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An investigation of visual contour integration ability in relation to writing performance in primary school students

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ABSTRACT

A previous study found a visual deficit in contour integration in English readers with dyslexia (Simmers & Bex, 2001). Visual contour integration may play an even more significant role in Chinese handwriting particularly due to its logographic presentation (Lam, Au, Leung, & Li-Tsang, 2011). The current study examined the relationship between children's performance in visual contour (VC) integration and Chinese handwriting. Twenty students from grade 3 to grade 6 were recruited ($M = 9.51$, $SD = 1.02$) from a mainstream primary school using the convenience sampling method. Ten students were identified by teachers as having handwriting problems, and the other 10 were typical students. Participants performed the VC tasks and their handwriting performance was assessed by a Chinese Handwriting Assessment Tool (CHAT) in a classroom setting. Correlation analyses revealed that VC accuracy was significantly and negatively correlated with on paper time and total writing duration. *t*-Test analyses revealed statistically significant differences in VC accuracy between students with typical and poor handwriting, with consistently better VC accuracy performance in all conditions in the typical handwriting group. The results may have important implications for interventions aiming at improving children's handwriting.

1. Introduction

Handwriting is a crucial task in academic studies and one of the most important means of determining the academic abilities of students in the Chinese educational system. Poor handwriting abilities may have adverse effect on students' performance in tests and public examinations. Apart from academic success, failure to attain handwriting competency during the school-age years has long-term negative effects on students' self-esteem (Feder & Majnemer, 2007). According to the Hong Kong Monthly Digest of Statistics (2009), there are about 9900 students with Specific Learning Difficulties (SpLD) in Hong Kong in 2009. In addition, approximately 1 out of 10 students in Hong Kong may have handwriting problems (Chan, Ho, Tsang, Lee, & Chung, 2007). Studies have shown that reading and writing in Chinese are closely related (Chan, Ho, Tsang, Lee, & Chung, 2006; Tan, Spinks, Eden, Perfetti, & Siok, 2005), and visual perception may affect handwriting (Cheung, 2007). A previous study found a visual deficit in contour integration in English readers with dyslexia (Simmers & Bex, 2001). This study aimed to explore the relationship between students' visual contour integration and Chinese handwriting performance. The findings may provide important insights for improving students' handwriting performance.

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1.1. Handwriting performance

Handwriting is a complex skill that involves many components such as fine motor control, precision, proprioception, and visual perception (Lam, Au, Leung, & Li-Tsang, 2011). Typical problems in handwriting include inaccuracy and illegibility of the written products, or good handwriting but with extremely slow writing speed, problems with punctuation and grammar, and confusing upper and lower case letters (Peer, 2001).

Speed and accuracy are two basic measures of handwriting performance (Cheung, 2007; Lam et al., 2011). The commonly used tools for assessing handwriting speed are the Tseng's Handwriting Speed Test (Tseng & Hsueh, 1997), the Handwriting Assessment Tool—Speed Test (HATS; Chow, Choy, & Mui, 2003), and The Handwriting Speed Test (THST; Wallen, Bonney, & Lennox, 1996); while the Tseng's Handwriting Problem Checklist (THPC; Tseng, 1993) and the Handwriting Difficulty Checklist (HDC; Tam, 2008) have been commonly used for evaluating accuracy of handwriting. However, these handwriting assessments are weak as the quality and accuracy of handwriting are often rated subjectively, and most of these assessments fail to provide substantive information regarding the process of handwriting which might better reflect the underlying problems (Lam et al., 2011). In this study, a newly developed objective and computerized handwriting evaluation system, the Chinese Handwriting Assessment Tool (CHAT) was adopted for examining students' handwriting performance (Li-Tsang et al., 2011).

1.2. Chinese handwriting

Unlike the alphabetic languages such as English that emphasize smoothness and continuity in their written forms, Chinese characters are characterized by its logographic nature and its complexity with multiple-stroke sequence and directions (Lam et al., 2011). Complex geometric figurations and stroke arrangements within a squared area are involved in Chinese handwriting (Chow, Choy, & Mui, 2003; Tan, Feng, Fox, & Gao, 2001). Thus, the problem of handwriting would appear to be more critical in Chinese if children have poor visual perceptual or visual motor integration abilities (Lam et al., 2011). As writing Chinese characters puts more demand on visual discrimination of the fine differences in the forms and positions of strokes and spatial organization ability to write characters legibly with appropriate positioning of strokes and proportioning of radicals, writing proficiency in Chinese is more difficult than in English (Lam et al., 2011). For example, when a child writes "Iam ab oy", the teacher can still guess the meaning (I am a boy) even though the spacing between the letters is incorrect. However, if a child writes the Chinese character with wrong strokes or radical positions and spacing, it can become another character with a very different meaning.

One of our previous studies found that visuo-motor skills and visual perceptual skills appeared to be the main factors affecting Chinese handwriting performance (Cheung, 2007). Because a previous study found a visual deficit in contour integration in English readers with dyslexia, and VC appears to be strongly related to the identification of Chinese characters, we further explored the relationship between performance in VC and Chinese handwriting.

1.3. Visual contour integration skills in relation to writing Chinese characters

In the last decade, many research studies have examined the relationship between visual perceptual skills and reading. Studies have found that people with dyslexia have impaired abilities in performing higher-order, global visual tasks, such as visual contour integration, implying that higher-order cortical areas are involved, and/or abnormal cooperative associations between distant cortical loci exist in dyslexia (Simmers & Bex, 2001; Sireteanu et al., 2008).Visual contour integration skill (VC skill) is defined as the ability to integrate local spatial inputs across the visual field to form a global percept of a contour or path. This ability can be measured psychophysically in a test that requires the detection of a path defined by aligned, spatially narrow-band elements on a dense field of otherwise similar elements that are randomly oriented and positioned (Simmers & Bex, 2001) (see Fig. 2).

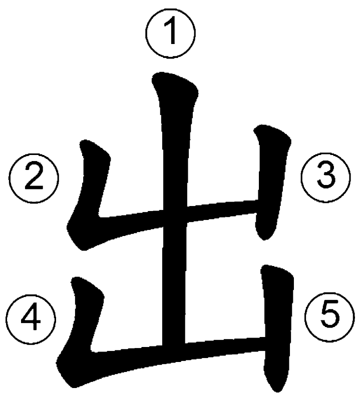

Fig. 1. The Chinese character 出 (means "out").

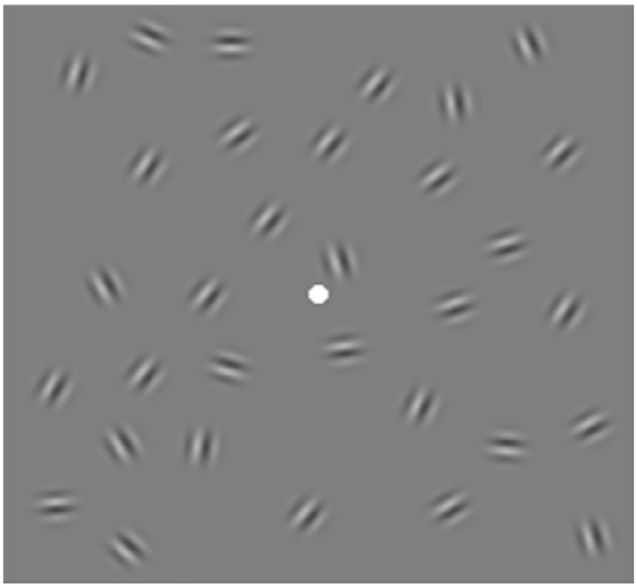

Fig. 2. A screen shot of the VC task; a straight contour consisted of 5 elements is embedded (0° orientation).

As mentioned earlier, Chinese characters involve complex geometric figurations and stroke arrangements (Lam et al., 2011). Since writing is a sequential process of arranging the strokes of individual characters appropriately, distortion in perceiving the strokes disturbs writing. This process can be related to contour integration (Schipper et al., 2009). According to a study which used VC task to investigate perceptual organization in dyslexia, people with dyslexia were found to be two to three times less sensitive to path stimuli than the control group (Simmers & Bex, 2001).

Visual contour integration may play a significant role in identifying individual strokes within a Chinese character, which in turn affect the handwriting performance. Take the Chinese character 出 (means "out") as an example (see Fig. 1).

This Chinese character is composed of five strokes. The stroke orders are listed above (Ministry of Education, 2010). When writing or copying a Chinese character, the individual needs to learn and write according to the stroke order, and needs to recognize the location and direction of each stroke correctly so as to locate the strokes and write the character. It should be noted that in this example, the first stroke is virtually separated into 2 short pieces by the first stroke. The ability to integrate and perceive the broken pieces into a single stroke without being affected by other nearby and overlapping strokes is highly related to the definition of visual contour integration, i.e., the ability to integrate spatially separated individual inputs into a continued whole and to identify integrated inputs from noise. Failure to perceive each stroke correctly right from the beginning will adversely affect how the individual locates the strokes during writing. For example, an individual who cannot perceive the broken pieces of the first stroke into a single stroke would separate it into two pieces during writing. As a result, the individual would write the character wrongly (with an additional extra stroke) as there is no such Chinese character that separates this stroke into two pieces, and the total writing time would be longer.

1.4. Purpose of the study

Although some studies have been conducted to examine the relationship of VC skills and English reading ability (Simmers & Bex, 2001), less information is available for Chinese handwriting. The aim of this study was to investigate the relationship between VC skills and handwriting performance of primary school students in Hong Kong. A contour detection task was used in this study to examine VC skills of the participants. We anticipated that by exploring the relationship between VC skills and handwriting performance among children with typical and poor handwriting, we would demonstrate a deficit in visual integration among children with poor handwriting. The findings may help bridge an important gap in our understanding of the underlying mechanisms of poor Chinese handwriting and provide new insights and directions for therapists to design effective visual training interventions for children with handwriting problems.

2. Methodology

2.1. Participants

The participants were 20 students (14 males) in grades 3 to 6 (age $M = 9.51$, $SD = 1.02$) in a mainstream primary school using the convenience sampling method. The sample consisted of 10 students who were identified by teachers as having handwriting problems, and 10 other age-matched students who were identified by teachers as having normal handwriting.

Students need to have normal or corrected-to-normal visual acuity and binocular vision in order to perform the visual contour detection task. Those who had been diagnosed with physical disabilities or medical conditions that would affect handwriting performance were excluded.

2.2. Measurements and outcome measures

2.2.1. Visual contour detection task (VC task)

The tests took place in a quiet and light-sufficient environment. Each participant was instructed to sit in front of a computer screen at a distance of 50 cm and to pay attention to the screen. The stimulus appeared in a circular area around the fixation point for 1 s and then disappeared. In the stimulus, a total of 32 Gabor elements were presented at random locations within the circular area as random noise. In half of the trials, a consistent pattern of contour (in a straight line or a curve) was embedded within the random noise (see Fig. 2). The participant was required to decide whether a contour pattern existed in each of the presented stimulus by pressing the YES (left arrow key) or NO (right arrow key) key on the keyboard as quickly as possible. If the participant did not respond within 5 s, the program skipped the trial and proceeded to the next trial. After pressing the key, the next trial followed within a second. The Mat lab computer software was used to measure and record the reaction time and the percentage of correct responses (accuracy) at each level of orientation (0°, 10° and 20°). The level of orientation is the orientation jitter which controlled the orientation of the element with respect to the contour (Simmers & Bex, 2001). The presentation order of the trials with and without the contour stimulus, and the orientation level among the constituting Gabor elements were made random. A 1-min break was given to the participant after every 40 trials. The screen displayed the instruction and the participant was asked to press SPACE bar to continue the test. Each participant was given a set of 30 practice trials ($3 \times 10 = 30$ practice trials) and 120 real trials ($3 \times 40 = 120$ real trials) in total.

2.2.2. The Chinese Handwriting Assessment Tool (CHAT)

The Chinese Handwriting Assessment Tool (CHAT) was adopted to evaluate the handwriting performance of each participant (Li-Tsang et al., 2011). It consisted of a digitized writing board (WACOM Intuos 3 digitizer) to be used with an ink pen, which could capture the handwriting data such as pressure exerted on the writing board while a user is writing on the grid paper. Each participant was instructed to sit in front of the computer screen at a distance of 50 cm. A template consisted of 90 common Chinese characters selected from a list of Chinese Characters recommended for the subject of Chinese Language in primary schools in Hong Kong (Li-Tsang et al., 2011). Ninety Chinese characters of primary 1 level with size 26,

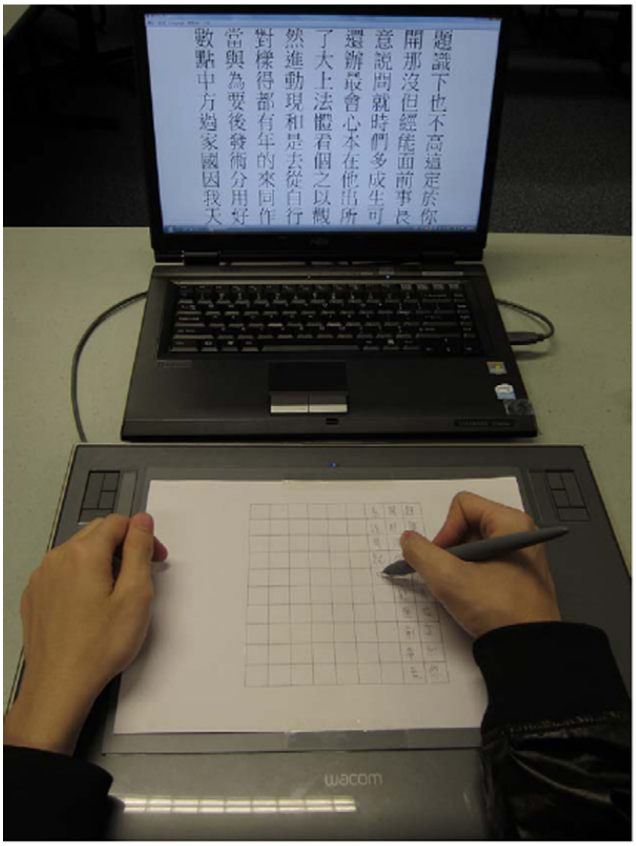

Fig. 3. The CHAT system which is composed of a laptop computer with the software installed, a digitized writing board (WACOM Intuos 3 digitizer), an ink pen, and a grid paper.

font type "Simsun" and triple-line spacing were shown on the computer screen. The characters were displayed in 9 columns of 10 characters. The display sequence of the columns was randomized each time when the system was operated. Each participant was instructed to copy the 90 characters as fast and accurately as possible on a piece of paper with a 9 × 10 grid pasted on the handwriting digitizer (Fig. 3). They were asked not to correct their writing if they wrote the character wrongly. Both the handwriting process and product were recorded by the system. Handwriting process includes: (1) total writing time (s); (2) total pause time (s); (3) total on-paper time (s); (4) pause time: on-paper time ratio; (5) speed (characters/min); (6) standard deviation (SD) of speed (characters/min); (7) mean pen pressure (Newton); (8) SD of pen pressure (Newton). Pause time is defined as the length of time when the pen is held in air; on-paper time is the length of time the pen touches the paper; and pen pressure is measured as the pressure of the pen exerted on the writing board during the on-paper time. Handwriting product includes: (1) accuracy (number of correctly written characters/90 characters); (2) total number of characters with stroke errors; (3) total number of characters which exceeded grid; (4) SD of the size of each character. The total number of stroke errors includes different types of stroke errors such as omitted strokes, added strokes, inverted or reversed strokes, broken strokes, concatenated strokes, and crossing over of strokes. All the observable handwriting product data, including the total number of characters with stroke errors and the total number of characters which exceeded grid were double checked and evaluated by the researchers as well.

2.2.3. Procedures

A cross-sectional age design was used to examine the VC skills and handwriting performance of 20 primary school students. Ten students were identified by teachers as having handwriting problems, and 10 age-matched students were identified by teachers as having normal handwriting. Two stations including VC task and CHAT were set in individual rooms, and participants were assigned to the stations in random order. As mentioned, for the VC task, 30 practice trials were provided before the 120 real trials. Students were instructed to judge the presence/absence of a contour on screen by pressing the corresponding YES or NO keys. There was a break after every 40 trials. Students could complete the whole VC task in about 20 min. For CHAT, students were instructed to use handwriting digitizer to copy the individual characters using the CHAT system, which could be completed in about 10 min.

3. Results

3.1. Descriptive statistics

Quantitative data were gathered from the VC task and the Chinese handwriting task. Table 1 displays descriptive statistics of age, as well as variables of writing and VC performance. The VC accuracy at 0°, 10° and 20° were 65%, 60% and 54%, respectively, implying that the VC accuracy at all orientations were slightly better than chance (50%) while the accuracy decreased with higher level of orientation.

3.2. Correlations between writing and VC performance

Pearson correlations between all the writing and VC performance variables are shown in Table 2. Only VC accuracy, but not VC reaction time, showed significant correlations with the writing performance variables. The on-paper time was

Table 1
Descriptive statistics of age, writing and VC performance ($N = 20$).

	M	*SD*	Range
Age	9.51	1.02	8.38–11.40
Number of missing words	.60	2.46	0–11
Number of wrong words	4.55	4.91	1–18
Number of characters exceed grid	8.05	11.93	0–53
Average size of characters (mm)	11.72	1.94	5.93–15.06
SD of size of characters	2.66	1.36	1.25–6.50
Average writing pressure (Newton)	.72	.41	.33–1.80
SD of writing pressure	.48	.29	.19–1.16
Average writing speed (characters/min)	11.22	3.62	6.00–20.59
Pause time (s)	168.26	51.62	104.80–268.77
On-paper time (s)	338.90	124.96	157.48–659.31
Pause time/on-paper time	2.00	.43	1.23–2.89
Total writing time (s)	507.16	168.02	226.28–899.37
VC accuracy at 0°	.65	.15	.43–.88
VC accuracy at 10°	.60	.15	.37–.85
VC accuracy at 20°	.54	.13	.33–.75
VC accuracy all	.60	.13	.38–.82
VC reaction time at 0°	.97	.40	.45–1.79
VC reaction time at 10°	1.02	.40	.51–1.86
VC reaction time at 20°	1.03	.39	.57–1.88
VC reaction time all	1.01	.39	.55–1.83

Table 2
Correlations between variables of writing and VC performance ($N = 20$).

Correlation	VC accuracy (0°)	VC accuracy (10°)	VC accuracy (20°)	VC accuracy (all)
Number of missing words	−.01	−.07	−.07	−.05
Number of wrong words	−.18	−.23	−.37	−.27
Number of characters exceed grid	−.30	−.29	−.29	−.31
Average size of characters	−.35	−.29	−.38	−.36
SD of size of characters	.09	.05	.04	.06
Average writing pressure	.14	.13	−.03	.09
SD of writing pressure	.16	.19	.01	.14
Average writing speed	.23	.30	.13	.24
Pause time (s)	−.32	−.39	−.16	−.32
On-paper time (s)	−.52*	−.57**	−.42	−.54*
Pause time/on-paper time	−.33	−.34	−.35	−.36
Total writing time (s)	−.48*	−.54*	−.36	−.50*

* $p < .05$.
** $p < .01$.

significantly and negatively correlated with VC accuracy at 0° and 10°, and the average of all orientations ($p < .05$). In addition, the total writing duration was significantly correlated with VC accuracy at 0° and 10°, and the average of all orientations ($p < .05$). The other correlations were not statistically significant.

3.3. *Writing and VC performance in typical handwriting and poor handwriting group*

In order to assess whether students' VC performance differed significantly between typical and poor handwriting group, independent sample *t*-test analyses were performed. It was found that only VC accuracy, but not VC reaction time, were significantly different between typical and poor handwriting groups.

Table 3 displays the descriptive statistics of age, and variables of writing and VC performance in typical and poor handwriting groups. Significant difference between groups was found in VC accuracy in all conditions (at 0°, 10° and 20° and the average of all orientations), all $p < .01$, in which students in typical handwriting group had significantly better VC accuracy performance than students in poor handwriting group in all conditions.

4. Discussions

According to the correlation analyses, VC accuracy was significantly and negatively correlated with the on-paper time and total writing time. These results appear to support that better VC accuracy is related to shorter time spent on writing, more so on the direct writing time on paper. These findings are supported by previous literature that VC skills are related to reading

Table 3
Descriptive statistics of age, and variables of writing and VC performance in typical handwriting and poor handwriting group ($N = 20$).

	Typical handwriting ($N = 10$)		Poor handwriting ($N = 10$)		t (18)
	M	*SD*	*M*	*SD*	
Age	9.54	1.08	9.48	1.02	.14
Number of missing words	.10	.32	1.10	3.48	−.91
Number of wrong words	2.20	1.62	6.90	6.01	−2.39*
Number of characters exceed grid	3.40	3.37	12.70	15.52	−1.85
Average size of characters	11.13	2.31	12.31	1.36	−1.39
SD of size of characters	2.50	1.45	2.82	1.32	−.53
Average writing pressure	.86	.50	.58	.25	1.59
SD of writing pressure	.59	.36	.37	.16	1.76
Average writing speed	12.35	2.70	10.09	4.19	1.43
Pause time (s)	147.25	29.73	189.28	61.31	−1.95
On-paper time (s)	272.80	55.88	405.00	141.90	−2.74*
Pause time/on-paper time	1.89	.35	2.16	.48	−1.45
Total writing time (s)	420.05	74.28	594.28	192.92	−2.67*
VC accuracy at 0°	.74	.14	.56	.10	3.43**
VC accuracy at 10°	.69	.13	.51	.11	3.33**
VC accuracy at 20°	.62	.08	.47	.12	3.23**
VC accuracy all	.68	.11	.51	.10	3.72**
VC reaction time at 0°	.96	.37	.98	.46	−.09
VC reaction time at 10°	1.06	.44	.99	.36	.39
VC reaction time at 20°	1.03	.40	1.03	.40	.05
VC reaction time all	1.02	.40	1.00	.39	.12

* $p < .05$.
** $p < .01$.

(Simmers & Bex, 2001), and supported our hypothesis that VC skills might play a significant role in handwriting speed in logographic writing systems such as Chinese.

Furthermore, *t*-test analyses revealed statistically significant differences in VC accuracy performance between students with typical and poor handwriting, with consistently better VC accuracy in all conditions in the typical handwriting group. These results further support our hypothesis that VC skills may be related to handwriting performance, particularly in writing Chinese characters that demand more visual contour integration abilities. The findings have important implications for practicing clinicians: when a student is found to have poor handwriting performance, one should also investigate the VC skills of the student in addition to their routine assessment on fine motor skills, visual motor integration skills and visual perceptual skills. In addition, future intervention programme may include training of VC skills using different methodology or treatment media such as using computerized training packages which incorporate training of VC skills. Further studies would be needed to investigate on the efficacy of these training programmes on handwriting performance.

4.1. Limitations of the present study

One of the limitations is that we did not measure students' cognitive abilities, such as attention span, impulsivity, reasoning skills and memory. It is crucial to take note of the co-morbid factors such as attention and impulsivity which may have affected students' performance in visual contour integration tasks. Past research studies (Brossard-Racine, Majnemer, Shevell, & Snider, 2008) have shown that these factors would influence students' handwriting performance including legibility and speed. Thus, future studies should measure variables such as attention and impulsivity which may influence students' performance in visual contour integration and handwriting. In our study, we only sampled subjects from one primary school. It is anticipated that by expanding our sample size, the external validity can be improved. Another important limitation is that we did not measure students' reading performance which may also be directly or indirectly influencing the process of handwriting.

5. Conclusion

This study aimed to find out the relationship between children's visual contour integration skills and Chinese handwriting performance in both speed and legibility. The results indicated positive relationships between VC skill and handwriting speed as well as the legibility. It may indicate that students may directly utilize their visual contour integration skills in order to write fast and legible. Thus, strengthening visual contour integration abilities can be one of the possible options for improving students' handwriting, particularly in logographic writing systems such as Chinese. We foresee that with more research in this new area, the findings can provide important information and new insights and directions for therapists to design effective visual training interventions targeting at the writing problems of children.

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