intervention program emphasized the integration of the unique features of the Chinese characteristics and handwriting fundamental skills training with the use of cognitive approach to ameliorate handwriting performance in children with ASD.

The results of this study demonstrated that participants received the intervention program showed significantly greater improvement in handwriting performance (handwriting legibility and stroke correctness) and handwriting-related fundamental skills (visual perception and eye-hand coordination domain of fine motor skill) compared to the control phase. Additionally, high ratings of acceptance and satisfaction were reported by participants and caregivers, indicating the program is highly recommended. The following sections will provide a more detailed discussion of each outcome, highlighting the effectiveness of this child- and caregiver-friendly Chinese handwriting intervention program.

4.1 Primary Outcomes

In the primary outcomes, the effectiveness in handwriting performance (including handwriting legibility, stroke correctness and handwriting speed) was examined. The handwriting legibility and stroke correctness, measured by the CHLAC, showed greater improvement for participants during the treatment phase compared to the control phase. However, the handwriting speed tests, measured by the BCBL, showed significant difference in changes of far copy and no significant difference in changes of near copy

doi:10.6342/NTU202400330

test between phases. The following sections will discuss each primary outcome in detail.

4.1.1 Handwriting Legibility: CHLAC

As mentioned in the results, the participants in intervention program demonstrated significant improvements in the overall legibility of their handwriting output. This study, being the first to investigate the effectiveness of Chinese handwriting specifically in the domain of legibility among individuals with Autism Spectrum Disorder (ASD), presents encouraging outcomes that can be beneficial for clinicians working in this field. The improvements on primary outcomes, particularly on the legality, might provide evidence to support the unique design of the important principles of this study.

First, the psycho-geometric theory was implemented in this study by integrating the Chinese writing properties into the activities. Previous research has highlighted the effectiveness of emphasizing the distinct properties of Chinese writing as an intervention medium (李冠儀等人，民國110年). These properties encompass the unique arrangement patterns of radicals (horizontal, vertical, P/L-shape, and enclosed characters) and the various strokes utilized in Chinese handwriting. In our study, these principles were integrated into the design of the handwriting intervention program for children with ASD, which could be a contributing factor to the observed improvements.

Second, the cognitive approach was utilized in this study by applying techniques from cognitive training theories. This approach assists children in identifying, developing and using cognitive strategies to perform a desirable legibility in Chinese handwriting. In this study, cognitive strategies such as Goal-Plan-Do-Check were taught, which facilitated the participants in planning, self-checking and self-correcting their written characters. Furthermore, the cognitive approach is particularly beneficial for children with ASD, as it can help address their unique visual processing pattern known as weak central coherence, which tends to focus primarily on details rather than

doi:10.6342/NTU202400330

the overall context. The finding of this study is consistent with previous research that demonstrated the benefits of incorporating cognitive strategies and techniques, such as specific types of feedback, instruction, and cueing, in improving handwriting performance in English in children with Autism Spectrum Disorder (ASD) (Ch'ng & Ahmand, 2021; Panos, 2019). This study further supports the effective of implementing cognitive approach in Chinese handwriting for the population.

Third, the program highlighted a sensorimotor approach, which has been shown to contribute to the improvement of Chinese handwriting in previous studies (Chang & Yu, 2017). Children with ASD often exhibit weaknesses in handwriting-related fundamental abilities, including visual perception, visual motor integration, and fine motor skills (Cartmill et al., 2009; Fuentes et al., 2009; Hellinckx et al., 2013). The program integrated these above fundamental skills to each of the intervention activity to strengthen participants' developmental skills. This design might also lead to improvements in legibility. The benefits of incorporating sensorimotor training in handwriting interventions have been supported by previous studies, and the results of this current study align with those findings and further extend to the Chinese handwriting in ASD population. (Ch'ng & Ahmand, 2021; Chang & Yu, 2017; Palsbo & Hood-Szivek, 2012; Poon et al., 2010)

Furthermore, while take a closer look at the subdomains of the legibility, the participants showed significantly improvement in three subdomains of the legibility: character size, radical proportion, and radical position. These results align with our expectations as the program successfully targets these outcomes. It is believed that the cognitive approach, integrated with the handwriting developmental fundamental skills training based on the uniqueness of Chinese writing system, contributed to the improvement in these three subdomains of legibility.

doi:10.6342/NTU202400330

For the character size, previous literature indicated that handwriting of children with ASD often shows enlarged written words, which are properly related to the atypical cerebellar development in this population (Beversdorf et al., 2001; Grace et al., 2017). In this study, the therapist provided verbal and visual guidance to the participants, aiding them in practicing and internalizing the learned techniques. One method utilized was the use of a transparent sheet, which ensured that the characters were of appropriate size within the designated box. Over time, as the participants' abilities improved, the size of the transparent sheet was gradually reduced. This approach helped the participants refine their handwriting skills and incorporate the techniques more effectively.

For the radical proportion and radical position, the appropriateness of these domain in the logographic writing system, Chinese handwriting, is believed to be affected in children with ASD due to their unique visual processing pattern known as weak central coherence. This detail-focused visual processing pattern tends to exhibit a defect in integrating local perceptions into global perception, resulting in hinderances or restrictions in their ability to see and copy a complete drawing and also Chinese handwriting (Booth & Happé, 2018; Chung & Son, 2020; Hinojosa & Hsu, 2013). In the intervention program, mnemonic techniques were taught to the participants to enhance their visual scanning techniques. These techniques aimed to assist participants in comparing the relative size and position of radicals within a character, thereby addressing the visual processing pattern of weak central coherence that may hinder their handwriting. The improvement in participants' legibility in this study could be attributed to the enhancement of their ability to integrate local perceptions into a global perception, facilitated by the application of mnemonic techniques taught during the intervention.

doi:10.6342/NTU202400330

In addition to the legibility dimension in CHLAC, the stroke correctness is another crucial aspect that greatly affect the handwriting appearance. The stroke correctness supplement outcome in CHLAC refers to the deduction of scores due to improper length, position, shape, failure to fulfill the uniqueness of the stroke and repetitive stokes. Children with ASD often encounter stroke problems, which may be correlated with their impairment in fine motor skills, leading to improper strokes in Chinese handwriting. (Fuentes et al., 2009; Grace, Enticott, et al., 2017; Hellinckx et al., 2013; Jansiewicz et al., 2006; Johnson et al., 2013; Li-Tsang et al., 2018). The 12-hours program consisted of 4 hours of activities related to fine motor training, further enhancing the participants' fine motor skills, especially the fine motor control. These activities could benefit the better manipulation of hand when producing proper and desired strokes. Additionally, the program's first lesson included an activity designed to impart knowledge regarding the uniqueness of stroke properties in Chinese handwriting. The program's emphasis on fine motor skills training and knowledge of stroke properties may be the contributing factors in addressing stroke problems in the participants.

4.1.2 Handwriting Speed: BCBL's near and far copy test

The results of the handwriting speed test based on BCBL in this study show significant differences between the treatment and control phases in far copy task, and no significant differences for near copy task. In far copy task, the changes of control period even larger than treatment period, indicating improvement in far copy speed in control period was larger than intervention period. This finding differs from the study conducted by Chang & Yu in 2014, which demonstrated improvement in far copy speed using a computer-assisted handwriting intervention. In the computer-assisted handwriting intervention study, the emphasis was placed on improving handwriting

doi:10.6342/NTU202400330

speed. However, in this current study, the focus was primarily on improving the legibility of written words, as the legibility is a crucial aspect of handwriting. By solidifying the techniques for legible handwriting and developing handwriting automaticity, participants will eventually achieve adequate handwriting speed with legible handwriting. An interesting observation was made during the evaluation immediately after the intervention: even though the participants took a similar amount of time to complete copying a character in both the near and far copy tasks, their legibility significantly improved as they practiced the techniques learned in the program, such as scanning the entire character and comparing the proportion and position of the radicals before writing (Figure 4).

Furthermore, the lack of improvement in handwriting speed may also be influenced by the participants' ability to write legibly with automaticity. This can be attributed to the short duration of the overall treatment period, which lasted only 4 weeks. The four-week intervention may not have provided sufficient time for the participants to fully internalize the learned strategies and develop automaticity. Therefore, a less intensive intervention spread over a longer interval period, such as extending the treatment from 4 weeks to 6 weeks without changing the total dosage, could be more beneficial for the development of handwriting automaticity (Li-Tsang et al., 2019; Prunty et al., 2014; Salameh-Matar et al., 2018). It is expected that handwriting speed will improve once the learned techniques are internalized, and the participants have fully developed automaticity in writing legible handwriting.

4.2 Secondary Outcome

In this study, several fundamental skills relating to Chinese handwriting were emphasized in the program by integrating them with the unique features of the Chinese writing system. According to the results in Table 5, some of the skills showed a

doi:10.6342/NTU202400330

significantly larger improvement in participants during the treatment phase. The following sections will discuss the result of the developmental fundamental skills changes in the study.

4.2.1 Visual Perception: TVPS-4

The visual perception of the participants showed a significant improvement in treatment phase, as indicated by the overall total score of the TVPS-4 test. This outcome was aligned with previous Chinese handwriting intervention studies targeting children with handwriting problems, supporting the repetitive training of visual perception in improving the skills (Chang & Yu, 2017; Poon et al., 2010). In this study, the 12-hour handwriting intervention program consisted of 4 hours of intervention activities aimed at strengthening the visual perception skills of the participants, and it has shown some positive effects in the evaluation results. Furthermore, the further analysis in subtests revealed that sequential memory, visual figure-ground and visual closure showed significant improvement in treatment phase compared with control phase.

As mentioned in the methodology, the intervention program focused on visual perception skills related to Chinese handwriting, especially visual discrimination, visual memory, and spatial relationships. Although these subtests did not show significant improvement when comparing the changes between phases, the improvement during treatment phase exceeded the standard error of measurements (SEMs) according to the TVPS-4 practice manual, indicating a positive effect of the program on these skills (Brown & Peres, 2018). However, the lack of statistical significance in these subtests might be attributed to the inadequacy in capturing the specific improvements related to Chinese characters. Nevertheless, the repetitive practice of visual perception skills contributed to the improvement of participants' visual perception, particularly in those areas where significant improvement was observed in this study.

doi:10.6342/NTU202400330

4.2.2 Visual Motor Integration: VMI-4

In the analysis of the changes in VMI-4 between the treatment and control phases, no significant effect was found, which was contrary to previous finding. However, it is important to consider the difference in writing systems between our study and previous study, which primarily focused on English alphabet-based writing system (Dessoye et. al., 2017). Our study specifically targeted the Chinese handwriting system, which has distinct characteristics compared to alphabetic writing systems. The differences in the writing systems may have contributed to the contrasting result in visual motor integration (VMI) after the intervention.

Although the program was designed with several activities aimed at enhancing the visual motor integration skills in participants, the focus of the training was primarily on Chinese handwriting-related visual motor integration. During the program, participants were tasked with completing various VMI activities, including copying Chinese characters and geometric figures. The geometric figures were specifically designed to resemble the properties of the Chinese writing system, with sharp turning points and multiple radicals/compartments arranged in an imaginary square. It is important to note that the chosen assessment tool, the VMI-4, may not have been sensitive enough to capture the specific improvements in visual motor integration skills related to Chinese handwriting. Chinese characters are often composed of various strokes and radicals arranged in a grid-like pattern, forming a visual representation within a defined square or rectangular shape. This may differ from the figures tested in VMI-4, which the figures tested tend to emphasize the smoothness and continuity of strokes or lines with single compartments, which may not fully reflect the acquired Chinese handwriting-related VMI skills that participants developed during the program. Additionally, the insensitivity in the chosen tool which only rated 1 or 0 to the task and the scoring criteria

doi:10.6342/NTU202400330

not being taught in our program also further affect the result. It is believed that the acquired Chinese handwriting relating-VMI skills may not have fully transferred and been accurately reflected in the VMI-4 test.

4.2.3 Fine Motor Skills: DTVP-3 and BOT-2

In the study, the changes of fine motor skills in participants were measured using DTVP-3 for the eye-hand coordination and BOT-2 for the manual coordination. The results, as shown in Table 5, yielded contrasting findings as the eye-hand coordination subtest in DTVP-3 performed a significant greater improvement in treatment phase while the manual coordination in BOT-2 did not.

The DTVP eye-hand coordination subtest was selected to examine the improvement of the skill that are vital in Chinese handwriting, particularly when writing with appropriate stroke properties. The significantly larger improvement in DTVP during the treatment phase indicated the effectiveness of our program in enhancing the eye-hand coordination performance in participants. Eye-hand coordination in children with ASD is often discussed as a factor affecting their handwriting performance in the literature (Fuentes et al., 2009; Grace et al., 2017; Li-Tsang et al., 2018). The activities in the program, such as mazes, dotted line tracing, and cotton bud painting, were designed and successfully facilitate eye-hand coordination in participants.

Although the eye-hand coordination yielded a positive result, another fine motor indicator in this study, manual coordination subtests in BOT-2 did not show significant improvement in the treatment phase. Handwriting is a task that requires the precise control and coordination of hand and wrist movements to enable proficient and effective writing. The program included training for fine motor skills, which related to the movement of hand during handwriting task. This involved pencil tasks and tasks using other tools, aimed at enhancing fine motor component coordination, proximal

doi:10.6342/NTU202400330

coordination of upper extremities, force regulation, and tool manipulation. However, the dosage for eye-hand coordination (pencil tasks) was significantly greater than that for manual coordination (whole upper limb). This difference in dosage may have influenced the results, with the manual coordination subtest not showing significant improvement while the Eye-Hand Coordination subtest of DTVP-3 did.

4.3 Motivation

Besides the handwriting-related outcomes, the program also received high appraisal from caregivers and participants, as indicated by the results of the Pediatric Motivation Questionnaire (PMQ) and Client Satisfaction Questionnaire (CSQ). The high appraisal from participants may be contributed by the playful intervention context designed, “adventure journey of an astronaut”. Meanwhile, the caregivers' expectations were met contribute to the high satisfaction in caregivers’ perception.

Among all the items in the PMQ and CSQ, the topic that caught the researchers' attention the most was the dosage of the program. In the PMQ, participants expressed contrasting opinions regarding the duration of each lesson. Some participants expressed to have longer durations, while others suggested shorter durations when rating item 10, "Is the duration of this program suitable?". The intervention program was initially planned to be delivered twice a week, with 90 and 120 minutes for each lesson, including a refreshing time of 10 and 20 minutes, respectively. However, based on observations from the therapist, engaging in sedentary tasks continuously for 120 minutes sometimes caused participants to be unable to fully concentrate and complete the tasks, which could affect the effectiveness of the training program. This was more apparent during weekday lessons compared to weekends. Modifying the duration of a single lesson from 120 to 90 minutes may be more suitable for participants, especially those in lower grades, to sustain attention throughout the entire lesson.

doi:10.6342/NTU202400330

In contrast, in the CSQ, over one-third of caregivers requested a longer overall treatment period. They expressed concerns about the internalization of the learned writing techniques if the program ended after the fourth week. The therapist in this study shared similar concerns. To address these concerns, extending the overall intervention time interval might benefit the internalization of the techniques learned by the participants. Hence, in this situation, it may be most appropriate to extend the overall intervention period while reducing the intensity or duration of each individual lesson, without making any adjustments to the total intervention dosage. However, this phenomenon (requesting for a longer overall intervention time interval) also reflects the satisfaction of caregivers with the intervention program.

In another observation, a participant rated a score of 1 for the item "Do you complete the program well?" in her first week PMQ. When asked about the reason for this low rating, she attributed it to her poor handwriting. In the intervention, the therapist not only taught techniques and strengthened the participant's fundamental skills but also guided the participants to observe their own improvement in handwriting performance. Fortunately, the item received a score of 5, indicating full satisfaction, during her last week/4th week PMQ. As previous research has indicated, poor handwriting performance can directly or indirectly affect a child's self-esteem (Katya & Majnemer, 2007; Gargot et al., 2020). This observation was also made in this study, and the child's self-esteem improved along with the improvement in handwriting when she observed her own progress during the treatment.

4.4 Study Limitation and future suggestion

Although the study yielded impressive findings, it is important to acknowledge several limitations and propose suggestions for future research. These limitations and suggestions can be categorized into three main issues: participants, assessment tools,

doi:10.6342/NTU202400330

and dosage. The following paragraphs will discuss the limitations and future suggestions for each of these aspects.

Firstly, regarding the participants, it is important to note that in this study, the participants consisted of children with Autism Spectrum Disorder (ASD) who had an intelligence quotient (IQ) higher than 70 standard scores according to the RCPM. However, ASD is a disorder that encompasses a wide range of IQ scores, including those with lower IQ. The cognitive approach used in this study may be more suitable for individuals with average to above-average IQ. As a result, the generalizability of the results to a broader population of children with ASD who struggle with handwriting difficulties may be limited.

Secondly, the suitability of the chosen assessment tools should be considered. While the selected tools were utilized in this study, they may have limitations in fully capturing and reflecting the unique demands of Chinese handwriting. However, to the best of our knowledge, there are currently no alternative assessment tools available that comprehensively evaluate the fundamental developmental skills associated with Chinese writing. Therefore, future studies should focus on searching and selecting valid assessment tools that effectively capture improvements in Chinese handwriting.

Lastly, the dosage of the intervention program is an important aspect to consider. In future studies, it is recommended to elongate the overall durations for the intervention while maintaining the total dosage of the intervention. Extending the intervention period would provide participants with more opportunities to internalize and solidify the learned techniques, eventually improving the automaticity of their handwriting. Achieving greater automaticity would enhance handwriting speed in children with ASD without sacrificing legibility. In summary, future studies focused on broader interval IQ of ASD population, more comprehensive Chinese handwriting

doi:10.6342/NTU202400330

related assessments, intervention program with longer overall intervention period, as well as a dose-matched active control design are suggested to valid this study findings.

doi:10.6342/NTU202400330

Chapter 5　Conclusion

In this study, a Chinese handwriting intervention program, which integrates unique features of the Chinese writing system and handwriting fundamental skills training with the use of cognitive approach for skill acquisition to address the handwriting problems in children with ASD, named 'Go Go Handwriting – ASD version,' yielded impressive findings. The study demonstrated significant improvements in Chinese handwriting legibility and stroke correctness as primary outcomes, along with enhancements in visual perception and eye-hand coordination as secondary outcomes. A "trade-off" effect emerged when participants were assigned a timed copy task; handwriting speed slowed down to ensure the maintenance of improved handwriting legibility. Moreover, the program received high praise from both participants and caregivers. These findings provide valuable clinical evidence supporting the integration of Chinese writing features, handwriting fundamental skill training, and a cognitive approach to improve the handwriting performance of children with ASD. This study offers an evidence-based method to enhance handwriting performance in this population, which has important implications for clinical practice.

doi:10.6342/NTU202400330

Chapter 6 References

Beery, K. E., Buktenica, N. A., & Beery, N. A. (2010). *The Beery-Buktenica Developmental Test of Visual Motor Integration for children and adults: Administration, scoring and teaching manual* (6th ed.). NCS Pearson.

Beversdorf, D. Q., Anderson, J. M., Manning, S. E., Anderson, S. L., Nordgren, R. E., Felopulos, G. J., & Bauman, M. L. (2001). Brief report: macrographia in high-functioning adults with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 31* (1), 97-101. https://doi.org/10.1023/a:1005622031943

Biotteau, M., Danna, J., Baudou, É., Puyjarinet, F., Velay, J. L., Albaret, J. M., & Chaix, Y. (2019). Developmental coordination disorder and dysgraphia: Signs and symptoms, diagnosis, and rehabilitation. *Neuropsychiatric Disease and Treatment*, *15*, 1873-1885. https://doi.org/10.2147/ndt.S120514

Booth, R. D. L., & Happé, F. G. E. (2018). Evidence of reduced global processing in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *48*(4), 1397-1408. https://doi.org/10.1007/s10803-016-2724-6

Brown, T. (2016). Validity and reliability of the Developmental Test of Visual Perception - Third Edition (DTVP-3). *Occupational Therapy in Health Care*, *30*(3), 272-288. https://doi.org/10.3109/07380577.2015.1136757

Brown, T., & Peres, L. (2018). An overview and critique of the Test of Visual Perception Skills - fourth edition (TVPS-4). *Hong Kong Journal of Occupational Therapy*, *31*(2), 59-68. https://doi.org/10.1177/1569186118793847

Bruininks, R. H., & Bruininks, B. D. (2005). *Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2)*.PsycTESTS..

Carsone, B., Green, K., Torrence, W., & Henry, B. (2021). Systematic review of visual

doi:10.6342/NTU202400330

motor integration in children with developmental disabilities. *Occupational Therapy International*, *2021*, 1801196. https://doi.org/10.1155/2021/1801196

Cartmill, L., Rodger, S., & Ziviani, J. (2009). Handwriting of eight-year-old children with autistic spectrum disorder: An exploration. *Journal of Occupational Therapy, Schools, & Early Intervention*, *2*(2), 103-118. https://doi.org/10.1080/19411240903146426

Ch'ng, H. L., & Ahmand, A. C. (2021). Assisting autistic students with handwriting difficulties using a combination of handwriting intervention. *Journal of Contemporary Social Science and Education Studies 1*(2), 140–156. http://www.jocss.com/index.php/multidiscipline/article/view/69

Chang, S. H., & Yu, N. Y. (2014). The effect of computer-assisted therapeutic practice for children with handwriting deficit: A comparison with the effect of the traditional sensorimotor approach. *Research in Developmental Disability*, *35*(7), 1648-1657. https://doi.org/10.1016/j.ridd.2014.03.024

Chang, S. H., & Yu, N. Y. (2017). Assisting autistic students with handwriting difficulties using a combination of handwriting intervention. *American Journal of Occupational Therapy*, *71*(2), 7102220030p7102220031-7102220030p7102220010. https://doi.org/10.5014/ajot.2017.021311

Chung, S., & Son, J. W. (2020). Visual perception in autism spectrum disorder: A review of neuroimaging studies. *Soa Chongsonyon Chongsin Uihak*, *31*(3), 105-120. https://doi.org/10.5765/jkacap.200018

Church, C., Alisanski, S., & Amanullah, S. (2000). The social, behavioral, and academic experiences of children with Asperger syndrome. *Focus on Autism and Other Developmental Disabilities*, *15*(1), 12-20. https://doi.org/10.1177/108835760001500102

doi:10.6342/NTU202400330

Cornhill, H., & Case-Smith, J. (1996). Factors that relate to good and poor handwriting. *American Journal of Occupational Therapy*, *50*(9), 732-739. https://doi.org/10.5014/ajot.50.9.732

Dessoye, J., Converse-Korhonen, C., McLaughlin, L., McSweeney, S., & Steinhoff, C. (2017). The effectiveness of iPad handwriting applications in improving visual-motor and handwriting skills in children with autism spectrum disorder. *American Journal of Occupational Therapy*, *71*(4_Supplement_1), 7111520282p7111520281-7111520282p7111520281. https://doi.org/10.5014/ajot.2017.71S1-PO2149

Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine & Child Neurology*, *49*(4), 312-317. https://doi.org/https://doi.org/10.1111/j.1469-8749.2007.00312.x

Fuentes, C. T., Mostofsky, S. H., & Bastian, A. J. (2009). Children with autism show specific handwriting impairments. *Neurology*, *73*(19), 1532-1537. https://doi.org/10.1212/WNL.0b013e3181c0d48c

Gargot, T., Asselborn, T., Pellerin, H., Zammouri, I., M Anzalone, S., Casteran, L., Johal, W., Dillenbourg, P., Cohen, D., & Jolly, C. (2020). Acquisition of handwriting in children with and without dysgraphia: A computational approach. *PLOS ONE*, *15*(9), e0237575-e0237575. https://doi.org/10.1371/journal.pone.0237575

Getchell, N., Schilder, A., Wusch, E., & Trask, A. (2018). Chapter 86 - A random practice schedule provides better retention and transfer than blocked when learning computer mazes: Preliminary results. In H. Ayaz & F. Dehais (Eds.), *Neuroergonomics* (pp. 303-304). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-811926-6.00086-5

doi:10.6342/NTU202400330

Grace, N., Enticott, P. G., Johnson, B. P., & Rinehart, N. J. (2017). Do handwriting difficulties correlate with core symptomology, motor proficiency, and attentional behaviors? *Journal of Autism and Developmental Disorders*, *47*(4), 1006-1017. https://doi.org/10.1007/s10803-016-3019-7

Grace, N., Johnson, B. P., Rinehart, N. J., & Enticott, P. G. (2018). re motor control and regulation problems part of the ASD motor profile? A handwriting study. *Developmental Neuropsychology*, *43*(7), 581-594. https://doi.org/10.1080/87565641.2018.1504948

Grace, N., Rinehart, N. J., Enticott, P. G., & Johnson, B. P. (2017). Do children with ASD have difficulty handwriting under time pressure? *Research in Autism Spectrum Disorders*, *37*, 21-30. https://doi.org/https://doi.org/10.1016/j.rasd.2017.02.001

Green, R. R., Bigler, E. D., Froehlich, A., Prigge, M. B., Travers, B. G., Cariello, A. N., Anderson, J. S., Zielinski, B. A., Alexander, A., Lange, N., & Lainhart, J. E. (2016). Beery VMI performance in autism spectrum disorder. *Child Neuropsychol*, *22*(7), 795-817. https://doi.org/10.1080/09297049.2015.1056131

Green, R. R., Bigler, E. D., Froehlich, A., Prigge, M. B. D., Zielinski, B. A., Travers, B. G., Anderson, J. S., Alexander, A., Lange, N., & Lainhart, J. E. (2019). Beery VMI and brain volumetric relations in autism spectrum disorder. *Journal of Pediatric Neuropsychology*, *5*(3), 77-84. https://doi.org/10.1007/s40817-019-00069-z

Hammill, D. D., Pearson, N. A., & Voress, J. K. (2014). *Developmental test of visual perception-Third Edition*. Pro-Ed.

Hellinckx, T., Roeyers, H., & Van Waelvelde, H. (2013). Predictors of handwriting in children with autism spectrum disorder. *Research in Autism Spectrum Disorders*,

doi:10.6342/NTU202400330

7(1), 176-186. https://doi.org/https://doi.org/10.1016/j.rasd.2012.08.009

Hinojosa, J., & Hsu, C.-J. (2013). Assessment and intervention protocol for improving figure-copying competence of children with autism spectrum disorder with weak central coherence. *Journal of Occupational Therapy Schools & Early Intervention*, *6*, 228-240. https://doi.org/10.1080/19411243.2013.850957

Huang, W.-F., Wang, T.-N., Chuang, P.-Y., & Chen, H.-L. (2023). Development and psychometric evaluation of the Computer-Aided Measure of Chinese Handwriting in School-aged Children. *American Journal of Occupational Therapy*, Advance online publication.

Hung, L. Y., Chang, Y. W., Chen, S. F., Lee, Y. D., & Chen, C. S. (2003). *Battery of Chinese Basic Literacy*. Psychological Publishing.

Hwang, Y.-S., Su, P.-F., Hsiao, Y.-L., Tsai, W.-H., & Hung, J.-Y. (2020). Developing a nomogram model to predict the risk of poor Chinese handwriting in first grade. *American Journal of Occupational Therapy*, *74*(5), 7405205080p7405205081-7405205080p7405205088. https://doi.org/10.5014/ajot.2020.038711

Jansiewicz, E. M., Goldberg, M. C., Newschaffer, C. J., Denckla, M. B., Landa, R., & Mostofsky, S. H. (2006). Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. *Journal of Autism and Developmental Disorders*, *36*(5), 613-621. https://doi.org/10.1007/s10803-006-0109-y

Johnson, B. P., Phillips, J. G., Papadopoulos, N., Fielding, J., Tonge, B., & Rinehart, N. J. (2013). Understanding macrographia in children with autism spectrum disorders. *Research in Developmental Disabilities*, *34*(9), 2917-2926. https://doi.org/10.1016/j.ridd.2013.06.003

Kaur, M., Srinicasan, S. M., & Bhat, A. N. (2018). Comparing motor performance,

doi:10.6342/NTU202400330

praxis, coordination, and interpersonal synchrony between children with and without Autism Spectrum Disorder (ASD). *Research in Developmental Disabilities*, *72*, 79-95. https://doi.org/10.1016/j.ridd.2017.10.025

Klein, S., Guiltner, V., Sollereder, P., & Cui, Y. (2011). Relationships between fine-motor, visual-motor, and visual perception scores and handwriting legibility and speed. *Physical & Occupational Therapy In Pediatrics*, *31*(1), 103-114. https://doi.org/10.3109/01942638.2010.541753

Kuo, L. J., Kim, T. J., Yang, X. Y., Li, H. W., Liu, Y., Wang, H. X., Park, J. H., & Li, Y. (2015). Acquisition of Chinese characters: The effects of character properties and individual differences among second language learners. *Frontiers in Psychology*, *6*. https://doi.org/ARTN 98610.3389/fpsyg.2015.00986

Lau, D. K.-Y. (2020). Orthographic and phonological processing in Chinese character copying: A preliminary report. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2020.02122

Li-Tsang, C. W. P., Li, T. M. H., Ho, C. H. Y., Lau, M. S. W., & Leung, H. W. H. (2018). The relationship between sensorimotor and handwriting performance in Chinese adolescents with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *48*(9), 3093-3100. https://doi.org/10.1007/s10803-018-3580-3

Li-Tsang, C. W. P., Li, T. M. H., Lau, M. S. W., Lo, A. G. W., Ho, C. H. Y., & Leung, H. W. H. (2019). Computerised Handwriting Speed Test System (CHSTS): Validation of a handwriting assessment for Chinese secondary students. *Australian Occupational Therapy Journal*, *66*(1), 91-99. https://doi.org/10.1111/1440-1630.12526

Luria, A. (1962). The role of speech in the regulation of normal and abnormal

doi:10.6342/NTU202400330

behaviour. In *Proceedings of the Royal Society of Medicine, 55*, 243.

Miller, M., Chukoskie, L., Zinni, M., Townsend, J., & Trauner, D. (2014). Dyspraxia, motor function and visual-motor integration in autism. *Behavioural Brain Research*, *269*, 95-102. https://doi.org/10.1016/j.bbr.2014.04.011

Nejati, V., Moradkhani, L., Suggate, S., & Jansen, P. (2021). The impact of visual-spatial abilities on theory of mind in children and adolescents with autism spectrum disorder. *Research in Developmental Disabilities*, *114*, 103960. https://doi.org/https://doi.org/10.1016/j.ridd.2021.103960

O'Brien, J. C., & Kuhaneck, H. (2019). *Case-Smith's Occupational therapy for children and adolescents* (8th ed.). Mosby Inc.

Palsbo, S. E., & Hood-Szivek, P. (2012). Effect of robotic-assisted three-dimensional repetitive motion to improve hand motor function and control in children with handwriting deficits: a nonrandomized phase 2 device trial. *American Journal of Occupational Therapy*, *66*(6), 682-690. https://doi.org/10.5014/ajot.2012.004556

Panos, K. M. (2019). *Effects of intervention on handwriting accuracy and speed for elementary students with autism spectrum disorder* [Unpublished master's thesis, University of Iowa].

Poon, K. W., Li-Tsang, C. W., Weiss, T. P., & Rosenblum, S. (2010). The effect of a computerized visual perception and visual-motor integration training program on improving Chinese handwriting of children with handwriting difficulties. *Research in Developmental Disability*, *31*(6), 1552-1560. https://doi.org/10.1016/j.ridd.2010.06.001

Prunty, M., Barnett, A. L., Wilmut, K., & Plumb, M. (2016). Visual perceptual and handwriting skills in children with Developmental Coordination Disorder.

doi:10.6342/NTU202400330

Human Movement Science, *49*, 54-65. https://doi.org/10.1016/j.humov.2016.06.003

Prunty, M. M., Barnett, A. L., Wilmut, K., & Plumb, M. S. (2014). An examination of writing pauses in the handwriting of children with developmental coordination disorder. *Research in Developmental Disabilities*, *35*(11), 2894-2905. https://doi.org/10.1016/j.ridd.2014.07.033

Reisman, J. (1999). *Minnesota handwriting assessment*. Psychological Corporation.

Salameh-Matar, A., Basal, N., & Weintraub, N. (2018). Relationship between body functions and Arabic handwriting performance at different acquisition stages. *Canadian Journal of Occupational Therapy*, *85*(5), 418-427. https://doi.org/10.1177/0008417419826114

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis* (4 ed.). Human Kinetics.

Shih, H. N., Tsai, W. H., Chang, S. H., Lin, C. Y., Hong, R. B., & Hwang, Y. S. (2018). Chinese handwriting performance in preterm children in grade 2. *PLOS ONE*, *13*(6), e0199355. https://doi.org/10.1371/journal.pone.0199355

Sköld, A., Hermansson, L. N., Krumlinde-Sundholm, L., & Eliasson, A. C. (2011). Development and evidence of validity for the Children's Hand-use Experience Questionnaire (CHEQ). *Developmental Medicine & Child Neurology*, *53*(5), 436-442. https://doi.org/10.1111/j.1469-8749.2010.03896.x

Taghizadeh, A., Webster, K. E., Bhopti, A., Carey, L., & Hoare, B. (2022). Are they really motor learning therapies? A scoping review of evidence-based, task-focused models of upper limb therapy for children with unilateral cerebral palsy. *Disability and Rehabilitation*, 1-13. https://doi.org/10.1080/09638288.2022.2063414

doi:10.6342/NTU202400330

Taverna, L., Tremolada, M., Dozza, L., Zanin Scaratti, R., Ulrike, D., Lallo, C., & Tosetto, B. (2020). Who benefits from an intervention program on foundational skills for handwriting addressed to kindergarten Children and First Graders? *Int J Environ Res Public Health*, *17*(6). https://doi.org/10.3390/ijerph17062166

Tse, L., Siu, A., & Li-Tsang, C. (2018). Developmental skills between kindergarten children with handwriting difficulties in Chinese and/or English. *Australian Occupational Therapy Journal*, *66*. https://doi.org/10.1111/1440-1630.12550

Tseng, M. H., & Chow, S. M. (2000). Perceptual-motor function of school-age children with slow handwriting speed. *American Journal of Occupational Therapy*, *54*(1), 83-88. https://doi.org/10.5014/ajot.54.1.83

van den Bos, N., Houwen, S., Schoemaker, M., & Rosenblum, S. (2022). Balancing text generative and text transcriptive demands: Written content and handwriting legibility and speed of children and youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *52*(10), 4540-4553. https://doi.org/10.1007/s10803-021-05325-w

Weimer, A. K., Schatz, A. M., Lincoln, A., Ballantyne, A. O., & Trauner, D. A. (2001). "Motor" impairment in Asperger syndrome: evidence for a deficit in proprioception. *Journal of Developmental and Behavioral Pediatrics*, *22*(2), 92-101. https://doi.org/10.1097/00004703-200104000-00002

Werner, J. M., Berggren, J., Loiselle, J., & Lee, G. K. (2021). Constraint-induced movement therapy for children with neonatal brachial plexus palsy: a randomized crossover trial. *Developmental Medicine & Child Neurology*, *63*(5), 545-551. https://doi.org/10.1111/dmcn.14741

Wuang, Y. P., Huang, C. L., & Tsai, H. Y. (2020). Sensory integration and perceptual-motor profiles in school-aged children with Autistic Spectrum Disorder.

doi:10.6342/NTU202400330

Neuropsychiatric Disease and Treatment, *16*, 1661-1673. https://doi.org/10.2147/ndt.S253337

Zwicker, J. G., & Harris, S. R. (2009). A reflection on motor learning theory in pediatric occupational therapy practice. *Canadian Journal of Occupational Therapy*, *76*(1), 29-37. https://doi.org/10.1177/000841740907600108

王姝婷（2020）。兒童中文書寫易讀性評估之發展。〔碩士論文。國立臺灣大學〕臺灣博碩士論文知識加值系統。 https://hdl.handle.net/11296/7b38h2。

李冠儀（2020）。書寫介入方案之發展與可行性研究：以中文字特徵為基礎。〔碩士論文。國立臺灣大學〕臺灣博碩士論文知識加值系統。https://hdl.handle.net/11296/c2fbu9。

陳榮華、陳心怡（2006）。瑞文氏矩陣推理測驗。台北市：中國行為科學社。 (J. Raven, 1998)

劉鴻香、劉莉（1997）。拜瑞-布坦尼卡 視覺-動作統整發展測驗。台北市：心裡出版社。(Beery, 2010)

doi:10.6342/NTU202400330

Appendix 1. Pediatric Motivation Questionnaire

兒童動機問卷(評整天)

個案編號： **日期與時間：**

項目	分數
1. 您參與課程活動時快樂嗎?	 1------------2------------3------------4------------5 一點也不 很快樂
2. 您喜歡這個課程活動嗎?	 1------------2------------3------------4------------5 一點也不 很喜歡
3. 您覺得自己做得好不好?	 1------------2------------3------------4------------5 一點也不 很好
4. 您會期待下一次課程嗎?	 1------------2------------3------------4------------5 一點也不 很期待
5. 我在活動中有發揮全力(盡最大努力)	 1------------2------------3------------4------------5 一點也不 盡最大努力

doi:10.6342/NTU202400330

Appendix 1. Pediatric Motivation Questionnaire (cont')

6. 這個活動對我來說很重要	 1------------2------------3------------4------------5 一點也不 很重要
7. 我覺得這個活動是很有趣	 1------------2------------3------------4------------5 一點也不 很有趣
8. 活動中我覺得很安心/放鬆	 1------------2------------3------------4------------5 一點也不 很安心／放鬆
9. 活動中治療師很關心我	 1------------2------------3------------4------------5 一點也不 很關心
10. 我覺得這個活動時間長度剛剛好	 1------------2------------3------------4------------5 一點也不 剛剛好
11. 這個活動對我來說是有幫助的	 1------------2------------3------------4------------5 一點也不 很有幫助
12. 這個活動讓我書寫更進步	 1------------2------------3------------4------------5 一點也不 進步很多

doi:10.6342/NTU202400330

Appendix 2. Satisfaction Questionnaire

The client satisfaction questionnaire (CSQ)

個案滿意度問卷

個案編號：________________
填寫日期：________________

請您配合填寫這份問卷，以協助我們改善這次的計畫。我們感謝您誠實的回饋和意見，無論是正面還是負面的評論。請您填寫以下所有問題，也歡迎提供意見和想法，非常感謝您的協助!

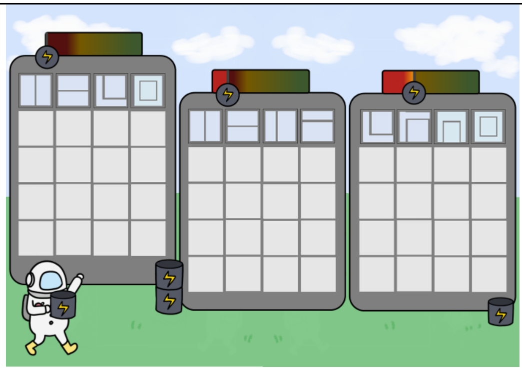
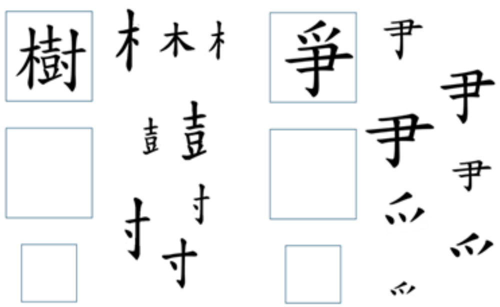
請將您的答案圈起來。

項目	4	3	2	1
1. 您對於這次課程的評價為?	很好	好	不錯	差
2. 您的小孩是否有得到您想要的課程?	有	大致有	沒有	完全沒有
3. 我們的課程能符合您小孩書寫的訓練需求?	很符合	符合	少許符合	完全沒有符合
4. 如果您朋友的小孩有類似的問題，您會推薦這個課程給他嗎?	會，當然會	會，我想是會的	不會，我不這麼認為	不會，當然不會
5. 您對於課程的總時數滿意嗎?	很滿意	滿意	有些不滿意	相當不滿意
6. 您的小孩參與的課程能幫助您的小孩更有效地處理書寫問題嗎?	能，提供很大的幫助	能，多少有幫助	不，幾乎沒有幫助	不，似乎把問題弄得更糟
7. 整體來說，您對於課程的滿意度為?	非常滿意	多數滿意	還好或有點不滿意	相當不滿意
8. 如果您之後還需要協助，您會再一次參與我們的課程嗎?	會，當然會	會，我想是會的	不，我不這麼認為	不，絕對不會

寫下您對於我們的建議:

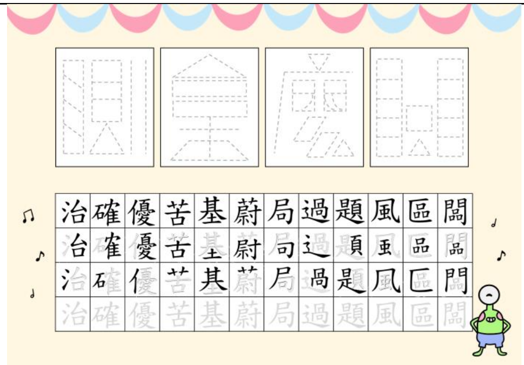
doi:10.6342/NTU202400330

Table 1. Activities of intervention program

Type of activities	Example of activities	Description
	Visual Perception	
		In this activity, the participant needs to discriminate and recognize the combination pattern of the radicals and match it with their corresponding combination of geometric figure.
		In this activity, the transparent sheets with different sizes of radicals. The participant needs to choose the appropriate size proportion of radicals and overlap with proper relative space between radicals. The participant has to complete the similar size and smaller size of radical combination.

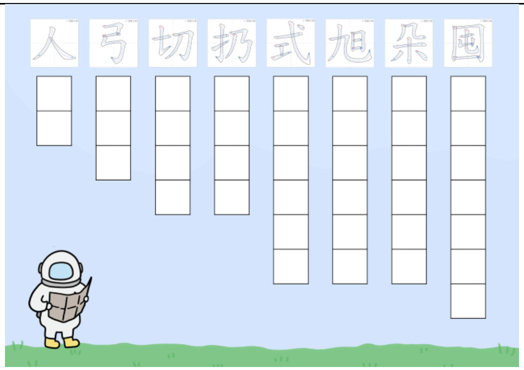
doi:10.6342/NTU202400330

Table 1. Activities of Intervention Program (cont')

Type of activities	Example of activities	Description
Visual Perception		
		In this activity, the participant was requested to throw the dice, and five seconds were given for the participants to remember the character. The following throws then perform with the same procedure. The participant was then requested to choose the character from the cards and arrange the order of dice thrown.
Fine Motor Skills		
Pencil & Paper task		In this activity, the participant needs to trace the dotted line and shaded radicals to complete the geometric figures and the Chinese character. For the Chinese character tracing task, the partial character, which is the radicals writing, will be practiced before the whole Chinese character tracing.

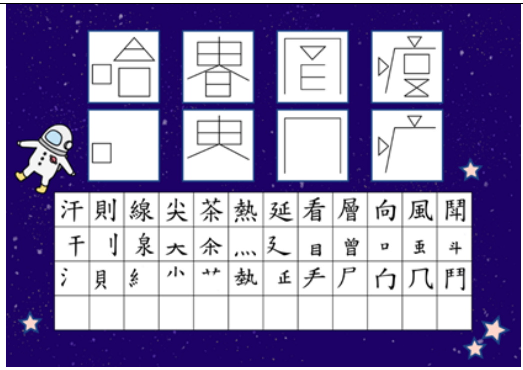
doi:10.6342/NTU202400330

Table 1. Activities of Intervention Program (cont')

Type of activities	Example of activities	Description
Fine Motor Skills		
Task using other tools		In this activity, the participant needs to use cotton buds which immersed in watercolor and dotted on the shaded stroke.
Visual Motor Integration		
Stroke		In this activity, the participant needs to copy the character according to the stroke sequence displayed.

doi:10.6342/NTU202400330

Table 1. Activities of Intervention Program (cont')

Type of activities	Example of activities	Description
	Visual Motor Integration	
Radicals and Character		In this activity, the participant needs to copy the missing lines and strokes to complete the geometric figures and the Chinese characters. For the Chinese character task, the partial character, which is the radicals writing, will be practiced before the whole character writing.

doi:10.6342/NTU202400330

Table 2. Comparison of demographic characteristic between groups

	Sequence A: treatment first	Waitlist Control Group	p Value
N	10	10	
Age (Months)	88.20 (8.22)	88.40 (5.91)	0.95[a]
Intelligent Quotient (RCPM)	94.80 (14.78)	100.10 (14.79)	0.43[a]
ASD Symptom (ABC-T)	23.40 (8.68)	24.10 (10.83)	0.88[a]
Gender			0.03[b]
Male	6	10	
Female	4	0	
Handedness			1.00[b]
Right-Handed	8	8	
Left-Handed	2	2	
Comorbidities			0.88 [b]
Attention Deficit Hyperactivity Disorder (ADHD)	5	5	
Attention Deficit Disorder (ADD)	1	1	
Tics/Tourette Disorder	2	1	

a: Independent t-test

b: Chi-square test

Abbreviations: RCPM, Raven's Coloured Progressive Matrices; ABC-T, Autism Behavioral Checklist- Taiwan Version

doi:10.6342/NTU202400330

Table 3. Baseline comparison between groups

	Sequence A: treatment first (N=10)	Waitlist Control Group (N=10)	p Value[a]
Handwriting Performance			
CHLAC			
Legibility	37.00 (6.06)	38.10 (6.84)	0.708
Character Dimension	17.60 (0.99)	18.70 (4.16)	0.513
Size	8.30 (2.95)	8.50 (3.60)	0.893
Space	9.30 (2.21)	10.20 (2.35)	0.389
Radical Dimension	19.40 (5.72)	19.40 (7.07)	1.00
Orientation	7.70 (3.77)	7.40 (3.44)	0.855
Radical Size	6.30 (2.91)	6.10 (3.67)	0.894
Radical Position	5.40 (2.22)	5.90 (2.64)	0.653
Stroke Correctness	38.90 (19.43)	39.50 (17.02)	0.942

doi:10.6342/NTU202400330

Table 3. Baseline comparison between groups (Cont')

	Sequence A: treatment first (N=10)	Waitlist Control Group (N=10)	p Value[a]
Handwriting Performance			
BCBL			
Near Copy (character/minute)	3.45(2.01)	5.30 (2.32)	0.071
Far Copy (character/minute)	3.25 (1.93)	5.20 (2.57)	0.073
Handwriting Fundamental Skill			
TVPS-4			
Total Score	75.60 (11.94)	70.60 (10.19)	0.327
Visual Discrimination	12.20 (2.86)	9.60 (2.72)	0.052
Visual Memory	9.80 (2.66)	10.40 (3.34)	0.662
Spatial Relationships	14.50 (2.27)	13.00 (3.13)	0.236
Form Constancy	9.60 (2.50)	8.80 (2.53)	0.486

doi:10.6342/NTU202400330

Table 3. Baseline comparison between groups (Cont')

	Sequence A: treatment first (N=10)	Waitlist Control Group (N=10)	p Value[a]
Handwriting Fundamental Skill			
TVPS-4			
Sequential Memory	11.80 (2.35)	11.80 (2.78)	1.00
Visual Figure-Ground	10.30 (3.59)	9.20 (2.97)	0.465
Visual Closure	7.40 (3.06)	7.80 (2.62)	0.757
VMI-4			
Visuomotor Integration	16.10 (2.64)	15.30 (2.27)	0.506
DTVP-3			
Eye-Hand Coordination	160.80 (16.71)	147.90 (15.68)	0.092

doi:10.6342/NTU202400330

Table 3. Baseline comparison between groups (Cont')

	Sequence A: treatment first (N=10)	Waitlist Control Group (N=10)	p Value[a]
Handwriting Fundamental Skill			
BOT-2			
Manual Coordination	59.90 (6.97)	61.40 (5.56)	0.577
Manual Dexterity	22.20 (4.05)	23.60 (2.76)	0.378
Upper Limb Coordination	21.60 (9.49)	23.10 (7.87)	0.705

a: Independent t-test

Abbreviations: CHLAC, Chinese Handwriting Legibility Assessment for Children; BCBL, The Battery of Chinese Basic Literacy; TVPS-4, Test of Visual Perceptual Skills – Fourth Edition; VMI-4, Beery-Buktenica Developmental Test of Visual-Motor Integration – Forth Edition; DTVP-3, Developmental Test of Visual Perception – Third Edition; BOT-2, Bruininks-Oseretsky Test of Motor Proficiency - Second Edition

doi:10.6342/NTU202400330

Table 4. The changes in primary outcomes during the control and treatment phase

N=20	Sequence A: Treat' First		Sequence B: Cont' First		Combine		p Value[a]	Effect Size
	Period 1	Period 2	Period 1	Period 2	Treatment	Control		
CHLAC								
Legibility	15.90 (9.35)	-2.40 (9.03)	3.20 (5.13)	15.60 (6.31)	15.75 (7.77)	0.40 (7.80)	<0.001	1.13
Character Dimension	4.60 (3.41)	-0.80 (4.18)	0.40 (3.44)	4.80 (1.87)	4.70 (2.68)	-0.20 (3.78)	0.001	0.92
Size	3.00 (2.79)	-1.30 (2.75)	1.00 (2.40)	2.20 (2.04)	2.60 (2.41)	-0.15 (2.78)	0.015	0.60
Space	1.60 (2.76)	0.50 (4.41)	-0.60 (2.27)	2.60 (1.96)	2.10 (2.38)	-0.50 (3.30)	0.051	0.47
Radical Dimension	11.30 (6.91)	-1.60 (6.62)	2.80 (3.79)	10.80 (6.89)	11.05 (6.72)	0.60 (5.72)	<0.001	1.06
Orientation	1.60 (4.38)	0.90 (3.63)	0.00 (3.53)	4.00 (4.19)	2.80 (4.35)	0.45 (3.52)	0.149	0.37
Radical Proportion	4.30 (4.06)	-0.60 (2.46)	2.10 (3.90)	4.40 (2.95)	4.35 (3.45)	0.75 (3.46)	0.011	0.63
Radical Position	5.40 (1.96)	-1.90 (3.96)	0.70 (3.50)	2.40 (3.84)	3.90 (3.34)	-0.60 (3.87)	0.006	0.70
Stroke Correctness	11.00 (9.87)	10.30 (12.39)	-4.4 (8.28)	21.60 (15.21)	16.30 (13.61)	2.95 (12.73)	0.004	0.73

doi:10.6342/NTU202400330

Table 4. The changes in primary outcomes during the control and treatment phase (Cont')

N=20	Sequence A: Treat' First		Sequence B: Cont' First		Combine		p Value[a]	Effect Size
	Period 1	Period 2	Period 1	Period 2	Treatment	Control		
BCBL								
Near Copy	-0.10 (1.81)	0.35 (1.47)	0.50 (1.62)	-1.35 (2.45)	-0.73 (2.19)	0.43 (1.51)	0.085	0.41
Far Copy	-0.30 (1.60)	0.40 (1.60)	1.25 (1.53)	-1.40 (2.09)	-0.85 (1.90)	0.83 (1.58)	0.005	0.72

a: Paired t-test

Abbreviations: CHLAC, Chinese Handwriting Legibility Assessment for Children; BCBL, The Battery of Chinese Basic Literacy

doi:10.6342/NTU202400330

Table 5. The changes in secondary outcomes during the control and treatment phase

N=20	Sequence A: Treat' First		Sequence B: Cont' First		Combine		p Value[a]	Effect Size
	Period 1	Period 2	Period 1	Period 2	Treatment	Control		
TVPS-4								
Total Score	15.70 (9.26)	-3.60 (6.83)	2.10 (11.57)	9.50 (12.10)	12.60 (10.96)	-0.75 (9.70)	<0.001	0.96
Visual Discrimination	2.00 (2.62)	-1.50 (3.50)	0.90 (3.90)	0.60 (2.46)	1.30 (2.58)	-0.30 (3.81)	0.112	0.37
Visual Memory	2.60 (3.65)	1.20 (2.70)	1.30 (3.83)	1.70 (3.23)	2.15 (3.39)	1.25 (3.23)	0.452	0.17
Spatial Relationships	1.20 (1.32)	0.50 (2.46)	0.20 (3.05)	1.80 (3.01)	1.50 (2.28)	0.35 (2.70)	0.144	0.34
Form Constancy	3.40 (3.10)	-0.70 (3.37)	0.20 (4.98)	1.20 (5.63)	2.30 (4.57)	-0.25 (4.67)	0.100	0.39
Sequential Memory	1.40 (1.84)	-2.20 (2.30)	-0.60 (2.32)	-0.50 (2.51)	0.45 (2.35)	-1.40 (2.39)	0.025	0.55
Visual Figure-Ground	1.60 (2.12)	0.40 (2.32)	-0.50 (3.03)	2.00 (3.62)	1.80 (2.89)	-0.05 (2.67)	0.023	0.55
Visual Closure	3.50 (3.14)	-1.30 (3.83)	0.60 (2.76)	2.70 (3.20)	3.10 (3.11)	-0.35 (3.39)	<0.001	1.22
VMI-4								
Visuomotor Integration	1.10 (3.73)	-3.10 (4.82)	1.20 (2.94)	-0.60 (2.72)	0.25 (3.29)	-0.95 (4.47)	0.357	0.21

doi:10.6342/NTU202400330

Table 5. The changes in secondary outcomes during the control and treatment phase (Cont')

N=20	Sequence A: Treat' First		Sequence B: Cont' First		Combine		p Value[a]	Effect Size
	Period 1	Period 2	Period 1	Period 2	Treatment	Control		
DTVP-3								
Eye-Hand Coordination	7.00 (13.91)	-1.00 (14.24)	3.60 (13.71)	18.50 (15.79)	12.75 (15.64)	1.30 (13.81)	0.009	0.65
BOT-2								
Manual Coordination	2.50 (5.10)	2.40 (4.55)	2.80 (7.79)	1.60 (5.21)	2.05 (5.04)	2.60 (6.21)	0.757	0.07
Manual Dexterity	1.00 (2.21)	1.30 (2.06)	1.10 (5.65)	1.90 (3.54)	1.45 (2.91)	1.20 (4.14)	0.839	0.05
UL Coordination	1.50 (3.89)	1.10 (3.51)	1.70 (3.23)	-0.30 (3.53)	0.60 (3.73)	1.40 (3.30)	0.371	0.21

a: Paired t-test

b: p-value > 0.50 = considered to have significant differences

Abbreviations: TVPS-4, Test of Visual Perceptual Skills – Fourth Edition; VMI-4, Beery-Buktenica Developmental Test of Visual-Motor Integration – Forth Edition; DTVP-3, Developmental Test of Visual Perception – Third Edition; BOT-2, Bruininks-Oseretsky Test of Motor Proficiency - Second Edition; UL, Upper Limb.

doi:10.6342/NTU202400330

Table 6. The program's acceptance of participants

Item	Rating Scores	
	Average	SD
Pediatric Motivation Questionnaire (PMQ) [a]	4.60	0.58
1. Do you feel happy when participating in the program?	4.65	0.64
2. Do you like this program?	4..61	0.86
3. Do you complete the program well?	4.63	0.71
4. Do you expect the next program?	4.35	1.22
5. Do you tried your best in the program?	4.80	0.46
6. Do you think these activities are important to you?	4.75	0.77
7. Do you think the activities are interesting?	4.58	0.94
8. Do you feel comfortable during the program?	4.58	0.82
9. Do you think the therapist cares about you?	4.56	0.88
10. Is the duration of this program suitable?	4.35	1.15
11. Do you think the program helps you?	4.76	0.66
12. Did the program improve your handwriting?	4.63	0.82

a: Average and standard deviation out of 5 total score were reported.

doi:10.6342/NTU202400330

Table 7. The program's satisfaction of caregivers

Item	Rating Scores	
	Average	SD
Client Satisfaction Questionnaire (CSQ) [a]	3.91	0.16
1. How is your appraisal of the program?	4.00	0.00
2. Do your children received a desired program?	3.95	0.22
3. Do the program meet your child's needs for handwriting?	3.85	0.37
4. Will you recommend the program to your friend's children with handwriting problems?	4.00	0.00
5. Do you satisfy with the total dosage of the program?	3.65	0.67
6. Do the program effectively overcome the handwriting problem of your child?	3.85	0.37
7. In overall, what is your satisfaction level to our program?	4.00	0.00
8. If you need further assistance in the future, would you participate in our program again?	3.95	0.22

a: Average and standard deviation out of 4 total score were reported.

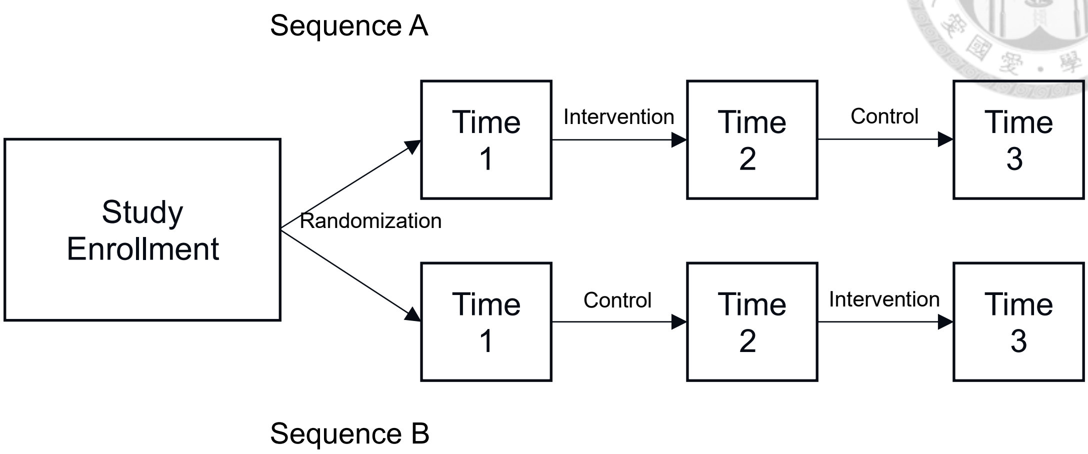
doi:10.6342/NTU202400330

Figure 1. Examples of the mnemonic

From left to right, from up to down	Global first, then local
	

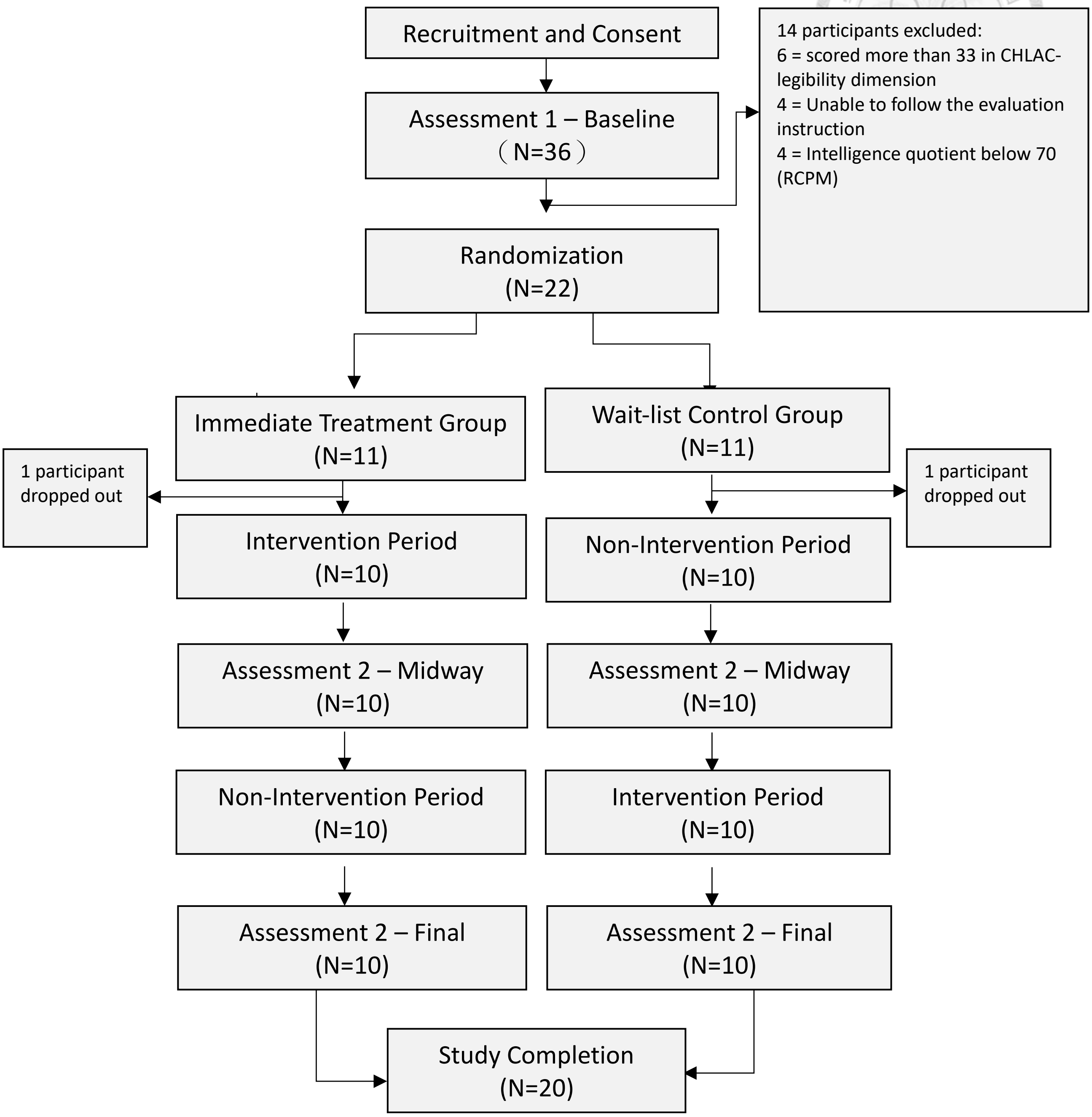
doi:10.6342/NTU202400330

Figure 2. Study design and measurement points



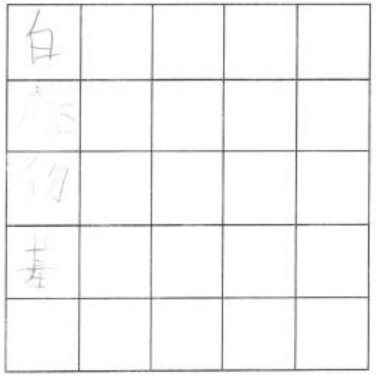
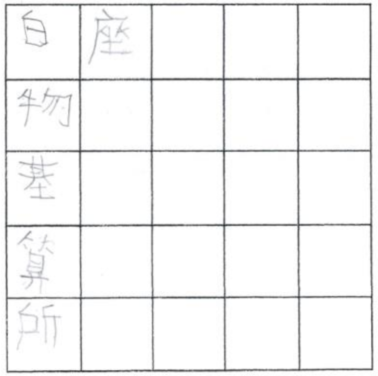
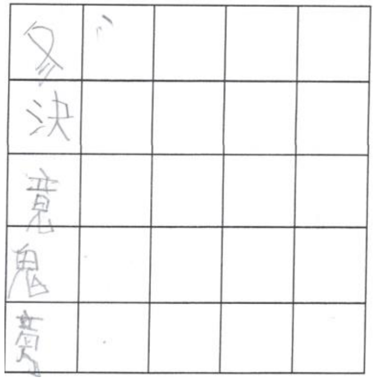
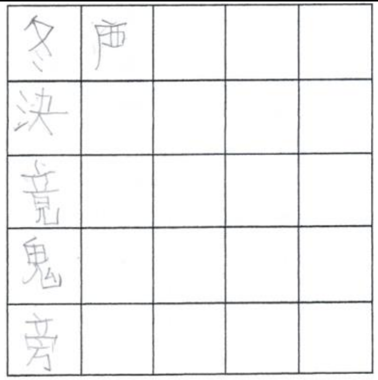
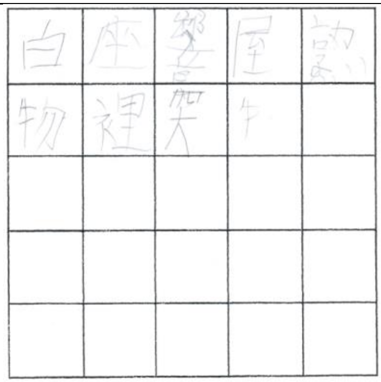
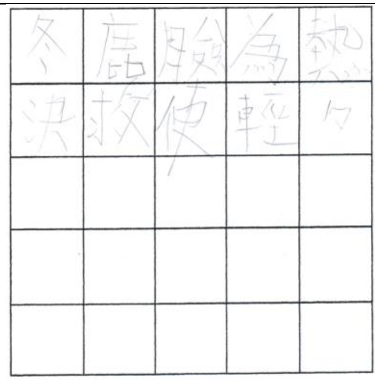
doi:10.6342/NTU202400330

Figure 3. Flow chart of the study



doi:10.6342/NTU202400330

Figure 4. The written word in BCBL test

	Near Copy		Far Copy	
	Before Treatment	After Treatment	Before Treatment	After Treatment
Participant A				
Participant B				

doi:10.6342/NTU202400330