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探討自閉症兒童中文書寫易讀性與國字處理能力

Chinese Handwriting Legibility and Character Processing Skills in Children with Autism Spectrum Disorder

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探討自閉症兒童中文書寫易讀性與國字處理能力

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本論文係翁芷琦（R11429001）於國立臺灣大學職能治療學系所完成之碩士學位論文，於民國 113 年 07 月 16 日經下列考試委員審查通過及口試及格，特此證明。

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摘要

前言

書寫是日常生活中一項基礎且重要的任務，特別是對於學齡兒童而言，然而罹患自閉症譜系障礙的孩童卻經常面臨書寫困難。其非典型的知覺處理模式，也被稱作中心聚合缺陷，可能對自閉症兒童的書寫易讀性表現產生更大的挑戰。不過，目前研究少有針對自閉症兒童中文易讀性的探討，也較缺乏考量中心聚合缺陷對其國字處理能力之影響。因此，本研究之研究問題如下：(1) 探討自閉症兒童與典型發展兒童之中文書寫易讀性差異， (2) 釐清自閉症與典型發展兒童對於國字處理模式的不同，(3) 了解自閉症兒童的書寫易讀性與國字處理能力間之相關性。

方法

本研究招募就讀小學一或二年級 30 名患有自閉症的兒童及 30 名典型發展兒童。受試者之書寫易讀性進行兩個面向的評估，包含字內及字間易讀性。此外，中心聚合缺陷對國字處理的影響透過國字處理測驗評量。資料分析使用 SPSS 22 進行，統計顯著性設定為 $a < 0.05$。統計方法上，本研究使用獨立 t 檢定，比較自閉症組與典型發展組之間的易讀性差異。另外，透過重複測量二因子變異數分析，確認國字處理測驗中，受試者組間及國字熟悉度之交互作用。最後，本研究透過皮爾森相關性檢定，探討自閉症兒童的書寫易讀性和國字處理之中心聚合缺陷間的關係。

結果

自閉症兒童在中文書寫易讀性的部件比例和部件位置（$p = 0.040$ 與 0.028），比典型發展兒童表現更差。當處理熟悉字時，自閉症與典型發展組間有相似的表現（$p = 0.324$），而自閉症兒童處理不熟悉的字時，表現出明顯聚焦於局部的模式

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（$p = 0.004$）。然而，本研究未發現自閉症兒童之中心聚合缺陷與其中文書寫易讀性之間的相關性。

討論

研究結果顯示，自閉症兒童在中文書寫的易讀性較差，特別是在字內部的部件結構方面。在處理不熟悉的字時，自閉症兒童會受到中心聚合缺陷的影響，但處理熟悉的字時，能夠與典型發展兒童呈現相似的處理模式，這突顯了熟悉程度，對於自閉症兒童視覺處理整體化的重要性。然而，本研究未能確定中心聚合缺陷與自閉症兒童書寫易讀性間的相關性，這項結果可能是由於未評估不熟悉字的易讀性所致。建議未來研究考量不熟悉字的易讀性評估，以更完整地了解中心聚合缺陷與自閉症兒童書寫易讀性的關係。

關鍵字: 自閉症譜系障礙、書寫易讀性、視覺處理、中心聚合缺陷

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Abstract

Background

Handwriting is a foundational and crucial task for school-aged children, but it often presents challenges for those with autism spectrum disorders (ASD). An atypical processing pattern identified as weak central coherence (WCC) potentially affects the legibility of handwriting. However, there is a lack of research focusing on the legibility of Chinese for children with ASD and the phenomena of WCC in processing Chinese characters. Thus, this research involves three specific objectives: (1) examining the difference in Chinese handwriting legibility between children with ASD and typical developing (TD), (2) investigating the phenomenon of WCC in the processing of recognizing Chinese characters and further exploring the interaction between groups and character familiarity, and (3) examining the relationship between handwriting legibility and WCC in children with ASD.

Methods

This study included 30 children with ASD and 30 TD children from first or second grade elementary school classes. Chinese handwriting legibility was evaluated including intra-character legibility and inter-character legibility. The Character Processing Test measured WCC effects on character recognition. Data were analyzed using SPSS 22, with statistical significance set at $\alpha < 0.05$. The independent t-test compared handwriting legibility between ASD and TD groups. Two-way repeated measures ANOVA analyzed group interactions with character familiarity. Pearson correlation examined relationships between handwriting legibility and WCC in children with ASD.

Results

The results of this study indicated significantly poorer Chinese handwriting legibility in children with ASD compared to TD children, particularly in intra-character radical

doi:10.6342/NTU202404599

proportion and spacing (p = 0.040 and 0.028). Children with ASD exhibited a local-focused processing pattern when handling unfamiliar characters (p = 0.004), while processing of familiar characters did not significantly differ between ASD and TD groups (p = 0.324). However, no significant correlation was observed between WCC and handwriting legibility in children with ASD.

Discussion

This study reveals that children with ASD exhibit poorer legibility in Chinese handwriting, particularly in intra-character radical aspects. Processing patterns for familiar characters show similarities between ASD and TD groups. In contrast, character processing in ASD is influenced by WCC, particularly evident during the processing of unfamiliar characters, highlighting the role of familiarity in facilitating holistic visual processing among children with ASD. However, the study did not establish a clear correlation between WCC and handwriting legibility in children with ASD, potentially due to the study's focus on familiar characters and the absence of assessment regarding unfamiliar characters. Future research should include assessments of unfamiliar characters to better understand the relationship between WCC and handwriting legibility in children with ASD.

Keywords: autism spectrum disorders, handwriting legibility, visual processing, weak central coherence

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Table of Contents

doi:10.6342/NTU202404599

doi:10.6342/NTU202404599

List of Tables and Figures

doi:10.6342/NTU202404599

Chapter 1 Introduction

1.1. Autism Spectrum Disorder (ASD)

ASD is a neurodevelopmental disorder that results in complicated developmental problems in individuals (Handle et al., 2022; Talantseva et al., 2023). According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), this disorder is characterized by impaired communication, poor social interaction, and restricted or repetitive patterns of behaviors (American Psychiatric Association & Association, 2013). Recent statistical finding indicates that approximately 1.18% of children are affected by ASD, and the prevalence of it is on the rise (Talantseva et al., 2023). Notably, the highest prevalence of this disorder is among children aged 6 to 12 (Talantseva et al., 2023). The care of children with ASD imposes substantial financial burdens on families and society, resulting in a significant public health issue (Salari et al., 2022). Therefore, early and effective intervention for these children is essential to benefit their outcomes and burdens of society (Salari et al., 2022).

1.2. Handwriting Performance in Children with ASD

1.2.1. Importance of Handwriting

Handwriting is the fundamental ability in daily living to transfer spoken language into graphic communication (Feder & Majnemer, 2007; Kushki et al., 2011; Rosenblum et al., 2016). In elementary school, students regularly dedicate 30 % to 60 % of their time to various handwriting tasks such as doing homework, taking notes, and completing tests (Rosenblum et al., 2016; Rosenblum et al., 2019). This ability is recognized as the activities and participation domains of health by the International Classification of Functioning, Disability, and Health—Children and Youth Version (Kushki et al., 2011;

doi:10.6342/NTU202404599

Rosenblum et al., 2016). Besides, it is also important for children to develop and refine their perception and motor skills (Rosenblum et al., 2016; Van den Bos et al., 2022).

Poor handwriting performance could affect the academic performance and mental health of children. As studies report, poor handwriting ability leads to poorer grades and lower academic achievement (Fuentes et al., 2009; Hellinckx et al., 2013; Kushki et al., 2011; Van den Bos et al., 2022). In addition, handwriting difficulties negatively impact children's psychosocial health. Children who encounter difficulties in handwriting are prone to experience poor social interaction, more frustration, and low self-esteem (Fuentes et al., 2009; Hellinckx et al., 2013; Kushki et al., 2011).

1.2.2. Handwriting Legibility

Creating a high-quality handwriting product is a complex process that involves various abilities from intention to execution of writing. During the intention stage, the brain processes the visual image of the target surface to develop an appropriate movement plan. Individuals are required to recognize the visual input, organize the spatial relationships of characters, and determine where to write based on their visual perceptual abilities (Rosenblum et al., 2003). Then, the plan of action is formulated by motor planning, including the sequence, direction, position, and force of each stroke (Verma & Lahiri, 2021). Afterward, the execution stage implies physically producing the characters on the writing surface, based on the previous preparation in the intention stage. To accurately execute the motor plan, continuous visual processing, and coordinative movement are necessary. As strokes are written on the surface, individuals receive a new visual stimulus from the written product. Based on the feedback of visual information, the position of each stroke could be adjusted through the visuo-spatial ability. By integrating perception and movement, individuals can efficiently create clear and readable handwriting products (Rosenblum et al., 2019; Verma & Lahiri, 2021). In summary,

doi:10.6342/NTU202404599

various abilities are involved in the process of handwriting. Any deficiencies in these fundamental abilities could impact the development and maturation of handwriting performance (Kushki et al., 2011).

To determine the quality of written products, legibility is a crucial standard to be assessed, which represents the clarity and ease of identifying written characters (Handle et al., 2022; Rosenblum et al., 2016). The legibility of handwriting is a main criterion to identify children with handwriting difficulty (Hammerschmidt & Sudsawad, 2004). Moreover, legibility is one of the vital aspects of handwriting that teachers prioritize for students for students who are in the initial phase of learning handwriting (Lee et al., 2016). As students begin to learn formal handwriting in Chinese characters, they often practice by repeatedly copying each character (McBride-Chang et al., 2011). The legibility of this phase is considered the foundation of other handwriting skills for students, such as writing speed, reading words, the content of essays, and other handwriting-related tasks (Rosenblum et al., 2019; Van den Bos et al., 2022). The study found that fluency and automaticity of handwriting are mainly developed before children reach fourth grade (Rosenblum et al., 2019). Thus, establishing a solid foundation of legible handwriting for students in lower grades is necessary, or their development of advanced writing-related skills may be impeded.

1.2.3. Handwriting Legibility in Children with ASD: The Alphabetic Language

Children with ASD are indicated to present overall poorer legibility compared to typical developing (TD) children (Hellinckx et al., 2013; Kushki et al., 2011; Rosenblum et al., 2019; Verma & Lahiri, 2021). Among children who receive occupational therapy, 86% of those with ASD experience handwriting dysfunction due to atypical visual processing patterns and poor visual-motor integration (VMI) skills (Frith & Mira, 1992;

doi:10.6342/NTU202404599

Kushki et al., 2011; Li-Tsang et al., 2018). Representative problems of legibility in children with ASD can be categorized into letter level and sentence level.

The legibility on the letter level indicates the neatness and readability within a single letter. Assessments for the legibility of written letters generally consider the size, form, space, and alignment of handwriting products (Handle et al., 2022). The size of the letter can be determined by the height and width of written characters (Van den Bos et al., 2022). According to previous studies, children with ASD write letters of significantly larger size than TD children (Hellinckx et al., 2013; Johnson et al., 2013). Evaluated through a task involving the writing of five sentences within a frame, the letter sizes were assessed on a scale from 0 (suitable) to 2 (large) points. The findings revealed that letters written by children with ASD scored 0.7 points, which was significantly different from TD children who received only 0.2 points (Hellinckx et al., 2013). In addition, the form domain refers to the internal structure of letters such as the shape and closure (Grace et al., 2017; Van den Bos et al., 2022). The letter form written by individuals with ASD is prone to be inappropriate. Measured by the Minnesota Handwriting Assessment (MHA), children with ASD were more likely to write letters with inaccurate characteristics compared to TD children, such as replacing a curved segment with a sharp one (Fuentes et al., 2009). The domain of space is defined by the position of each letter on the baseline (Van den Bos et al., 2022). However, Fuentes et al. (2009) conducted the MAH and suggested that there was no significant difference in the spacing of letters between children with ASD and TD. Finally, the alignment of the letter can be identified by the degree of slant, which is measured by the angle between the vertical axis and the stroke line (Johnson et al., 2013). In the study by Johnson et al. (2013), participants were enrolled to write four cursive "l"s. It was found that the alignment of characters did not significantly differ

doi:10.6342/NTU202404599

between children with ASD and TD, which may be attributed to the cursive font of this test and the single unit of English letters.

The legibility on the sentence level means that the clarity of reading is influenced by the relative relationship between letters and words, which could be characterized by size consistency, relative space between letters, and sentence alignment. First, the consistency of size describes the degree of variation in the size of letters within a sentence (Rosenblum et al., 2016). Children with ASD have been proven to write letters with lower consistency of size compared to TD (Grace et al., 2017; Hellinckx et al., 2013; Rosenblum et al., 2016). Additionally, the relative space of written letters is another issue of legibility of sentences for children with ASD, which is measured by the interval between letters and words. Rosenblum et al. (2016) used the Hebrew Handwriting Evaluation to measure the legibility of a copied paragraph, and the findings indicated that children with ASD had wider intervals between words compared to TD children. Another research conducted the copying test in repeated English sentences (Johnson et al., 2013). This research found that the uniformity of spacing between words showed shorter intervals and larger variability for children with ASD than in TD. These two studies confirm the inappropriate spacing arrangement between words in children with ASD. Finally, the inter-word alignment represents the straightness of sentences (Rosenblum et al., 2016). The research confirmed that the sentence written by children with ASD deviated more severely from the straight line compared to TD children (Hellinckx et al., 2013; Johnson et al., 2012; Rosenblum et al., 2016).

In conclusion, children with ASD do face difficulty in handwriting legibility, which can be classified as letter level and sentence level. To completely understand the legibility of handwriting, analyzing these levels is essential. This investigation can enhance a more complete comprehension of handwriting legibility among children with ASD, which

doi:10.6342/NTU202404599

could facilitate the clarification of impact factors and the development of further intervention. Recently, many studies have discussed the handwriting problems of ASD children in English, Dutch, and other alphabetic language, but few of them have specifically determined the legibility of Chinese characters. However, the performance of handwriting in alphabetic letters or words might demonstrate different perspectives from that of logographic Chinese characters (Li-Tsang et al., 2018; Perez, 2004).

1.2.4. Difference between Alphabetic and Logographic Languages

Languages can be divided into two main writing systems —— the alphabetic language and the logographic language (Handel, 2015; Sampson, 1985). The alphabetic language depends on the connection between letters and the phonemes (Li-Tsang et al., 2018; Perez, 2004). Conversely, the logographic language is created based on the morphological structure and the meaning of the characters, such as Chinese, which is the most commonly used logographic language (Perez, 2004; Qu & Damian, 2017; 陳奕全等人，2009). Considering the writing characteristics of these two language systems, Chinese features a more complex intra-character structure and more diversified starting strokes between characters than alphabetic language.

In comparison to the single and simple units of the typical alphabetic language, Chinese characters are especially complicated (Li-Tsang et al., 2018; Lee, 2016; 陳學志等人，2011). The characters in Chinese are structured hierarchically, beginning with individual strokes, then combining into radicals, and ultimately forming complete characters. The basic unit of the Chinese characters is radical which defines a structure repeatedly appearing in different characters and comprising certain strokes (洪儷瑜，1997; 陳學志等人，2011). According to different spatial relations of radicals, shapes of Chinese characters can be classified into five basic types, including horizontal, vertical, P-shaped, L-shaped, and enclosed characters (陳學志等人，2011; 葉素玲等人，1999).

doi:10.6342/NTU202404599

When writing in Chinese, individuals must adjust to the complicated spatial and proportional relationships of each component (Lee et al., 2016). Thus, the ability of visual perception, spatial recognition, and integration of logographic structure requires to be more proficient when writing Chinese characters (Cahill, 2009; McBride-Chang et al., 2011; Li-Tsang et al., 2018; 洪儷瑜, 1997).

In addition to a single character, there are some differences between languages on the inter-character level. Alphabetic languages emphasize the fluency and continuity of the written product, which could be easily written in cursive (Fuentes et al., 2009; Lee, 2016; Li-Tsang et al., 2018). The arrangement of alphabetic languages generally is written horizontally with a single left-right direction (Li-Tsang et al., 2018). Contrarily, Chinese handwriting is a complex structure task with irregular requirements of starting strokes between characters. When writing in Chinese, it is instructed to initiate each character from a noticeably different position with different directions of strokes (Lee et al., 2016). To carefully plan the placement of characters within a sentence before beginning each stroke according to the alternating position and sequence of writing direction, skilled visual-spatial ability is necessary (Lee et al., 2016).

In conclusion, Chinese characters are distinguished by their complex structure and the various requirements of each initiating stroke between characters. Owing to these features of the Chinese writing system, it is indispensable to conduct an assessment specifically focused on Chinese handwriting. With the advanced requirement of visual perception, handwriting in Chinese is supposed to be more challenging for children with ASD than in other languages.

1.2.5. Handwriting Legibility in Children with ASD: The Logographic Language, Chinese

doi:10.6342/NTU202404599

Numerous studies have examined the handwriting performance of children with ASD in the alphabetic language; however, the research on handwriting in Chinese for children with ASD is limited (Handle et al., 2022). Following the literature review, there are only two available studies that examine Chinese handwriting products for children with ASD.

One of the studies investigating Chinese handwriting performance for ASD children was conducted by Li-Tsang et al. (2018), who recruited 15 ASD and 174 TD aged 12 to 18 years old. This study aimed to understand the handwriting accuracy and kinematic process of children with ASD. There were no significant differences in the accuracy between ASD and TD when writing in Chinese. For the kinematic processes, adolescents with ASD presented longer on-paper and in-air time, slower writing speed, and lower consistency of speed compared to the TD group. This research provided evidence of handwriting performance in Chinese characters for adolescents with ASD, assessing their accuracy and kinematic process of handwriting.

Another study in Chinese handwriting analyzes the performance of school-age children with ASD (陳品華，2018). It involved 34 children with ASD between the ages of 8 to 12 years old in this study. The Tseng Handwriting Problem Checklist (THPC) and the Battery of the Chinese of Pupils (BCP) were measured to explore the handwriting performance of children with ASD. To assess the legibility of Chinese handwriting, the THPC, a quality questionnaire, was designed to screen children with difficulties in handwriting, including issues with handwriting construction, sequencing, behavior, accuracy, motor, and directionality (葉素玲等人，1993). According to teachers' reports, the study revealed that numerous children with ASD showed inadequate intra-character legibility. There were 44%-71% of them usually face difficulty in modifying the relative placement or adjusting the appropriate size of radicals within a character. Additionally,

doi:10.6342/NTU202404599

children with ASD also experiment with defects in the inter-character legibility in Chinese. There were 56% of children with ASD frequently experienced inconsistency in character sizes. 62% of them difficulty maintained suitable spacing between characters, and failed to follow appropriate alignment while writing. For the BCP, there are 76% and 62% of ASD writing with poor accuracy in copying and transcribing tasks. Besides, 76% of them wrote slower than the average of the norm. This research confirmed the handwriting problems for children with ASD in legibility, accuracy, and speed. However, this study evaluated the legibility of children with ASD by a questionnaire without a performance-based assessment. In addition, there is still insufficient evaluation to clarify handwriting legibility in lower-grade students, who are at the early stage of learning handwriting.

These two studies provide some insight into the performance of Chinese handwriting among children with ASD. Individuals with ASD experience diverse handwriting problems such as slow writing speed in school-age children to adolescents, and reduced accuracy in school-age children. For legibility, research indicated that children with ASD in grades 3-6 present illegible handwriting products. Nevertheless, it remains unknown about the performance-based evaluation of Chinese legibility in lower-graded children with ASD.

1.3. Weak Central Coherence (WCC)

1.3.1. Handwriting Performance and WCC

Children with ASD often present multiple symptoms, some of which may arise from their unique processing patterns (Horlin et al., 2016). Abnormal visual processing is one of the notable features of ASD that has been investigated in previous studies. In general, typical individuals can realize the entirety of the visual stimulation without operating each specific detail (Fuentes et al., 2009). This ability enables typical individuals to understand

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coherent information efficiently and comprehensively (Bojda et al., 2021). However, children with ASD tend to focus on detailed features of visual stimulation without considering the whole structure (Fuentes et al., 2009; Kushki et al., 2011; Li-Tsang et al., 2018). This impairment of visual processing performance might hinder their identification of processing-related activities.

Writing in Chinese necessitates the visual processing skill to deal with the intricate composition of characters; however, children with ASD seem to process information with an atypical pattern which may influence their handwriting performance. According to clinical observation, children with ASD may struggle to form whole characters while handwriting. A child with ASD exhibited poor legibility when writing each individual character within designated frames. However, when attempting to write more than one character inside a frame, the legibility of each character significantly worsened. It is interesting to note that rather than writing characters as a helictical symbol, the child with ASD appears to write each radical of characters in a disorganized manner, lacking a clear and cohesive structure. This phenomenon might be attributed to the difficulty in holistically processing for children with ASD, which is called Weak Central Coherence (WCC).

1.3.2. Overview of WCC

The concept of WCC is used to explain the difficulty in perceiving and integrating separate elements into a complete and holistic symbol (Baixauli et al., 2021; Neufeld et al., 2020; Horlin et al., 2016). As a representative characteristic of children with ASD, WCC impairs ASD children to understand the connotation of the whole structure or context (Horlin et al., 2016). Instead of perceiving the global feature, individuals with ASD tend to focus on local details and neglect global information, which leads to a bias toward local (Bojda et al., 2021; Li-Tsang et al., 2018; Van der Hallen et al., 2015). For

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instance, TD individuals identify the forest; however, the population of ASD is prone to see trees (Fuentes et al., 2009). When forced to process global stimuli, children with ASD face difficulty in ignoring irrelated details and are more susceptible to the influence of details compared to TD children (Mottron & Soulières, 2013). Accordingly, children with ASD demonstrate slower global processing speed compared to local processing (Neufeld et al., 2020). These impairments result in the imbalance of local and global processing in children with ASD.

In contrast to WCC, central coherence is the ability to incorporate small stimuli into a complete and structured symbol (Bojda et al., 2021; Hatfield et al., 2019). This ability is crucial for recognizing and interacting with varied environmental information by identifying the consistency of fragmental data and merging them into a structured unit for understanding (Van der Hallen et al., 2015). Generally, people are inclined to notice the holistic information before focusing on specific details, which demonstrates the maturation of central coherence called the global precedence effect (Kumar, 2013; Mills, 2016). The findings from Navon (1997) first revealed this effect, which is attributed to the global advantage effect and the global interference effect (Primativo & Arduino, 2023). The global advantage effect suggests that the reaction speed and accuracy of global information are better than processing local information (Primativo & Arduino, 2023). With the automatic filtering of irrelevant details and the combination of local information, individuals can identify a global stimulus within 150 milliseconds (Lefebvre & Beaucousin, 2023; Mills, 2016). While, the global interference effect is characterized by the influence of global information when individuals process local features (Primativo & Arduino, 2023).

Typically, the ability of central coherence develops through the growth of brains and experience from the environment, and matures at approximately 6 years old (Lefebvre &

doi:10.6342/NTU202404599

Beaucousin, 2023). Nevertheless, children with ASD often experience impairments in central coherence, which could lead to difficulties in various perceptual tasks due to an imbalance in local-global processing.

1.3.3. WCC in Children with ASD

The phenomenon of WCC can be observed in different perceptual processing domains including the visual, spatial, and auditory perceptions (Bojda et al., 2021; Hatfield et al., 2019). Several studies have put effort into the influence of WCC on ASD children. The severity of WCC can be measured by comparing the performance in processing between global and local information (Mottron & Soulières, 2013). One of the classic assessments for WCC is a local-global task with the Navon stimuli, which are hierarchical compound stimuli with a large object formed by small items (Mottron & Soulières, 2013; Navon, 1977). Based on the Navon stimuli task, children with ASD present lower accuracy and slower response time in processing global features than TD children (Muth et al., 2014). It suggests that the ASD do not prioritize processing global information as TD individuals, which can be evidence that WCC impacts the processing of visual information in ASD.

WCC is a theory to describes the global-local imbalance phenomenon at the perceptual level; therefore, whether its impact on specific cognitive dimensions needs to be defined separately (Bojda et al., 2021). Visual information, such as faces, can be represented as a symbol with both global and local features and has been reported to be processed holistically under typical conditions (Chen et al., 2013; Mills, 2016). Previous studies have indicated that faces, which are frequently investigated in ASD research, are affected by WCC (López et al., 2004; Primativo & Arduino, 2023). Interestingly, this

doi:10.6342/NTU202404599

local-focused phenomenon has been found more pronounced in unfamiliar conditions but less so in familiar conditions (Chung & Son, 2020).

Recently, Chen et al (2013) found character identification processing presents a similar holistic processing phenomenon as facial recognition. To verify the processing pattern of Chinese characters, the study was based on an electrophysiological experiment for 16 undergraduate students. In this study, participants were instructed to identify whether the upper portions of two characters were identical with each character divided into upper and lower halves by a red line. The results revealed a decrease of the potential called early potential (P1) when the upper portions of characters match, which indicates the brain recognized two stimuli are the same. This situation, that brain responds to the same stimulus and results in a decrease of electrical frequency changes, is called the adaptation effect. However, when the upper halves were the same, the brain exhibited a greater potential change when the lower halves were different compared to when they were identical. This finding implied that due to the holistic process of characters, participants remained affected by the lower portions of characters, even when their attention was directed at the upper parts. In addition, it is noteworthy that these effects were observed in characters without misaligned or pseudo. This study established the processing pattern of Chinese characters in TD undergraduate students. Still, there is a gap in understanding the character processing pattern in school-age children with ASD.

To summarize, Chinese characters are processed as global symbols in typical individuals (Chen et al., 2013). However, the effect of WCC on the holistic processing of Chinese characters in children with ASD remains unknown. Thus, a study to clarify the influence of WCC on character processing in children with ASD is warranted. Additionally, as previously noted, handwriting tasks, particularly in Chinese, involve significant visual skills. The impaired visual processing pattern with a local bias due to

doi:10.6342/NTU202404599

WCC may affect an individual's ability to perceive and replicate the structure of characters during handwriting (Li-Tsang et al., 2018). Nevertheless, it remains unclear whether the processing pattern of characters is related to handwriting legibility.

1.4. Purpose of this Study

Based on previous research, this study aims to investigate handwriting legibility and the phenomenon of WCC on character processing in children diagnosed with ASD. The research questions include three objectives:

(1) Examining the difference in Chinese handwriting legibility between children with ASD and TD: legibility of intra-character and inter-character

(2) Investigating the phenomenon of WCC in the processing of recognizing Chinese characters and further exploring the interaction between groups and character familiarity

(3) Confirming the relationship between handwriting legibility and the WCC on character processing in children with ASD

doi:10.6342/NTU202404599

Chapter 2 Methods

2.1. Participants

This study enrolled two groups, one comprising 30 children diagnosed with ASD and another consisting of 30 TD children. Children with ASD were recruited from medical institutions and related associations, and the TD children were recruited from elementary schools in the north of Taiwan.

The sample size of participants was estimated according to previous studies using G*power 3.1. For purpose one, previous studies found that school-age children with ASD showed significantly poorer handwriting legibility in the alphabetic language compared to TD children with Cohen's d = 0.85-1.27 (Fuentes et al., 2009; Hellinckx et al., 2013; Rosenblum et al., 2016). With the large effect size, α = 0.05, and power = 0.8, the suggested sample size calculated by G*power 3.1 is 42 individuals, comprised of 21 individuals in each group. In addition, for the second purpose, the interaction between groups (ASD and TD groups) and familiarities of character is suspected with medium effect size. Combined with α = 0.05 and power = 0.8, a total sample size of 52 is recommended by G*power 3.1. Last, for the purpose three, previous studies confirmed significant relations between handwriting legibility and visual-related skills, such as visual perception and VMI skills, with low to medium effect size (Hellinckx et al., 2013; Van den Bos et al., 2022). The processing pattern of character is hypothesized to be more related to handwriting performance with at least medium effect size. Hence, based on G*power 3.1 using a medium effect size, α = 0.05, and power = 0.8, it is determined that 23 participants per group are adequate. Accordingly, considering the potential exclusivity of participants, a total of 60 children, consisting of 30 children in each group, were recruited for this study.

doi:10.6342/NTU202404599

Regarding the participant selection of the ASD group, the inclusion criteria was as follows: (1) diagnosed with ASD, (2) scored equal to or higher than 7 points of the Autism Behavior Checklist-Taiwan Version (ABC-T), and (3) studying in the first or second grade of elementary school. The exclusion criteria for the ASD group involved (1) other diagnoses affecting the physical ability of upper limbs (e.g. cerebral palsy), (2) intelligence score of the Raven's Colored Progressive Matrices (RCPM) equal to or lower than the 5^{th} percentile rank, or (3) physiological or behavioral problems that prevent the completion of assessments in this study.

While, the inclusion criteria for the TD group included: (1) with the score of the ABC-T less than 7 points, and (2) studying in the first or second grade of elementary school. Children were excluded from the TD group as follows: (1) diagnosed with any neurodevelopmental disorders, (2) other diagnoses affecting the physical ability of the upper limbs, (3) the RCPM scored equal to or lower than the 5^{th} percentile rank, or (4) physiological or behavioral problems that prevent the completion of assessments in this study.

2.2. Procedure

The study has been approved by the National Taiwan University Hospital Research Ethics Committee. Posters were distributed to medical institutions, associations, and elementary schools in northern Taiwan to recruit participants for the research. Then, researchers connected with individuals willing to participate in this study and obtained their informed consent before gathering data.

The data collection involved the screening and assessment stages. First, the ABC-T and the RCPM were applied to screen for the recruiting criteria. The ABC-T was used to confirm the characteristics of ASD, and the RCPM was used for intelligence screening.

doi:10.6342/NTU202404599

Simultaneously, their caregivers spent around 10 minutes on the ABC-T. Next, the assessing stage enrolled the participants who met the recruiting criteria of this study. They underwent a 55-minute assessment to complete the remaining evaluations of handwriting legibility and character processing. The entire experiment took 80 minutes and was conducted at the Department of Occupational Therapy of the National Taiwan University.

2.3. Measurements

2.3.1. Screening Tools

Before the experiment, a screening process was conducted to filter eligible participants based on inclusion and exclusion criteria. This process involved using the ABC-T and the RCPM to assess the features of participants.

ABC-T is a self-report measure for caregivers, screening for potential ASD individuals aged 3 to 15 years old (Krug et al., 1980). There are 47 items in this checklist including the sensory, relating, body and object use, language, social, and self-help subtests. Caregivers or teachers evaluate according to whether each behavior describing items occurred or not (1 or 0 points) in approximately 10 minutes. A total score equal to or exceeding 7 points indicates the possibility of ASD. The ABC-T has been validated with acceptable to excellent internal consistency reliabilities (Cronbach's α = 0.95 for parents, 0.96 for teachers, and 0.75-0.87 for subscales), good test-retest reliability (r = 0.89), content validity, and differential validity with ASD as the criterion (黃君瑜等人，2013).

RCPM is one version of Raven's Progressive Matrices which is designed to screen the general cognition by reasoning the relationship of evidence without language or formal education (Raven, 1938). The content of RCPM especially focuses on the intelligence of children between 6 to 8 years old. 36 items are present in this assessment,

doi:10.6342/NTU202404599

and individuals are required to choose one pattern-matching option to fit in the missing part for each item. It takes 20 minutes to finish the task. Individuals scored below the 5th percentile rank are screened out as intelligence impaired. Regarding the psychometric properties, RCPM exhibits good to excellent internal consistency reliabilities (Cronbach's α = 0.86-0.92), acceptable test-retest reliability (r = 0.73), and demonstrates criterion-related validity through its correlation with academic performance (陳榮華等人，2006).

2.3.2. Handwriting Legibility Assessments

The legibility of handwriting in Chinese comprises both intra-character legibility and inter-character legibility. To examine these legibility domains, this study incorporated two assessments: the Chinese Handwriting Legibility Assessment for Children (CHLAC) and the Sentence Copy Test.

CHLAC is an assessment to evaluate the intra-character legibility of Chinese handwriting for students in first or second grade. Participants are directed to replicate each Chinese character within 2 cm × 2 cm in a square frame on examination sheets. The 10 characters in this assessment are chosen based on five character structures in three main versions of textbooks for lower-grade students, including vertical (花要), horizontal (的到), P-shaped (有原), L-shaped (這起), and enclosed (雨開). The completion of CHLAC takes approximately 10 minutes. Evaluating the intra-character legibility, there are five domains: size (the dimension of the entire character), position (the placement of a character in the frame), orientation (the slop of character), radical proportion (proportions of radicals within the character), and radical space (the spatial relationship between radicals). Each item can be recorded as passed (1 point) or wrong (0 point) for each character. The CHLAC exhibits excellent intra-rater reliability (r = 0.90-0.99), good to excellent inter-rater reliability (r = 0.82-0.95), and acceptable test-retest reliability (r = 0.52-0.83). The validities of this tool were also examined including the content validity,

doi:10.6342/NTU202404599

the criterion-related validity with the Chinese Handwriting Evaluation Form, and the discriminate validity of children with handwriting difficulty (王姝婷等人，2024).

The Sentence Copying Test is applied to measure the inter-character legibility of Chinese characters. The content of this test is according to the coherency subtest of the Tablet-based Evaluation for Chinese Handwriting performance (TECH) (黃文豐，2023). Participants are instructed to copy a sentence within a rectangular frame without any lines or marks inside on sheets. The sentence is comprised of 10 Chinese characters with five structures, selected from the textbooks of first and second grade students in elementary school. This test could be completed within 10 minutes. Assessing domains of the Sentence Copying Test include size control, space control, and alignment control. The size control defines the consistency of character sizes within a sentence, which is determined by the variation in the size of each character. Additionally, space control means the consistency of intervals between characters. The variance of intervals is recorded in this test to clarify the space control domain. The last domain, alignment control, is the deviation from the baseline of the sentence. It is examined by calculating the variation of distances that characters deviate from the baseline. To measure these results, the sheets of written sentences are scanned into a computer, and then analyzed by the TECH system.

2.3.3. Character Processing Test for WCC

The Character Processing Test was developed to assess the processing pattern of Chinese characters, modified from the experiment designed by Chen et al. (2013). During the test, participants are asked to identify whether two paired characters are identical or different. It requires about 30 minutes to complete the test. The accuracy and the reaction time (RT) of each response in this test are collected. To clarify the processing difference on a holistic or broken structure of characters, outcomes of aligned and misaligned trials

doi:10.6342/NTU202404599

are subtracted. A smaller difference in RTs between aligned and misaligned trials suggests that the impact of the WCC on character processing is more significant.

Materials of the test involve the computer and external keyboard. During the test, the participant is requested to sit in front of a computer at 60 cm and enter responses using two buttons (identical/different) on the external keyboard. The stimuli of trials are displayed on a white background on the screen. Each trial in this test is composed of two characters spaced 4 cm (visual angle of 3.81°) apart as a pair. In addition, each character is in black with BiauKai font (Traditional Chinese) and is approximately 2 cm × 2 cm in size (visual angle of 1.91°).

The main conditions of the test were designed with alignment (aligned/misaligned) and familiarity of character (actual/pseudo). The alignment indicated the wholeness of the characters. Aligned characters were presented without displacement; on the contrary, the upper halves of the misaligned character were slightly moved by 0.8 cm (visual angle of 0.76°). It was to confirm whether there were differences due to the destroyed entirety of Chinese characters. For the familiarity of character, there were two types of characters, actual and pseudo characters, included in this condition. By default, the actual characters were selected to be recognized by children studying first or second grade in elementary school. The pseudo characters were designed to simulate the situation in children processing unfamiliar characters.

In the test, there were 20 Chinese characters chosen to form 40 basic pairs of characters (10 pairs of characters × 2 disparities of difference × 2 responses), and 20 pseudo characters designed according to these actual characters. The actual Chinese characters were selected according to the criteria: (1) vertical structure, which is the majority structure of Chinese characters (陳學志等人，2011) and in line with a previous study (Chen et al., 2013), (2) involved in the textbooks for the first or second grades of

doi:10.6342/NTU202404599

elementary school, (3) included in at least one out of the three common versions of textbooks in Taiwan (康軒, 翰林, and 南一), (4) with high-frequency (frequency of appearance > 196) (陳茹玲等人，2010), (5) with similar radicals' proportions of two paired characters, (6) the strokes' number of paired characters differing ≤ 2 strokes, and (7) the average stroke number of all characters is 9.8 (the average number of strokes in textbooks for lower-grade students in three versions) ± 1 strokes. While, the design of pseudo characters follows the criteria of (1) comprised of radicals from actual characters, (2) arranged radicals according to the principle of composition, (3) with similar radicals' proportions of two paired characters, and (4) the strokes' number of paired characters differing ≤ 2 strokes. Besides, there are an additional 4 actual characters and 4 pseudo characters involved for the practice section in the test. All of the characters selected for this test are listed in Appendix A.

Additionally, to diversify the test to simulate the life context, there were other two considerations for the test design, including the placement (right-left/up-down) and disparity of difference (total/partial). The placement of trials described the spatial relationship of two paired characters on the screen as right-left or up-down. This variation was to balance the interference from reading orders in different directions. Finally, the disparity of difference was defined as the number of halves that are different between two paired characters. A total difference trial referred to all halves of paired characters was different, while a trial with partial difference meant that the difference only appeared in the upper or lower halves between paired characters. It is uncertain whether the amount of difference affects the processing of discrimination; therefore, the multiformity of difference helps to average this impact.

The procedure of the Character Processing Test consists of the basal reaction section, the practical section, and the experimental section (Appendix B). The test begins with the

doi:10.6342/NTU202404599

basal reaction section to measure the individual baseline of reaction time. During each trial of this section, a cross sized 1 × 1 (cm) is presented on the center of the screen. After a random duration of 1000-3000 ms, the cross is replaced by a red dot with a 2 cm diameter. Participants are guided, "When the red dot appears on the screen, please press this button as fast as possible," to complete 10 trials of this section. Subsequently, the practical section contains 32 trials (4 pairs of characters × 2 alignments × 2 responses × 2 placements) to confirm that participants clearly understand the requirements of the test. In this section, participants are asked, "Are the following two shapes identical or different" and instructed, "Please answer by pressing the left button on the keyboard when the answer is identical and pressing the right button when the answer is different". To ensure the comprehension of requirements and familiarity of the procedure for the participant, the experimenter is allowed to provide the participant with feedback and answers to practical trials. Ultimately, the experimental section is operated to assess participants' processing patterns of characters. There are 320 trials (40 basic pairs of characters × 2 alignments × 2 familiarities × 2 placements) for this section. Trials with different placements (right-left/up-down) are divided into two blocks separately, which forms four blocks in total. At the start of each block, the instruction of "Please identify whether the following two characters are identical or different, and answer as quickly and correctly as possible" is reiterated. These blocks are completed in random order with about a 30-second break time every 40 trials and 2 minutes between blocks. Then, to avoid interference between trials, the center of the screen is prompted by a cross as the gaze point for 1000 ms before each trial starts.

RTs in the Character Processing Test are converted through three steps for the outcomes analysis. First, RTs with incorrect answers are eliminated as atypical responses. Next, to reduce the impact of individual differences, each RT of experimental trials is

doi:10.6342/NTU202404599

divided by the mean RT of each participant's basal reaction trials. In the last step of conversion, the average and the standard deviation (SD) of normalized RTs are calculated separately for the aligned and misaligned trials. Then, RTs that are greater or less than 1.5 SDs of the average are trimmed as outliers to collect consistent performance. After this conversion, the mean RT of aligned trials was subtracted from that of misaligned trials, which indicates the difference in processing between the two types of trials. Typically, because of the trend to process whole characters, the aligned trials must be reacted faster than misaligned ones. The small difference means that the participant produces a similar processing pattern for structurally complete and incomplete characters, which can be considered a more localized trend and infer the phenomenon of WCC on character processing.

2.3.4. Developmental Test of Visual Perception, Third Edition (DTVP-3)

DTVP-3 is the test to assess the visual perception and VMI skills of individuals aged between 4 to 12 years old (Hammill et al., 2014). It is composed of five subtests including eye-hand coordination, copying, figure-ground, visual closure, and form constancy. The subtest of eye-hand coordination was used for this research to control the motor ability of participants. In this subtest, participants are required to draw lines within narrow paths. It is scored by the distance and times of the excess in each trial. This subtest could be finished within 5 minutes. The psychometrics of DTVP-3 are considered good to excellent internal consistency (Cronbach's α = 0.80-0.95), and it shows convergent validity as highly correlated with the Visual-Motor Integration Test, sixth edition (Brown, 2016).

2.4. Statistical Analysis

doi:10.6342/NTU202404599

The statistical analyses were conducted using SPSS 22 with a significance level set at $a < 0.05$. Outliers were identified based on scores greater than three interquartile range (IQR) distances above the third quartile (Q3 + 3IQR) or below the first quartile (Q1 - 3IQR) of continuous variables. If an individual scored such a distance away in only one of the assessments, that individual was not considered an outlier for this study.

To analyze the demographic variables between groups, the categorical variables including gender and dominant hand, were examined using the chi-square analysis. Besides, the continuous variables of demographic data, such as age, intelligence (RCPM), and motor coordination ability (the subtest of DTVP-3) were analyzed by the independent t-test.

For purpose one, the handwriting legibility (CHLAC and Sentence Copying Test) between the ASD group and the TD group were compared using independent t-tests. Subsequently, to verify purpose two, the two-way repeated measures ANOVA was conducted to analyze the subtracted RTs of the Character Processing Test, and further confirmed the interaction between groups and familiarities of characters. Finally, for purpose three, the research certified the relationship between handwriting legibility (CHLAC and Sentence Copying Test) and the influence of WCC on processing actual characters (Character Processing Test) for children with ASD by the Pearson correlation.

2.5. Hypotheses

(1) Examining the difference in Chinese handwriting legibility between children with ASD and TD: legibility of intra-character and inter-character

Several studies have revealed that handwriting products in the alphabetic language written by ASD children are more illegible than TD children (Hellinckx et al., 2013; Johnson et al., 2013; Kushki et al., 2011; Grace et al., 2017; Rosenblum et al., 2019; Van

doi:10.6342/NTU202404599

den Bos et al., 2022; Verma & Lahiri, 2021). Compared to the alphabetic language, Chinese characters feature complex structures and irregular starting strokes between characters, which require more detailed visual-spatial skills (Cahill, 2009; McBride-Chang et al., 2011; Li-Tsang et al., 2018; Lee, 2016; 陳學志等人，2011). Hence, it is supposed that children with ASD show significantly poorer intra-character and inter-character legibility in Chinese handwriting than TD.

(2) Investigating the phenomenon of WCC in the processing of recognizing Chinese characters and further exploring the interaction between groups and character familiarity

According to previous research, the aligned condition could result in faster RTs compared to misaligned trials due to the benefit of holistic processing in TD children (Bojda et al., 2021; Fuentes et al., 2009; Neufeld et al., 2020; Horlin et al., 2016). Suspected to be influenced by WCC, children with ASD may not process characters holistically (Bojda et al., 2021; Fuentes et al., 2009; Kushki et al., 2011; Li-Tsang et al., 2018; Van der Hallen et al., 2015). Consequently, the integrity of characters may not significantly affect their performance, leading to similar RTs between aligned and misaligned trials. In addition, this situation might be worse in unfamiliar characters, without the experience of guiding (Chung & Son, 2020). Therefore, it is hypothesized to be an interaction between groups and familiarity of character.

(3) Confirming the relationship between handwriting legibility and the WCC on character processing in children with ASD

Handwriting is a task involving visual and motor ability (Cahill, 2009; McBride-Chang et al., 2011; Li-Tsang et al., 2018; Rosenblum et al., 2003; Verma & Lahiri, 2021). If the visual processing of characters is impacted by WCC, the quality of handwriting is supposed to be influenced (Kushki et al., 2011; Lee et al., 2016). Therefore, this study

doi:10.6342/NTU202404599

assumes that handwriting legibility in Chinese is correlated with the impact of WCC on character processing in actual characters for children with ASD.

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Chapter 3 Results

This study initially included 69 children, but nine were excluded due to issues with the ABC-T, the RCPM, or incomplete evaluations. Consequently, 30 children with ASD and 30 TD children comprised the final sample. Within the ASD group, 10 children were also diagnosed with attention deficit hyperactivity disorder. In the size control scoring of the Sentence Copying Test, two data points from the ASD group and one from the TD group were trimmed as extreme outliers. The same process was applied to the space control data, excluding one data point from the ASD group and one from the TD group. After trimming outliers, all continuous variables of outcomes were confirmed to match the normal distribution.

The demographic information of the participants is presented in Table 1. Comparisons between the ASD and TD groups revealed no significant differences in age (t = 0.590, p = 0.558), studying grade (χ^2 = 0.287, p = 0.789), grade level (χ^2 = 1.491, p = 0.360), dominant hand (χ^2 = 0.000, p = 1.000), RCPM scores (t = 0.104, p = 0.918), or subtest of DTVP-3 (t = -0.869, p = 0.388). Thus, participants in both groups were comparable regarding demographic variables, intelligence, and motor coordination abilities.

3.1. Handwriting Legibility in Children with ASD

Handwriting legibility in this study was measured by both intra-character and inter-character legibility. The results for intra-character legibility, assessed using the CHLAC, are presented in Table 2. The findings indicate that children with ASD exhibited poorer overall intra-character legibility compared to TD children (t = -2.611, p = 0.011).

doi:10.6342/NTU202404599

To conduct a more thorough comparison, the analysis focused on specific domains of the CHLAC, including size, position, orientation, radical proportion, and radical space. The results indicated that children with ASD had significantly poorer legibility than TD children in radical proportion (t = -2.105, p = 0.040) and radical space (t = -2.611, p = 0.028). However, the ASD and TD groups demonstrated comparable performance in terms of size (t = -1.583, p = 0.118) and position (t = -0.918, p = 0.362) of the characters. Additionally, for the orientation domain, both groups reached the ceiling of this assessment, precluding any meaningful comparison.

Table 3 reports the comparison of inter-character legibility between children with ASD and TD. Assessed by the Sentence Copying Test, inter-character legibility was evaluated across three domains: size control, space control, and alignment control. The statistical analysis showed no significant differences between groups in the consistency of size (t = -0.726, p = 0.471), space (t = -1.446, p = 0.154), and alignment (t = -1.239, p = 0.220). These results suggest that children with ASD exhibited similar inter-character legibility compared to TD children in this test.

3.2. WCC on Character Processing in Children with ASD

In the Character Processing Test, both the ASD (93.5%) and TD (92.9%) groups demonstrated high accuracy with no significant differences between groups (t = 0.477, p = 0.635). The ASD group (448.99 ± 178.99 ms) demonstrated significantly slower reaction times compared to the TD group (377.92 ± 66.19 ms) at baseline (t = 2.040, p = 0.004). The descriptive statistics of normalized reaction times (RTs) are presented in Table 4, and the outcomes of the two-way repeated measures ANOVA are shown in Table 5 and Figure 1.

doi:10.6342/NTU202404599

A two-way repeated measures ANOVA revealed a significant interaction between groups and character familiarity ($F = 5.363$, $p = 0.024$). The simple main effect of the group indicated a significant difference in processing pseudo characters between children with ASD and TD ($p = 0.004$), with children with ASD showing less differentiation between aligned and misaligned trials than TD children. However, no difference was observed between the groups when participants processed actual characters ($p = 0.324$). Regarding the simple main effect of character familiarity, a significant difference was found between the performance of actual and pseudo characters in children with ASD ($p < 0.001$). Specifically, the phenomenon of WCC in children with ASD was significantly more pronounced when processing pseudo characters compared to familiar characters. In contrast, TD children exhibited similar performance regardless of character familiarity ($p = 0.179$).

3.3. Correlation between Legibility and WCC in Children with ASD

To further understand the potential influence of WCC on the handwriting legibility of children with ASD, the correlation between these variables was analyzed. Table 6 presents the relationships between handwriting legibility and WCC in character processing for children with ASD. The analysis revealed no significant correlations between various legibility outcomes and WCC ($r = -0.313$ to 0.167; $p = 0.092$ to 0.976).

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Chapter 4 Discussion

This study aims to investigate the legibility of Chinese handwriting in children with ASD and to explore the phenomenon of WCC in Chinese character processing. In line with the research objectives, three main findings have been identified: (1) children with ASD exhibit poorer handwriting legibility, particularly in terms of the proportions and spatial relationships between radicals, compared to TD children; (2) the impact of WCC on character processing is notably severe with unfamiliar characters in children with ASD; and (3) the phenomenon of WCC is not significantly related to the legibility of familiar Chinese characters in children with ASD. However, whether this relationship exists for unfamiliar characters remains unclear.

4.1. Handwriting Legibility in Children with ASD

The results are consistent with the hypothesis that children with ASD exhibit poorer intra-character legibility in Chinese handwriting compared to TD children. However, contrary to the hypothesis, there are no significant differences between the groups in inter-character legibility, which may be attributed to the design of the assessment.

Children with ASD demonstrated overall poorer intra-character legibility in Chinese handwriting compared to TD children, aligning with previous studies on alphabetic handwriting legibility (Hellinckx et al., 2013; Kushki et al., 2011; Rosenblum et al., 2019). To further confirm the domains of intra-character legibility, the CHLAC can be analyzed with specific domains: size, position, orientation, radical proportion, and radical space.

In terms of radical proportion and radical space, children in the ASD group exhibited a more noticeable difficulty than those in the TD group. They produce more illegible characters with inappropriate proportions and disorganized spatial relationships between

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radicals. To arrange radicals into a character and maintain legibility, participants need to view the whole character as a unit and compare the relative relationships between radical-to-radical and radical-to-character while writing (Lee et al., 2016; 洪儷瑜，1997; 陳品華，2018; 陳學志等人，2011). Previous research on alphabetic languages has shown that children with ASD tend to write with worse internal structure of letters compared to TD children (Fuentes et al., 2009; Grace et al., 2017; Van den Bos et al., 2022). Organizing Chinese characters presents a greater challenge due to their hierarchical structures with radicals, in contrast to the simpler internal structures of alphabetic languages (Cahill, 2009; McBride-Chang et al., 2011; Li-Tsang et al., 2018; Lee, 2016; 陳學志等人，2011). This unique radical structure of Chinese characters has indeed been proven to pose challenges for children with ASD in this study.

While the analysis of intra-character legibility revealed no significant differences in size and position between children with ASD and TD children, the nature of the domains may explain these results. Differing from the radical proportion and radical space, which focus on the relationship between radicals within characters, size and position emphasize the relationship between the character and its surrounding frame. In these domains of size and position, the frames provide obvious visual cues. Namely, with structured and distinct visual guides, the performance of size and position in children with ASD appears comparable to that of TD children. Johnson et al. (2015) investigated the handwriting legibility of children with ASD, comparing the size of letters written on papers with different line widths and blank paper. It was discovered that when children with ASD wrote within given lines, their average letter size was similar to that of TD children. However, without any lines provided, the letters written by children with ASD were notably larger than those written by TD children in that research. Supported by these findings, it suggests that visual cues, such as lines and frames, could benefit intra-

doi:10.6342/NTU202404599

character handwriting legibility among children with ASD on character size and position. In domains regarding radical arrangement, as maintained above, which present more complex relational challenges, children with ASD still face significant difficulties.

Results of inter-character legibility indicated that children with ASD had comparable performance with TD children, possibly because the Sentence Copying Test was not comprehensive enough to present the difference. Previous studies on inter-character legibility in alphabetic languages, children with ASD wrote letters with lower consistency of size, inter-character space, and sentence alignment (Grace et al., 2017; Hellinckx et al., 2013; Johnson et al., 2013; Rosenblum et al., 2016). These studies assessed inter-character legibility with multiple sentences or paragraphs. However, the Sentence Copying Test used in this research only involved copying a single sentence. It could be not challenging enough to present differences of ability between groups. Additionally, the consistency of size, space, and alignment may not be representative enough to present the inter-character legibility difficulties in Chinese handwriting of children with ASD. Based on the observation, children with ASD still perform with a lower quality of inter-character legibility than TD children. Their characters written within the sentence are present without a clear structure as a unit, tending to be more fragmented compared to those of TD children. Besides, 13% of participants in the ASD group completed the test with errors, including exceeding the boundaries of designated boxes, omitting characters, or generating incorrect characters. In contrast, no participants in the TD group exhibited such errors. As a result, in terms of accuracy of completion, participants in the ASD group show slightly lower performance compared to TD, suggesting that writing sentences may still be a challenge for children with ASD.

In conclusion, this research indicates that children with ASD exhibit poorer legibility in Chinese handwriting compared to TD children. This difficulty is particularly in terms

doi:10.6342/NTU202404599

of arranging and organizing radicals into a character. While inter-character legibility showed no significant differences, possibly due to assessment limitations. According to the observation, children in the ASD group wrote characters without a structure as a unit and made more errors during the test, suggesting persistent difficulties in inter-character legibility.

4.2. WCC on Character Processing in Children with ASD

For WCC on character processing, an interaction between groups and character familiarity was observed, confirming the initial hypothesis. The interaction between groups and character familiarity indicates that the phenomenon of WCC on character processing differs depending on the groups and whether the characters are familiar or unfamiliar to the participants. In the context of processing pseudo characters, children with ASD exhibit more pronounced WCC compared to TD children. However, in processing actual characters, the two groups perform comparably. Moreover, children with ASD demonstrate significantly more severe phenomena of WCC when processing pseudo characters compared to processing actual characters, whereas TD children show no difference between processing actual and pseudo characters.

Among children with ASD, the phenomenon of WCC particularly appeared during the processing of unfamiliar characters rather than familiar ones. It suggests that when processing unfamiliar characters, children with ASD tend to rely on their accustomed strategies characterized by WCC. However, when processing familiar characters, they could adjust their strategies to minimize the impact of WCC and process the characters more holistically. A previous study on face processing found that the familiarity of visual stimuli affected brain activity in children with ASD (Chung & Son, 2020). Specifically, the activation of the fusiform gyrus in ASD, which is related to face processing deficits,

doi:10.6342/NTU202404599

significantly decreases when processing unfamiliar faces compared to TD individuals. Interestingly, this phenomenon of hypoactivation returned to normal levels when processing familiar faces (Chung & Son, 2020). This finding supports the notion that familiarity can influence visual processing patterns. Additionally, increased familiarity may facilitate holistic processing in children with ASD.

Furthermore, analysis of the Character Processing Test revealed that WCC on character processing is more severe in children with ASD compared to TD children on pseudo characters. The ASD group exhibited minimal differences between aligned and misaligned trials, indicating a tendency to focus on specific details without being affected by the disruption to character integrity. WCC is a phenomenon at the perceptual level, and its impact on different cognitive dimensions requires separate investigation (Bojda et al., 2021). This atypical local-focused processing pattern in children with ASD has been documented in previous studies, especially in terms of face recognition (Chen et al., 2013; Kushki et al., 2011; López et al., 2004; Primativo & Arduino, 2023). Our study extends these findings by verifying that WCC observed in children with ASD also manifests in their visual processing of recognizing Chinese characters.

To sum up, the processing of Chinese characters for children with ASD appears a phenomenon of WCC. This tendency becomes particularly noticeable with unfamiliar characters, while familiarity helps them process characters more holistically as TD children do. These findings emphasize the importance of character familiarity in reducing WCC on visual processing for children with ASD.

4.3. Correlation between Legibility and WCC in Children with ASD

Analyzing the correlation between the severity of WCC and legibility including intra-character and inter-character legibility, there were no significant relationships. This

doi:10.6342/NTU202404599

result conflicts with the original hypothesis of this study. It might be owing to the absence of assessing the legibility of unfamiliar characters.

Based on the above finding, the phenomenon of WCC only appears when processing unfamiliar characters for children with ASD, but the characters used for the legibility assessments in this study were all familiar to the participants. As maintained early, the familiarity of characters likely allowed children with ASD to employ compensatory strategies to mitigate the impact of WCC. A more accurate representation of WCC on character processing in ASD can be observed through their performance with pseudo characters in the Character Processing Test. The unfamiliarity with the characters prevents the use of compensatory strategies and purely presents the phenomenon of WCC on character processing. Consequently, the correlation between legibility and WCC might be more evident when participants are required to copy unfamiliar characters. This inference could be supported by our clinical observation. When writing unfamiliar characters, children with the more severe phenomenon of WCC exhibit more radical-focused handwriting products, which are organized without a coherent structure of characters.

For familiar characters, handwriting difficulties observed in children with ASD may be attributed to the integration of motor and visual perception, rather than purely to visual processing affected by WCC. Despite no differences in motor coordination or visual processing patterns of familiar characters between ASD and TD groups assessed in this study, children with ASD still face challenges in handwriting legibility. Previous research has shown no significant correlation between legibility and visual perception, but a relationship exists between legibility and VMI in children with ASD (Fuentes et al., 2009; Handle et al., 2022; Van den Bos et al., 2022). In addition, Nebel et al. (2016) investigated visual-motor synchrony in ASD using functional magnetic resonance imaging. The results revealed that while children with ASD showed comparable activation to TD

doi:10.6342/NTU202404599

children in brain regions responsible for motor and visual perception, the synchrony between these regions was significantly lower in ASD. These findings suggest that the difficulty in handwriting legibility for children with ASD may result from immature integration skills.

In summary, the results are unexpected as the initial hypothesis, that it found no significant relationship between the severity of WCC and legibility in children with ASD. This absence of significant correlation is potentially due to the handwriting legibility assessed with only familiar characters to the participant in this study; while the phenomenon of WCC is more severe when children with ASD process unfamiliar characters. Besides, for the illegibility of familiar characters, the relation between character processing and legibility may be more complex than originally anticipated, and involve other skills such as the VMI.

4.4. Limitations of This Study

This study provides evidence regarding handwriting legibility and WCC in character processing among children with ASD. However, several limitations should be carefully considered. Firstly, the study had a limited representation of children with ASD. The participants included in this study were without intellectual disabilities or other physical impairments, representing a higher-functioning ASD subgroup. Therefore, caution is needed when generalizing the findings to the broader ASD population.

In addition, the inter-character legibility of participants requires a more comprehensive evaluation. The Sentence Copy Test used in this study involves copying a single sentence within a rectangular frame, and evaluating the consistency of size, space, and alignment between characters. Previous studies that identified poorer inter-character legibility in children with ASD compared to TD children employed assessments involving

doi:10.6342/NTU202404599

multiple sentences (Hellinckx et al., 2013; Rosenblum et al., 2016). Therefore, replicating a single sentence may not be sufficiently challenging to reveal differences in inter-character legibility between groups. Furthermore, the structural integrity of characters, particularly the radical composition unique to Chinese characters, should be carefully considered. The current scoring domains may not sensitively capture these features.

Finally, the assessment should include the intra-character legibility of unfamiliar characters. The Character Processing Test in this study revealed that the phenomenon of WCC is particularly evident when children with ASD process pseudo characters. However, the evaluation of legibility was confined to familiar characters. To deepen our understanding of the relationship between WCC and handwriting legibility in children with ASD, future assessments should incorporate unfamiliar characters.

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Chapter 5 Conclusions

This research indicates that children with ASD show poorer legibility in Chinese handwriting compared to TD children, particularly in the radical aspect of intra-character legibility. The phenomenon of WCC becomes especially pronounced when children with ASD process pseudo characters, which confirms the impact of WCC on character processing. On the contrary, the processing pattern of familiar characters is comparable between children with ASD and TD children. These results highlight the significance of character familiarity in facilitating holistic visual processing of characters for children with ASD. However, the correlation between the impact of WCC on character processing and handwriting legibility was not supported in this study. This result may be attributed to the absence of considering the legibility of unfamiliar characters. Future research should incorporate assessments of unfamiliar characters to gain a clearer understanding of the relationship between WCC and handwriting legibility in children with ASD.

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Table 1. Demographic Characteristics of Participants

	Group		p
	ASD	TD	
Age, years, mean (SD)	7.76 (0.66)	7.67 (0.58)	0.558
Grade level, first grade, n (%)	20 (0.67)	18 (0.60)	0.789
ABC-T, scores, mean (SD)	19.23 (8.31)	1.87 (2.90)	< 0.001***
Gender, male, n (%)	25 (83.33)	21 (70.00)	0.360
Dominant hand, right, n (%)	29 (96.67)	29 (96.67)	1.000
RCPM, standard scores, mean (SD)	108.23 (12.40)	107.90 (12.48)	0.918
DTVP-3, scale scores, mean (SD)	9.27 (2.64)	9.83 (2.41)	0.388

*p < 0.05; **p < 0.01; ***p < 0.001

Abbreviations: SD, standard deviation; ASD, autism spectrum disorder; TD, typically developed; ABC-T, Autism Behavior Checklist-Taiwan Version; DTVP-3, Developmental Test of Visual Perception, Third Edition; RCPM, Raven's Colored Progressive Matrices.

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Table 2. Intra-character Legibility between ASD and TD Groups

	Group		p
	ASD	TD	
Total score, mean (SD)	50.03 (6.20)	54.13 (7.18)	0.011*
Size	10.87 (2.84)	11.97 (2.86)	0.118
Position	9.70 (2.84)	10.40 (3.06)	0.362
Orientation	12.00 (0.00)	12.00 (0.00)	-
Radical Proportion	7.60 (2.39)	8.93 (2.52)	0.040*
Radical Space	9.70 (2.83)	11.20 (2.31)	0.028*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Abbreviations: SD, standard deviation; ASD, autism spectrum disorder; TD, typically developed.

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Table 3. Inter-character Legibility between ASD and TD Groups

	Group		p
	ASD	TD	
Size control, mean (SD)	0.75 (0.91)	0.92 (0.91)	0.471
Space control, mean (SD)	0.98 (0.93)	1.45 (1.48)	0.154
Alignment control, mean (SD)	3.99 (3.63)	5.11 (3.31)	0.220

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Abbreviations: SD, standard deviation; ASD, autism spectrum disorder; TD, typically developed.

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Table 4. Reaction Time of Different Trials in the Character Processing Test between ASD and TD Groups

	Group		p
	ASD	TD	
Normalized RT, units, mean (SD)			
Actual characters			
Aligned	3.29 (0.99)	3.26 (0.56)	0.009**
Misaligned	3.52 (1.09)	3.56 (0.61)	0.004**
Pseudo characters			
Aligned	3.48 (1.05)	3.45 (0.61)	0.010*
Misaligned	3.54 (1.06)	3.70 (0.64)	0.006**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Abbreviations: RT, reaction time; SD, standard deviation; ASD, autism spectrum disorder; TD, typically developed.

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Table 5. Two-way Repeated Measures ANOVA of Character Processing Test

	Subtracted normalized RT, unit, mean (SD)		Simple main effects of familiarity	*F* values		
	Actual characters	Pseudo characters		Group × Familiarity	Group	Familiarity
ASD	0.24 (0.27)	0.06 (0.27)	Pseudo < Actual ***	5.363*	5.017*	17.991***
TD	0.30 (0.19)	0.25 (0.19)	Pseudo = Actual			
Simple main effects of group	ASD = TD	ASD < TD *				

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Abbreviations: RT, reaction time; SD, standard deviation; ASD, autism spectrum disorder; TD, typically developed.

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Table 6. Pearson correlation of legibility and WCC in Children with ASD

	Subtracted normalized RT (*r*)
Intra-character	
Total score	-0.117
Size	-0.133
Position	0.034
Orientation	-
Radical Proportion	0.167
Radical Space	-0.313
Inter-character	
Size control	-0.035
Space control	-0.006
Alignment control	0.142

*p < 0.05; **p < 0.01; ***p < 0.001

Abbreviations: RT, reaction time.

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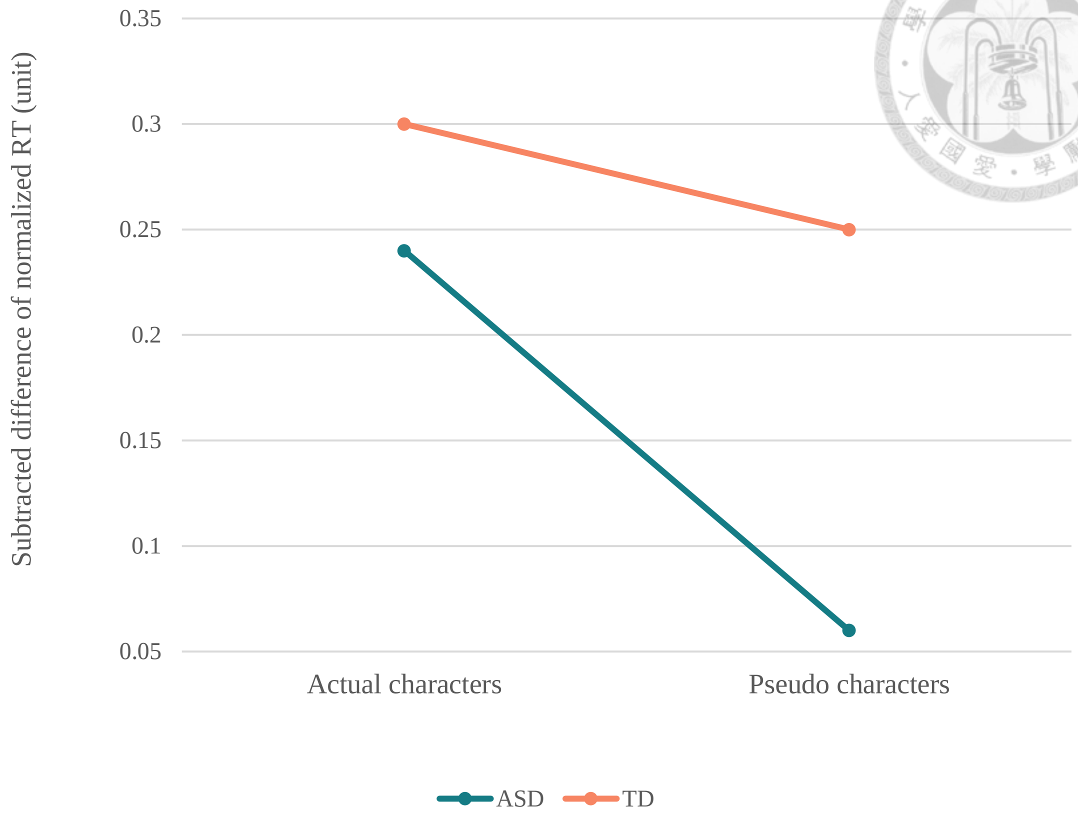

Figure 1. Line Graph of Groups and Familiarity of Character in the Character Processing Test

Abbreviations: RT, reaction time; ASD, autism spectrum disorder; TD, typically developed.

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Reference

王姝婷、翁芷琦、馮家樂、黃文豐、陳顥齡、王湉妮 (2024)。兒童中文書寫易讀性測驗之發展。*台灣職能治療研究與實務*，20。

洪儷瑜 (1997)。漢字視知覺測驗編製初步報告。*師大學報：教育類*，42，59-73。

陳奕全、葉素玲 (2009)。漢字辨識理論模型中的部件表徵。*應用心理研究*，43，177-205。

陳學志、張瓅勻、邱郁秀、宋曜廷、張國恩 (2011)。中文部件組字與形構資料庫之建立及其在識字教學的應用。*教育心理學報*，43，269-290。

陳品華 (2018)。影響自閉症兒童中文寫字表現的知覺動作相關因素探討（未出版碩士論文）。國立臺灣師範大學，臺北市。

陳茹玲、蘇宜芬 (2010)。國小不同認字能力學童辨識中文字詞之字元複雜度效果與詞長效果研究。*教育心理學報*，41，579-604。

陳榮華、陳心怡 (2006)。瑞文氏矩陣推理測驗指導手冊。*中國行為科學社。*

黃文豐 (2023)。平板電腦化中文書寫表現評估系統之發展（未出版博士論文）。國立臺灣大學，臺北市。

黃君瑜、吳佑佑 (2013)。台灣版自閉症行為檢核表。*心理出版社。*

曾美惠 (1993)。曾氏寫字問題檢核表之因素效度。*職能治療學會雜誌*，11，13-27。

葉素玲、李金鈴、陳洸民 (1999)。中文字型分類系統的再確立：類別與字數的控制。*中華心理學刊*，41，65-85。

doi:10.6342/NTU202404599

American Psychiatric Association (2013). Diagnostic and statistical manual of mental disorders: DSM-5 (Vol. 5). *American Psychiatric Association Washington, DC.*

Baixauli, I., Rosello, B., Berenguer, C., Téllez de Meneses, M., & Miranda, A. (2021). Reading and Writing Skills in Adolescents With Autism Spectrum Disorder Without Intellectual Disability. *Front Psychol,* 12, 646849.

Bojda, A., Srebnicki, T., Konowałek, Ł., & Bryńska, A. (2021). Weak central coherence-construct conception, development, research methods. *Psychiatria Polska*, 55, 1373-1386.

Brown, T. (2016). Validity and reliability of the developmental test of visual perception–third edition (DTVP-3). *Occupational Therapy in Health Care,* 30, 272-287.

Cahill, S. M. (2009). Where does handwriting fit in? Strategies to support academic achievement. *Intervention in School and Clinic*, 44, 223-228.

Chen, H., Bukach, C. M., & Wong, A. C. N. (2013). Early electrophysiological basis of experience-associated holistic processing of Chinese characters. *PLoS One*, 8, e61221.

Chung, S., & Son, J. W. (2020). Visual perception in autism spectrum disorder: a review of neuroimaging studies. *Journal of the Korean Academy of Child and Adolescent Psychiatry*, *31*(3), 105.

Frith, U., & Mira, M. (1992). Autism and Asperger syndrome. *Focus on Autistic Behavior*, 7, 13-15.

Fuentes, C. T., Mostofsky, S. H., & Bastian, A. J. (2009). Children with autism show specific handwriting impairments. *Neurology*, 73, 1532-1537.

Hammerschmidt, S. L., & Sudsawad, P. (2004). Teachers' survey on problems with handwriting: Referral, evaluation, and outcomes. *The American Journal of Occupational Therapy,* 58, 185-192.

doi:10.6342/NTU202404599

Hammill, D. D., Pearson, N. A., & Voress, J. K. (2014). DTVP-3: Developmental test of visual perception. *Austin: Pro-Ed.*

Handel, Z. (2015). Logography and the classification of writing systems: a response to Unger. *Scripta,* 7, 109-150.

Handle, H. C., Feldin, M., & Pilacinski, A. (2022). Handwriting in Autism Spectrum Disorder: A Literature Review. *Journal of Neuroscience,* 3, 558-565.

Happé, F. (2021). Weak central coherence. *Encyclopedia of Autism Spectrum Disorders*, 5166-5168.

Hatfield, T. R., Brown, R. F., Giummarra, M. J., & Lenggenhager, B. (2019). Autism spectrum disorder and interoception: Abnormalities in global integration? *Autism*, *23*, 212-222.

Hellinckx, T., Roeyers, H., & Van Waelvelde, H. (2013). Predictors of handwriting in children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 7, 176-186.

Herringshaw, A. J., Kumar, S. L., Rody, K. N., & Kana, R. K. (2018). Neural Correlates of Social Perception in Children with Autism: Local versus Global Preferences. *Neuroscience,* 395, 49-59.

Henninger, N. A., & Taylor, J. L. (2013). Outcomes in adults with autism spectrum disorders: A historical perspective. *Autism*, 17, 103-116.

Horlin, C., Black, M., Falkmer, M., & Falkmer, T. (2016). Proficiency of individuals with autism spectrum disorder at disembedding figures: A systematic review. *Developmental Neurorehabilitation,* 19, 54-63.

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, 2917-2926.

doi:10.6342/NTU202404599

Johnson, B. P., Phillips, J. G., Papadopoulos, N., Fielding, J., Tonge, B., & Rinehart, N. J. (2015). Do children with autism and Asperger's disorder have difficulty controlling handwriting size? A kinematic evaluation. *Research in Autism Spectrum Disorders*, *11*, 20-26.

Krug, D. A., Arick, J., & Almond, P. (1980). Behavior checklist for identifying severely handicapped individuals with high levels of autistic behavior. *Child psychology & psychiatry & allied disciplines.*

Kumar, S. L. (2013). Examining the characteristics of visuospatial information processing in individuals with high-functioning autism. *The Yale Journal of Biology and Medicine*, 86, 147.

Kushki, A., Chau, T., & Anagnostou, E. (2011). Handwriting difficulties in children with autism spectrum disorders: A scoping review. *Journal of Autism and Developmental Disorders*, 41, 1706-1716.

Lee, T. I., Howe, T. H., Chen, H. L., & Wang, T. N. (2016). Predicting handwriting legibility in Taiwanese elementary school children. *The American Journal of Occupational Therapy,* 70, 7006220020p7006220021-7006220020p700622002 9.

Lefebvre, S., & Beaucousin, V. (2023). Seeing the forest or the tree depends on personality: Evidence from process communication model during global/local visual search task. *PLoS One, 18*, e0284596.

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, 3093-3100.

doi:10.6342/NTU202404599

López, B., Donnelly, N., Hadwin, J., & Leekam, S. (2004). Face processing in high-functioning adolescents with autism: Evidence for weak central coherence. *Visual Cognition,* 11, 673-688.

McBride-Chang, C., Chung, K. K., & Tong, X. (2011). Copying skills in relation to word reading and writing in Chinese children with and without dyslexia. *Journal of Experimental Child Psychology*, 110, 422-433.

Mills, M. (2016). Global/local processing in the incidental perception of hierarchical structure. The University of Nebraska-Lincoln.

Mottron, L., & Soulières, I. (2013). Global Versus Local Processing. In F. R. Volkmar (Ed.), *Encyclopedia of Autism Spectrum Disorders,* 1445-1451. Springer New York.

Muth, A., Hönekopp, J., & Falter, C. M. (2014). Visuo-spatial performance in autism: a meta-analysis. *Journal of Autism and Developmental Disorders,* 44, 3245-3263.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive psychology,* 9, 353-383.

Nebel, M. B., Eloyan, A., Nettles, C. A., Sweeney, K. L., Ament, K., Ward, R. E., Choe, A. S., Barber, A. D., Pekar, J. J., & Mostofsky, S. H. (2016). Intrinsic visual-motor synchrony correlates with social deficits in autism. *Biological psychiatry*, *79*(8), 633-641.

Neufeld, J., Hagström, A., Van't Westeinde, A., Lundin, K., Cauvet, É., Willfors, C., Isaksson, J., Lichtenstein, P., & Bölte, S. (2020). Global and local visual processing in autism - a co-twin-control study. *Journal of Child Psychol Psychiatry,* 61, 470-479.

Perez, B. (2004). Writing across writing systems. *Sociocultural contexts of language and literacy,* 69-87.

doi:10.6342/NTU202404599

Peristeri, E., & Tsimpli, I. M. (2022). Disentangling Language Disorder and Bilingualism in Children with Developmental Language Disorder and Autism Spectrum Disorder: Evidence from Writing. *Journal of Autism Development Disorder*.

Primativo, S., & Arduino, L. S. (2023). Global and Local Processing of Letters and Faces: The Role of Visual Focal Attention. *Brain Sciences,* 13, 491.

Qu, Q., & Damian, M. F. (2017). Orthographic effects in spoken word recognition: Evidence from Chinese. *Psychonomic Bulletin & Review,* 24, 901-906.

Raven, J. C. (1938). Raven standard progressive matrices. *Journal of Cognition and Development.*

Rosenblum, S., Ben-Simhon, H. A., Meyer, S., & Gal, E. (2019). Predictors of handwriting performance among children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 60, 16-24.

Rosenblum, S., Simhon, H. A. B., & Gal, E. (2016). Unique handwriting performance characteristics of children with high-functioning autism spectrum disorder. *Research in Autism Spectrum Disorders*, 23, 235-244.

Rosenblum, S., Parush, S., & Weiss, P. L. (2003). The in air phenomenon: Temporal and spatial correlates of the handwriting process. *Perceptual and Motor Skills,* 96, 933-954.

Salari, N., Rasoulpoor, S., Rasoulpoor, S., Shohaimi, S., Jafarpour, S., Abdoli, N., Khaledi-Paveh, B., & Mohammadi, M. (2022). The global prevalence of autism spectrum disorder: a comprehensive systematic review and meta-analysis. *Italian Journal of Pediatrics*, 48, 1-16.

Sampson, G. (1985). Writing systems. London, UK: Hutchinson.

Van den Bos, N., Houwen, S., Schoemaker, M., & Rosenblum, S. (2021). Balancing text generative and text transcriptive demands: Written content and handwriting legibility

doi:10.6342/NTU202404599

and speed of children and youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders,* 1-14.

Van den Bos, N., Houwen, S., Schoemaker, M., & Rozenblum, S. (2022). Using Structural Equation Modeling to analyze the handwriting of children and youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*.

Verma, P., & Lahiri, U. (2021). Deficits in handwriting of individuals with autism: a review on identification and intervention approaches. *Review Journal of Autism and Developmental Disorders,* 1-21.

doi:10.6342/NTU202404599

Appendix A

Actual characters	
Experiment	
空	突
笑	第
異	界
旁	帝
花	草
怎	忽
合	告
堅	型
音	香
然	魚
Practice	
桌	柔
書	拿

Pseudo characters	
Experiment	
[illegible]	[illegible]
旹	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	咅
[illegible]	[illegible]
Practice	
[illegible]	[illegible]
[illegible]	[illegible]

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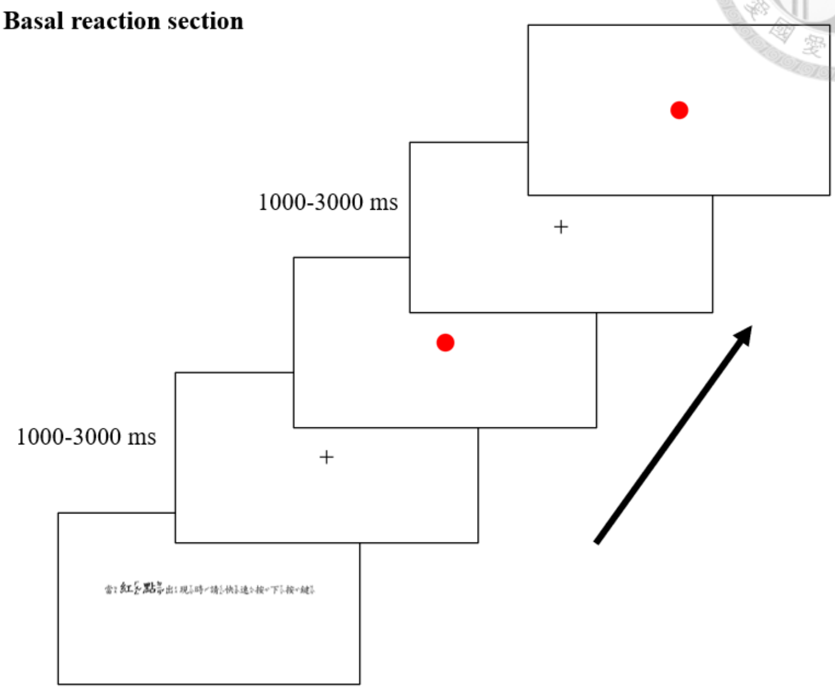
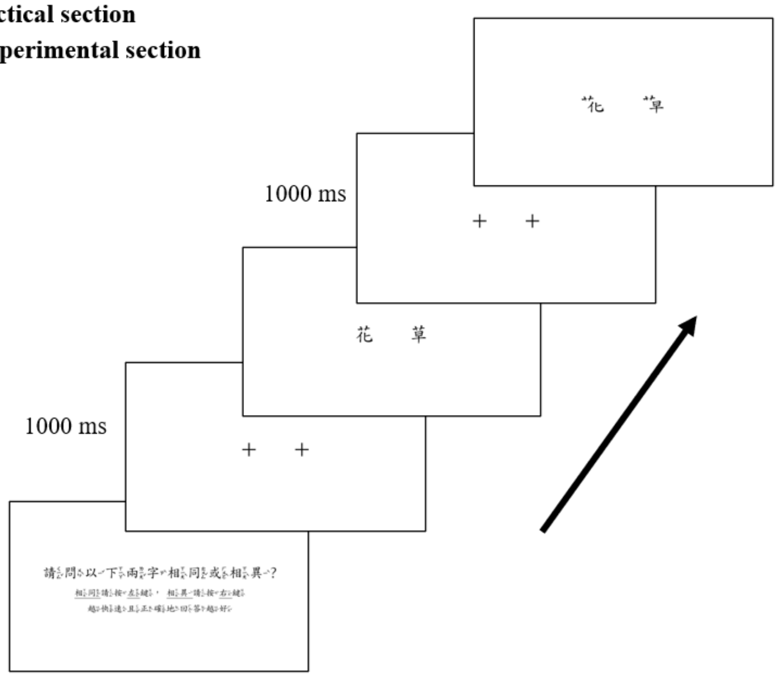
Appendix B

Basal reaction section



Practical section
/ Experimental section



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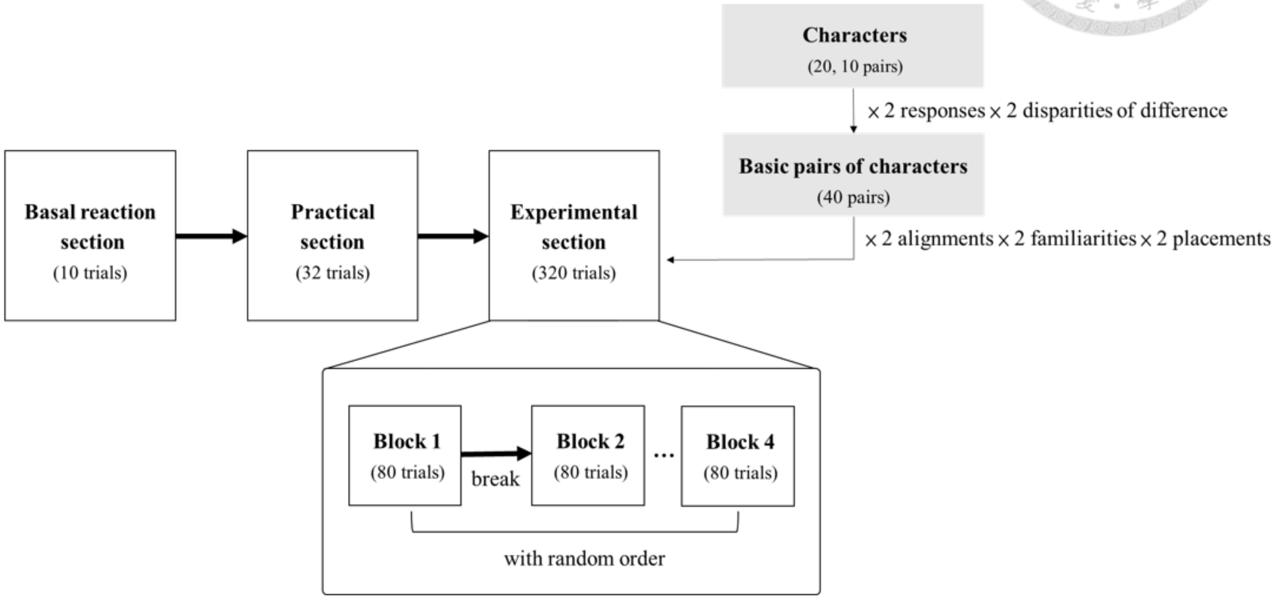
Structure of experimental trials



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