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Visual-perceptual-kinesthetic inputs on influencing writing performances in children with handwriting difficulties

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ABSTRACT

This study investigated the role of visual-perceptual input in writing Chinese characters among senior school-aged children who had handwriting difficulties (CHD). The participants were 27 CHD (9–11 years old) and 61 normally developed control. There were three writing conditions: copying, and dictations with or without visual feedback. The motor-free subtests of the Developmental Test of Visual Perception (DTVP-2) were conducted. The CHD group showed significantly slower mean speeds of character production and less legibility of produced characters than the control group in all writing conditions ($ps < 0.001$). There were significant deteriorations in legibility from copying to dictation without visual feedback. Nevertheless, the Group by Condition interaction effect was not statistically significant. Only position in space of DTVP-2 was significantly correlated with the legibility among CHD ($r = -0.62$, $p = 0.001$). Poor legibility seems to be related to the less-intact spatial representation of the characters in working memory, which can be rectified by viewing the characters during writing. Visual feedback regarding one's own actions in writing can also improve legibility of characters among these children.

1. Introduction

Proficient handwriting is an important scholastic skill that children must acquire to meet common classroom demands (Feder & Majnemer, 2007; Volman, van Schendel, & Jongmans, 2006). This skill has also been regarded as an indicator of students' academic achievement (Opper, 1996). Handwriting involves complex visual-perceptual-motor processing mediating by attention, perception, memory, motor, and executive functions. These functions are synchronized and integrated at various levels to produce a word (Haas & Rees, 2010; Shams & Kim, 2010). After perceiving a word, the visual image of letters or shapes will be processed based on which of the actions involved in the writing are planned and executed (Erhardt & Meade, 2005). Other studies reveal that the integration of the visual-perceptual-motor processes demands substantial attentional function, with more intense functioning required for easy or familiar words than for complex or less familiar words (i.e., automaticity; Torrance, 2007; Tucha, Mecklinger, Walitza, & Lange, 2006). Besides attention, working memory plays an important role in writing (Hayes, 1996; Kellogg, 2004). In particular, visuospatial storage and processing

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abilities are crucial to the transcription and generation of written words (Berninger, 1999; Jeffries & Everatt, 2004). Text generation is the translation of ideas into language representations in memory. Transcription is the translation of language representations into written words. It encodes letter forms and letter sequences in short-term memory to monitor and revise, and then handwriting output occurs. At the same time, working memory works in conjunction with long-term memory (Hayes & Grawdol-Nash, 1996), with representation of the word retrieved from long-term memory and maintained in working memory for effective transcription (McCutchen, 2000). By viewing how a word is produced, visual feedback provides inputs for forming a mental picture of the written word in working memory, which can guide the movements of the hand in handwriting (Hagura et al., 2007; Shams & Kim, 2010). A previous study revealed enhancement of legibility by visual strategies, which were found useful for learning new words or alleviating children's writing difficulties (Daly, Kelley, & Krauss, 2003). The absence of visual feedback would limit the rehearsal process in maintaining a mental picture and spatial orientation in the execution of movement. The use of a mental picture to guide the movement would become less effective because of the weak linkage between visual and motor control. Thus, feedback would rely significantly on a kinesthetic sense that is insufficient to provide the necessary information for spatial orientation. It results in a decline of the word's legibility.

Handwriting difficulty, also known as dyslexic dysgraphia, is defined as a specific learning disability in written language production that is not related to low intelligence (Hamstra-Bletz & Blote, 1993). Previous studies indicated that 10–20% of school-age children, especially boys, experienced different types of handwriting difficulties (Ratzon, Efraim, & Bart, 2007; Rosenblum, Parush, & Weiss, 2003). Besides handwriting difficulty, poor legibility of characters was revealed in other developmental disabilities, such as Attention Deficit Hyperactive Disorder (ADHD; Karande et al., 2007; Racine, Majnemer, Shevell, & Snider, 2008) and developmental coordination disorders (Miller, Missiuna, Macnab, Malloy-Miller, & Polatajko, 2001; Tseng, Howe, Chuang, & Hsieh, 2007). In English writing, typical words produced by individuals with handwriting difficulty are characterized by incorrect letter formation, poor alignment, uneven size of letters, and irregular spacing between letters and words (Case-Smith, 2002; Graham, Struck, Santoro, & Berninger, 2006; Tseng & Chow, 2000). These individuals also tend to write slowly. In addition, they might present with phonological awareness problems (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Bishop & Snowling, 2004), as proper decoding of spoken words into sequences of smaller units of sound segments can help formulate the written words (Berninger et al., 2010; Tan, Spinks, Eden, Perfetti, & Siok, 2005). Other studies suggested that children with handwriting difficulties had poor legibility, but no speed problems in producing written words (Hamstra-Bletz & Blote, 1993; Rubin & Henderson, 1982).

In contrast to the letter of the English language, the Chinese character is primarily logographic in nature, comprising radicals within a square configuration. A radical is composed of strokes. The accuracy in spatial relationships between strokes and a radical, and between radicals and a character, are the essence of written Chinese characters. The ability to maintain spatial orientations of strokes and radicals, and to produce them in a written form, is a challenge to all school-aged children (Ho, Chan, Lee, Tsang, & Luan, 2004; Lai & Leung, 2012). Deficiencies associated with handwriting difficulty in producing Chinese characters include slowness and poor legibility (Tseng & Chow, 2000). The common features attributable to poor legibility were in stroke formation (superfluous and missing strokes) and sequencing of strokes to the geometric position of the components in a character (i.e., disproportionate spacing and size among components; Tseng & Hsueh, 1997). For example, it is common for children to confuse "大" (*di*, which means large or big) and "太" (*tei*, which means very or rather), words that have similar features but different meanings. The grapheme-phoneme correspondence rules cannot be applied to a Chinese character as it maps onto the morpheme, or meaning (Siok & Fletcher, 2001). Instead, writing a spoken character involves phonological awareness and visual-orthographic processes, which are carried out in the working memory (Baddeley, Gathercole, & Papagno, 1998; Berninger et al., 2006). Various studies identified that both processes were problematic among children with handwriting difficulties (Chen, Dent, You, & Wu, 2009; Ho, Chan, Tsang, Lee, & Chung, 2006; Law, Wong, & Kong, 2006).

This study investigated the roles of visual feedback inputs (or feedbacks) on modulating the production of Chinese characters. The visual inputs were manipulated by using writing tasks progressing from copying to dictation with or without visual feedbacks. In the copying task, a sample character was displayed while the subject read and wrote the word. This would involve continuous visual (from the sample and written character) and kinesthetic feedbacks to be received by the participant seeing the character, spatial orientation of components within the character, and position in space of the character. In the dictation with visual feedback condition, the participant saw the sample character, which disappeared before the participant wrote it. The participant was allowed to read the character when writing. The feedbacks, if any, were from the written character. In the dictation without visual feedback condition, the participant saw the sample character, which disappeared at the time of the writing. The vision of the participant was blocked and therefore he or she did not read the character when writing. This enabled any feedbacks to be received by the subject to only come from the kinesthetic—but not the visual—sense of the written character. We anticipated that the cognitive demand to the participants for maintaining the speed and legibility would increase from the copying to dictation without visual input tasks. We also hypothesized that the participants with handwriting difficulty would perform more poorly, i.e., slower speed and lower legibility, than those in the control group. Across three writing tasks, we further hypothesized that the children with handwriting difficulty would perform at the lowest level when writing Chinese characters without visual feedback. Finally, we hypothesized that their performance on the writing tasks also would correlate with their visual perceptual abilities. These results help to gain a better understanding of the visual-perceptual-motor processes that modulate Chinese handwriting. The findings can also shed light on the design of visual perception assessments and interventions for children with handwriting difficulties.