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Running head: FREQEUCNY OF LOGOGRAPHEMES

Interaction between Absolute and Positional-sensitive Frequency of Logographemes on Writing across Primary Grades

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Abstract

The present study investigated the interaction between absolute and positional-sensitive frequency of logographemes on writing in Grade One and Grade Four students. Thirty Grade One and 30 Grade Four students with normal reading, nonverbal cognitive, visual-memory, visual-spatial and visual-motor abilities participated in the delayed copying of pseudocharacters which were constructed by logographemes of neither semantic nor phonetic radicals. The results showed that only Grade Four students demonstrated absolute and positional-sensitive frequency effect, and the positional-sensitive frequency effect was significant only when the absolute frequency was low. The results suggested that the logographemes are the basic orthographic units in lexical representation in writing, and that Grade Four students have acquired these orthographic units and their respective positional codes. It supported that children have to learn the units of logographemes and their positional information in the process of learning to write in Chinese.

Interaction between Absolute and Positional-sensitive Frequency of Logographemes on Writing across Primary Grades

The Chinese writing system is often described as logographic in which the basic orthographic units, characters, correspond directly to morphemic meanings (Hoosain, 1991). In fact, over 80% of modern Chinese characters are phonetic compounds that consist of two components, namely semantic radical and phonetic radical (Law & Caramazza, 1991). Semantic radicals carry information about meaning, whereas phonetic radicals carry information about pronunciation. This suggests that the Chinese writing system is actually not absolutely logographic.

In the past, some researchers believed that characters were the primary units of mental representations in reading Chinese script, and due to the great number of visually distinct characters and the absence of grapheme-phoneme correspondence (GPC) rules in Chinese, characters were processed as a whole (e.g., Hoosain, 1991; Liu, 1988). More recently, researchers have come to a consensus that Chinese character processing involves sub-character processing with the decomposition of characters into sub-character units (e.g., Ho, Ng, & Ng, 2003; Taft & Zhu, 1997; Wu, Zhou, & Shu, 1999).

There has been considerable interest in the character processing in Chinese in the recent years. One reason is that the development of models of word processing has been based primarily on studies of alphabetic languages, and Chinese script presents a great contrast to

alphabetic scripts (Perfetti, Liu & Tan, 2005). In Chinese, there are some sub-character units (e.g., 尹 in 爭) which do not possess meaning and pronunciation, suggesting the processing of Chinese characters may not always happen simultaneously with phonological and semantic processing (Shu, 2003). In alphabetic scripts, the basic units, letters, carry their own pronunciations, and "pure orthographic" processing appears to be impossible. The presence of pure orthographic units makes the Chinese script an excellent platform for researchers to study orthographic processing, and this study intended to utilize this particular feature of Chinese to study character processing.

Theoretical models of Chinese processing

Several theoretical models have been suggested in explaining the processing of Chinese characters, and most of them focus on reading (Sears, Hino, & Lupker, 1999). Two commonly adopted models are the multilevel interactive-activation model proposed by Taft and Zhu (1997) and the lexical constituency model proposed by Perfetti and Tan (1999).

In the multilevel interactive-activation model, lexical memory is viewed as a hierarchy of levels, including stroke level, radical level and character level. During the processing of Chinese characters, each level of representation is activated and the activation spreads through the hierarchy from the stroke level, through the radical level, to the character level. The activation can subsequently pass to the corresponding phonological units and semantic units at the character level.

The lexical constituency model suggests that there are four separate constituent representation subsystems, including the character orthographic, the noncharacter orthographic, the phonological and the meaning subsystems. The character orthographic units are connected with the phonological and meaning units, whereas the noncharacter orthographic units are linked with the meaning units. In this model, all the orthographic units, including character and noncharacter, are connected to meaning and/ or phonological units.

One main difference between these two models is that there is no pure orthographic unit, which does not possess meaning and pronunciation, in the lexical constituency model, while there can be such a level of representation in the multilevel interactive-activation model. This study manipulated pure orthographic units, and aimed to confirm the presence of this psychological entity. When the psychological entity of pure orthographic units was present, it would appear to be more consistent with the multilevel interactive-activation model.

Research on reading and writing Chinese

A number of studies have been conducted on sub-character processing of reading in Chinese. The majority of these studies took phonetic radicals and semantic radicals as the basic sub-character units, suggesting Chinese characters were decomposed from visual input into their phonetic and semantic radicals to activate their own phonological and semantic properties in both adult skilled readers (Zhou, Lu, & Shu, 2000; Zhou & Marslen-Wilson, 1999) and primary school students (Wu et al., 1999).

More recently, studies have also shown that positional information placed an influence on activating the sub-character information during character recognition (Ding, Peng, & Taft, 2004; Ho et al., 2003; Shu, 2003; Taft, Zhu & Peng, 1999). Even preschoolers and primary school students made use of their positional knowledge in character decision (Chan & Nunes, 1998; Shu & Anderson, 1999), suggesting that positional information played a role in processing of reading and was acquired at the early stage of learning.

The relationship between reading and writing has been controversial in literature (Tainturier & Rapp, 2001). Some studies regarded reading and writing as distinct processing components (e.g., Caramazza, 1988), whereas some regarded them as shared processing components with exception of the more peripheral processes (e.g., Behrmann & Bub, 1992). With this dubitable relationship between reading and writing, it appears to be inappropriate to apply directly the results of studies on reading to writing.

In comparison with those on reading, studies on writing were more preliminary and relatively few. Some studies took phonetic radicals and semantic radicals as the basic units in writing, and they suggested that reading and writing demonstrated similar processing rules in phonetic radicals and semantic radicals (Meng, Shu & Zhou, 2000a; Meng, Shu & Zhou, 2000b). Many studies took smaller sub-character units, logographemes (Lam, 2004; Law, Ki, Chung, Ko, & Lam, 1998; Law & Leung, 2000), as the basic units in writing. It was shown that some phonetic radicals and semantic radicals could be further decomposed (Chen, Zhou,

& Chen, 1987). The basic units, logographemes, were conceptually comparable to letters in alphabetic writing systems (Law & Leung, 2000). Unlike the use of positional information in reading, the use of positional information in the writing had not been widely studied.

In view of the lack of empirical data on the use of positional information of the basic units in writing, the present study aimed at determining whether smaller units, logographemes, were activated in the processing and whether their positional information was processed. The identification of basic units in writing would be important for constructing writing models. The use of positional information of the logographemes would further support that the lexical representation in writing was attained via the processing at the logographeme level (Taft & Zhu, 1997).

Basic units of writing

There have been a variety of terms applied in literature to describe the basic units of writing in Chinese, resulting in a potential confusion. These terms included “logographemes” (e.g., in Law & Leung, 2000), “radicals” (e.g., in Taft & Zhu, 1997), “bujian” (e.g., in Chen et al., 1987), “components” (e.g., in Feldman & Siok, 1997) and “subcomponents” (e.g., in Shu, 2003). Although the term “radicals” was the most commonly used in literature, it was not adopted in the present study. It was because it would be easily confused with the phonetic radicals and semantic radicals in phonetic compounds, and many of these radicals could be further decomposed into smaller units (Taft & Zhu, 1997). The term “logographeme” was

selected in this study because it described its nature specifically, with Chinese characters often referred to as “logographs” and the term “grapheme” often used to represent the basic unit in spelling (Law & Leung, 2000). Logographemes referred to the basic units of writing in Chinese.

Law and Leung (2000) proposed an inventory of logographemes for traditional Chinese characters based on the writing errors of a dysgraphic adult patient. The inventory was adopted in this study because it provided clear rules in identifying logographemes in traditional Chinese characters, which included the rule of spatial separation, replaceability of components and co-occurrence of components. The logographemes identified were generally larger than a stroke and smaller than a character (Chen et al., 1987). Their inventory of logographemes and the Hong Kong Corpus of Primary School Characters (HKCPSC) (Leung & Lee, 2002) were used as the reference in the establishment of corpus of logographemes in this study to provide the frequency statistics for the logographemes in different grades of primary school. HKCPSC was compiled of Chinese characters collected from Chinese and General Studies textbooks and workbooks in Hong Kong where approximately 90% of students’ written words originated. It provides a representative database for written characters exposure in ordinary primary schools.

Developmental studies of learning Chinese characters

Reading and writing are learnt behaviors, and children’s knowledge of processing

grows with increasing experience with written materials. The recent studies suggested that children processed Chinese characters as an unanalyzed whole at the early stage of learning, and after encountering similar stroke patterns repeatedly, they began to be aware of the sub-character units and develop adult-like sub-character processing skills (Ho et al., 2003; Shu & Anderson, 1997). It was generally agreed that Grade Four students had mastered the mature sub-character processing of reading (Ho et al., 2003) and writing in Chinese (Meng et al., 2000a; Pak et al., 2005). On the other hand, it was demonstrated by studies on reading that the sub-character processing of Chinese was still developing in Grade One students (Ho et al., 2003; Shu & Anderson, 1997). The development of sub-character processing was further investigated in terms of writing in this study.

Characteristics of the current study

This study utilized the absolute token frequency (AF) and the positional-sensitive token frequency (PF) of logographemes to determine whether the logographeme level of representation was activated, and whether their positional codes were processed during writing. AF referred to the frequency of occurrence of logographemes regardless of their positions, and PF referred to the frequency of occurrence of the logographeme at one particular position in characters. Both of them were token frequencies which indicated how often the logographemes were encountered. The more often the units were encountered, the more accurate these units were processed (Taft & Zhu, 1997). If the accuracy of output was

influenced by AF and PF, it would support that the level of logographeme was passed through and the positional information was processed before reaching a higher level, the character level (Luan, Shu, & Zhang, 2001; Taft & Zhu, 1997). Meanwhile, this study deliberately manipulated only logographemes which possessed neither meanings nor pronunciations, and it aimed at providing stronger evidences of the presence of the psychological entity in Chinese character processing which was not interfered by semantic and phonological processing.

By investigating the performance of students in different primary grades, the development of the logographeme level of representation and their positional code, if any, in children could be captured.

Method

Participants

A total of 60 Chinese children, 30 in Grade One (mean age = 6 years, 10 months) and 30 in Grade Four (mean age = 9 years, 10 months), were recruited from an ordinary government-subsidized primary school in Hong Kong. There were 15 boys and 15 girls in Grade One, and 13 boys and 17 girls in Grade Four. They were tested at the end of the first semester of their academic year.

Four standardized tests were administrated initially to control for the confounding factors like below-aged reading ability, nonverbal cognitive ability, visual memory ability,

visual spatial ability and visual-motor coordination. These tests included the Standardized Graded Character Naming Test for School-age Children in Hong Kong (Leung, Chang-Lai, & Kwan, 2006), the Raven's Standard Progressive Matrices (Raven, 1986), the Visual memory test and the Visual spatial test of the test of Visual-Perceptual Skills (non-motor) Revised (Gardner, 1996a) and the Test of Visual-Motor Skills (Gardner, 1996b). All the participants demonstrated normal reading ability (within -1.46*SD* to +1.80*SD*), nonverbal cognitive ability (within -1.33*SD* to +2.33*SD*), visual memory ability (within -1.27*SD* to +1.73*SD*), visual spatial ability (within -1.13*SD* to +2.20*SD*) and visual-motor coordination (within -1.33*SD* to +2.00*SD*).

Design

A 2 (grade) × 2 (AF) × 2 (PF) mixed factorial design with a delayed copying paradigm of pseudocharacters was adopted. Grade (Grade One versus Grade Four) was the between-group factor, and AF of logographemes (high versus low) and PF of logographemes (high versus low) were the within-group factors.

Delayed copying paradigm was adopted to make the processing of pseudocharacters similar to the processing of writing of real characters which involved the temporary storage of logographemes (Tainturier & Rapp, 2001).

Materials

A number confronting factors were controlled in the preparation of stimuli for the

experiment. These factors included the semantic and phonological representations of stimuli and their corresponding logographemes, the number of strokes and the structure of stimuli.

In order to avoid simultaneous activation of semantic and phonological representations of real characters, only pseudocharacters were employed. Similarly, only logographemes that were neither phonetic radicals nor semantic radicals were manipulated. When the logographeme was a phonetic radical or a semantic radical, its semantic representation and phonological representation would be activated (Zhou & Marslen-Wilson, 1999; Wu et al., 1999). The activation of semantic and phonological representations would affect the accuracy of pseudocharacters, and it might confound the independent variables (AF and PF).

The number of strokes in pseudocharacters and logographemes was controlled. The number of strokes affected the complexity of characters and the difficulty in processing of Chinese characters (Yu & Cao, 1992; Zhang, Zhang, Zhou, & Shu, 1999), and it would affect the accuracy of pseudocharacters.

Pseudocharacters of vertical top-bottom structure were constructed for the present study. Most Chinese characters are of horizontal left-right structure or vertical top-bottom structure (Feldman & Siok, 1997), and the number of logographemes which are neither phonetic radicals nor semantic radicals in horizontal left-right structure is relatively small. Consequently, pseudocharacters of only vertical top-bottom structure were employed to promote external validity.

Thirty-two pseudocharacters were constructed as targets for each grade, and each pseudocharacter was comprised of two logographemes in vertical top-bottom structure (see Appendix A and B). The pseudocharacters were divided into four conditions according to the corresponding AF and PF of the top and bottom logographemes calculated from the Hong Kong Corpus of Primary School Characters (HKCPSC) (Leung & Lee, 2002). The experimental design and sample stimuli are presented in Table 1.

Procedures

All pseudocharacters were in *biu-kai* font (標楷體) because this font is commonly adopted in primary school textbooks. The pseudocharacters were generated by a graphic editing software (CorelDraw 11) and stored as individual image files on a hard disk. Stimuli were presented to participants through a projector on a 1.8 m × 1.8 m classroom screen using PowerPoint 2000. The order of presentation of the stimuli was arranged in a Latin square such that pseudocharacters of each condition preceded and followed those of other conditions equally often to balance the possible practice effects of repeated testing.

Pilot study was conducted prior to the experiment. The duration of exposure of pseudocharacters and the duration of delay in writing were altered in each grade in order to prevent the possible floor effect observed in Grade One and the possible ceiling effect observed in Grade Four.

In the experiment, the participants were seated in a classroom in groups of about twenty,

Table 1

Design and Sample Stimuli

	High AF		Low AF	
	High PF	Low PF	High PF	Low PF
Pseudocharacter	金	貝	弊	隶
AF *Mean (range)*				
Grade 1	721	748	149	117
	(208 - 1908)	(204 - 1627)	(118 - 175)	(46 - 164)
Grade 4	1794	1995	266	251
	(1161 - 2645)	(859 - 4214)	(142 - 396)	(100 - 616)
PF *Mean (range)*				
Grade 1	150	23	119	27
	(64 - 301)	(6 - 42)	(88 - 151)	(7 - 37)
Grade 4	786	43	226	34
	(305 - 1480)	(20 - 88)	(140 - 308)	(27 - 49)
Number of strokes				
Mean (range)				
Grade 1	8.8 (6-10)	9.0 (7-10)	9.5 (6-12)	9.0 (7-12)
Grade 4	9.5 (8-12)	9.3 (8-11)	9.3 (8-12)	9.5 (8-11)

seating about one meter away from each other and four meters away from the screen. About seven clinicians were present in each test session to monitor the participants' behaviors and ensure they followed the instructions given.

In each trial, each pseudocharacter was presented for six seconds for Grade-One students and four seconds for Grade-Four students, followed by two slides of random Arabic digits for Grade-One students and six slides of random Arabic digits for Grade-Four students. Each Arabic digit lasted for 1 second. The participants were told to clap their hands and read aloud the Arabic digits to prevent any copying and verbal production of associated characters, which may lead to the activation of characters. The participants were asked to write down the stimuli they saw when a slide signifying 'start writing' appeared.

The whole procedure was divided into two sessions and a 10-minute break was given between the sessions. A list of four practice trials were shown at the beginning of each session, and four fillers were inserted in the sessions. The complete test sessions for each group of participants lasted for about 45 minutes.

Results

To examine the effects of AF and PF in writing in each grade, the number of correct pseudocharacters written by each participant in each condition was determined. Pseudocharacters were scored as correct only if both logographemes were the same as their targets and were at the same positions as those in the targets. Mean number of correct

pseudocharacters with the corresponding 95% confidence intervals is plotted in Figure 1. There was a general pattern in Grade Four that pseudocharacters with high AF demonstrated higher accuracy than those with low AF, and those with high PF had higher accuracy than those with low PF. However, no such pattern was observed in Grade One.

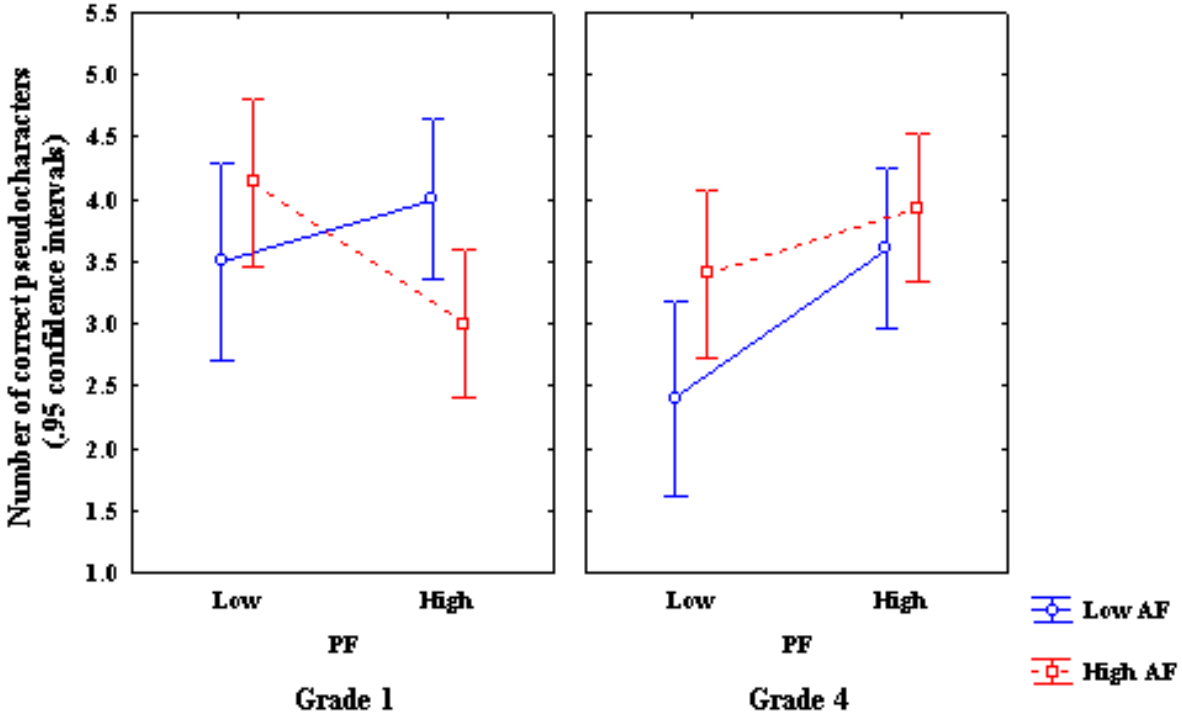

Figure 1. Mean number of correct pseudocharacters (out of possible eight) as a function of grades, PF and AF

Overall analyses were first conducted, using repeated measure analysis of variance (ANOVA), with the grade as a between-subject factor and AF and PF as within-subject factors. The interaction amongst the three factors, grade, AF and PF, was not significant. However, the interactions between AF and grade [$F(1, 58) = 6.88$, $p < .05$], between PF and grade [$F(1, 58) = 7.65$, $p < .01$], and between AF and PF [$F(1, 58) = 12.13$, $p < .001$] were

significant, and it indicated that the patterns of AF and PF effects were not the same for the two grades and the patterns of PF effect were not the same for the two levels of AF. The interaction effects were analyzed with Tukey HSD post-hoc comparisons. The results showed that pseudocharacters with high AF had significantly higher accuracy than those with low AF in Grade Four ($p < .05$), and those with high PF had significantly higher accuracy than those with low PF in Grade Four ($p < .05$). However, the effects of AF and PF were not significant in Grade One.

To further study the frequency effects in each grade, separate analyses were then conducted for each grade. For Grade One, the interaction effect between AF and PF was significant [$F(1, 29) = 12.41$, $p < .005$]. Tukey HSD post-hoc comparisons showed that pseudocharacters with high PF had significantly lower accuracy than those with low PF when the AF was high ($p < .05$). However, no significant difference between the two levels of PF was noted when the AF was low.

For Grade Four, the interaction effect was not significant, indicating that there were similar patterns of PF effects for the two levels of AF. The main effects of AF [$F(1, 29) = 9.28$, $p < .005$] and PF [$F(1, 29) = 7.56$, $p < .05$] were significant. Tukey HSD post-hoc comparisons showed that pseudocharacters with high PF had significantly higher accuracy than those with low PF when the AF was low ($p < .01$), whereas there was no such significant difference when the AF was high.

In conclusion, only Grade-Four students demonstrated expected AF effect and PF effect, in which pseudocharacters with high token frequency demonstrated higher accuracy than those with low token frequency. The difference in accuracy between pseudocharacters with high and low PF was significant only when AF was low in Grade Four.

Discussion

In this study, the development of sub-character processing in writing of Chinese characters in primary school students was investigated. The significant frequency effects of logographemes in Grade Four was consistent with the finding of Meng et al. (2000a) and Pak et al. (2005), suggesting Grade Four students demonstrated sub-character processing in writing similarly as adult skilled users.

Psychological entity of logographemes

The significant AF and PF effect of logographemes observed in Grade Four supported that logographemes were the basic units of representation activated during the writing of Chinese characters in children. When a level of representation was activated in the processing, the properties of that representation would alter the accuracy of output (Taft & Zhu, 1997). In this study, the accuracy of pseudocharacters was affected by the AF and PF of the logographeme, and it was thus suggested that the level of logographeme was activated.

Only logographemes that were neither phonetic nor semantic radicals were adopted in this study, and these logographemes could be combined with other logographemes to form

phonetic and semantic radicals. The results of this study were consistent with many recent studies (Lam, 2004; Law et al., 1998; Law & Leung, 2000), suggesting logographemes, instead of phonetic and semantic radicals, were the basic units of processing in writing Chinese characters. It further confirmed that in Chinese character processing, there was a level of representation that could be purely orthographic and did not possess semantic nor phonological information.

While this study supported that there was a logographeme level in the processing of writing in Chinese, the results did not preclude the possibility of the presence of another level of phonetic and semantic radicals. However, if the radical level was present, it was likely to be placed in-between the logographeme level and the character level in the activation. It was because logographemes could be the building blocks to form phonetic and semantic radicals. In fact, the results of some studies on the effects of phonetic and semantic radicals in writing suggested that there could be a level of representation for phonetic and semantic radicals (Meng et al., 2000a; Meng et al., 2000b).

Positional information of logographemes

The positional information of logographemes was investigated by manipulating PF in the study. The significant PF effect observed in Grade Four supported that positional information of logographemes was processed in writing, and it was similar to studies in reading (Taft et al., 1999; Taft & Zhu, 1997). One question raised in these studies was that

whether logographemes of different positions (e.g., 业 in 並 and 業) were distinct units of processing. The results of the present study provided some clues to this question.

While there was a significant PF effect in Grade Four, the AF effect was also significant. When logographemes of different positions were distinct units of representation in processing, the accuracy of logographemes of similar PF would be similar regardless of the AF. However, the results of the study showed that the accuracy of pseudocharacters with high AF were significant higher than that of pseudocharacters with low AF. The significant AF effect suggested that units of different position were unlikely to be distinct from the others.

Developmental patterns

While children's experience with print languages increases, their knowledge of sub-character is expected to grow. When children encounter the same stroke patterns repeatedly in different words, these stroke patterns consolidate into units which are processed as wholes. The representation of logographemes will gradually develop.

The significant frequency effects of logographemes observed in Grade Four students suggested that the representation of logographemes and their positional codes have been developed by Grade Four. The results were consistent with findings of previous studies (Meng et al., 2000a; Pak et al., 2005), and it tended to support that Grade Four students had mature sub-character processing skills in writing which were similar to those of adult skilled users.

Similar to the studies on reading (Ho et al., 2003; Shu & Anderson, 1997), the results of this study suggested that the sub-character processing skills in Grade One students were still developing. The absence of significant AF and PF effect tended to support that Grade One students had not mastered the mature form of different levels of representation, and they did not make systematic use of sub-character units, logographemes, as the adult skilled users did.

One interesting finding in Grade One was that pseudocharacters with high PF demonstrated significantly lower accuracy than that with low PF when AF was high. The results contradicted with the typical frequency effects, which suggested that increasing the token frequencies would increase the accuracy (Taft & Zhu, 1997). The stimuli employed for Grade One in this study were thus reviewed, and it was noted that logographemes with high AF and high PF also demonstrated higher type frequencies than the other groups. Type frequency referred to the number of different characters containing the logographemes, and it had been proposed that increasing the type frequency could increase the chance for competition during processing, resulting in an inhibitory effect (Taft & Zhu, 1997). The contradictory results observed in Grade One might suggest that there was an increased weight on type frequency at the early grades when the representation of logographemes was still developing. However, further research would be necessary to support this claim.

Theoretical implications

The significant effects of AF and PF observed in Grade Four suggested that the

processing of writing in Chinese could pass through a level of pure orthographic processing without the interference of semantic and phonological processing. The presence of the pure orthographic units did not go along with the lexical constituency model, in which the orthographic units were always connected with the semantic units and/ or phonological units (Perfetti & Tan, 1999). On the other hand, the results appeared to be consistent with the multilevel interactive-activation model proposed by Taft and Zhu (1997). In the multilevel interactive-activation model, the processing of Chinese characters spreads through the hierarchy of stroke, logographeme and character in the orthographic subsystem before activating the phonological and semantic subsystems. The significant AF and PF effects observed in this study suggested that the logographeme level in the hierarchy was activated in writing, and the processing of this level could be isolated from phonological and semantic processing.

This study further supplemented the present interactive-activation model by emphasizing the activation of positional code of logographemes. The significant effect of PF not only supported that the logographeme level was activated (Taft & Zhu, 1997), but also pointed out that the positional information was processed at this level. Although there was no conclusive result on how the positional information was stored, this study demonstrated clearly that positional information was activated at this level.

Similar to many studies on reading Chinese (e.g., Ding et al., 2004; Taft & Zhu, 1997),

this study demonstrated that the sub-character processing interacted with the frequency, and there were different patterns of PF effect in high and low AF conditions in Grade Four. While significant PF effect was noted at low AF, there was no PF effect observed at high AF. This suggested that when AF of logographemes was low, positional information was activated during the processing. However, when the AF was high, the logographemes were activated directly without the intervention of positional information. This pattern was similar to the reading studies and agreed with the multilevel interactive-activation model that some information might not be activated at high frequency conditions.

Educational implications

The results of this study were consistent with many recent research findings (Lam, 2004; Law et al., 1998), confirming that logographemes were important orthographic units in the writing of Chinese characters for children. It also suggested that the positional information of logographemes was processed in writing. These findings provided some useful educational implications for Chinese teachers.

Chinese teachers in Hong Kong traditionally have emphasized on drilling and rote memorization of the Chinese characters. They have placed little attention on the sub-character orthographic units, and employed a “whole-character approach” in teaching Chinese (Ho, Wong, & Chan, 1999). After exposing to a sufficient amount of Chinese characters, children are expected to acquire the knowledge of logographemes and their positional information

spontaneously. Some children, however, may fail to acquire this knowledge, resulting in poor writing abilities. Knowing that logographemes are important orthographic units in writing, it is proposed that explicit teaching of the units of logographemes and their positional information can be facilitative to the development of children's decoding skills and writing ability. In order to test this hypothesis, a training study with Chinese children with dyslexic can be conducted in the future.

Limitations and suggestions

Although the present study was a preliminary study on children's writing development in Chinese, it has laid a good foundation for future research. Outlining the limitations of the study in this section would help to propose suggestions for further research.

The first limitation of the present study was that the database adopted was based on the reading materials in textbooks. There was a general assumption that the reading frequency was approximately equal to the writing frequency. Despite the fact that over 80% of the written materials were taken from the reading materials in textbooks as reported by the participating school, it might still not be justified to say the reading frequency was exactly equal to the writing frequency. Researchers may consider establishing a database on the writing materials in textbooks and manipulating the writing frequency directly in their future studies.

The second limitation was that only the token frequency effect was investigated in this

study. Apart from the token frequency, it has been proposed that other factors could influence the sub-character processing of logographemes. As suggested above, type frequency, which referred to the number of different characters containing the logographemes, could have an effect on writing. Increasing the type frequency could increase the competition in the activation, resulting in reduced accuracies (Taft & Zhu, 1997). Besides, more recent studies suggested that the positional consistency of logographemes, which described whether the logographemes always appeared at the same position in different characters, could have an important effect in naming Chinese characters (Lee, Tsai, Su, Tzang, & Hung, 2005). Therefore, future research may consider taking factors like type frequency and positional consistency of logographemes into account.

Lastly, this study was a cross-sectional study covering two grades only over a short assessment period. The results suggested that there were great developmental changes between the performances of the two grades. Cross-sectional studies covering more grades and longitudinal studies over a longer assessment period in the future will help to identify more detailed developmental patterns in learning to write Chinese characters in children.

References

Behrmann, M., & Bub, D. (1992). Surface dyslexia and dysgraphia: dual routes, single lexicon. *Cognitive Neuropsychology, 9,* 209-251.

Caramazza, A. (1988). Some aspects of language processing revealed through the analysis of acquired dysgraphia: the lexical system. *Annual Review of Neuroscience, 11*, 395-421.

Chan, L., & Nune, T. (1998). Children's understanding of formal and functional characteristics of written Chinese. *Applied Psycholinguistics, 19,* 115-131.

Chen, A. -W., Zhou, J. -Z., & Chen, S. -N. (1987). *Hanzi zixingxue he biaosing fuhao bianma (Chinese logography and the coding of pictographic symbols).* Beijing: Guangmingribao chubanshe (in Chinese).

Ding, G. -S., Peng, D. -L., & Taft, M. (2004). The nature of the mental representation of radicals in Chinese: a priming study. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(2), 530-539.

Feldman, L. B., & Siok, W. W. T. (1997). The role of component function in visual recognition of Chinese character. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(3), 776-781.

Gardner, M. F. (1996a). *Test of Visual-Perceptual Skills (non-motor) Revised.* San Francisco: Psychological and Educational Publications.

Gardner, M. F. (1996b). *Test of Visual-motor Skills Revised.* San Francisco: Psychological and

Educational Publications.

Ho, C. S. -H., Ng, T. -T., & Ng, W. -K. (2003). A radical approach to reading development in Chinese: the role of semantic radicals and phonetic radicals. *Journal of Literacy Research, 35*(3), 849-978.

Ho, C. S. -H., Wong, W. -L., & Chan, W. -S. (1999). The use of orthographic analogies in learning to read Chinese. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 40*(3), 393-403.

Hoosain, R. (1991). *Psycholinguistic implications for linguistic relativity: a case study of Chinese.* Hillsdale: Erlbaum.

Lam, M. P. -M. (2004). *Spelling without sound and meaning.* Unpublished bachelor dissertation. The University of Hong Kong.

Law, S. -P., & Caramazza, A. (1995). Cognitive processes in writing Chinese characters: basic issues and some preliminary data. In B. de Gelder, & J. Morais (Eds.), *Speech and reading: comparative approaches* (pp. 143-190). Hove: Lawrence Erlbaum.

Law, N., Ki, W. -W., Chung, A. L. -S., Ko, P. Y., & Lam, H. -C. (1998). Children's stroke sequence errors in writing Chinese character. *Reading and Writing: an Interdisciplinary Journal, 10*, 267-292.

Law, S. -P., & Leung, M. -T. (2000). Structural representations of characters in Chinese writing: evidence from a case of acquired dysgraphia. *Psychologia, 43*, 67-83.

Lee, C. -Y., Tsai, J. -L., Su, E. C. -I., Tzeng, O. J. -L., & Hung, D. -L. (2005). Consistency, regularity and frequency effects in naming Chinese characters. *Language and Linguistics, 6*(1), 75-107.

Leung. M. -T., & Lee, A. (2002). *The Hong Kong corpus of primary school characters (HKCPSC)*. Paper presented at the 9th meeting of the International Clinical Phonetic and Linguistic Association, Hong Kong.

Leung, M. -T., Chang-Lai, A., & Kwan, E. (2006). *The standardized graded character naming test for school-age children in Hong Kong.* Paper to be presented at the annual general meeting of the Hong Kong Psychological Society, Hong Kong.

Liu, I. -M. (1988). Context effects on word-character naming: alphabetic versus logographic language. In I. -M. Liu, H. -C. Chen, & M. -J. Chen (Eds.), *Cognitive aspects of the Chinese language* (pp. 81-92). Hong Kong: Asian Research Services.

Luan, H., Shu, H., & Zhang, D. (2001). The characteristics and factors affecting children's character output under the dictation task. *Psychological Development and Education, 17,* 1-5 (in Chinese).

Meng, X. -Z., Shu, H., & Zhou, X. -L. (2000a). Children's Chinese character structure awareness in character output. *Psychological Science, 23*(3), 260-264 (in Chinese).

Meng, X. -Z., Shu, H., & Zhou, X. -L. (2000b). The relationship between tasks in Chinese reading development research. *Psychological Science, 23*(6), 677-681 (in Chinese).

Pak, A. K. -H., Cheung-Lai, A., Tso, I. F., Shu, H., Li, W. -L., & Anderson, R. C. (2005). Visual chunking skills of Hong Kong children. *Reading and Writing, 18,* 437-454.

Perfetti, C. A., Liu, Y., & Tan, L. -H. (2005). The lexical constituency model: some implications of research on Chinese for general theories of reading. *Psychological Review, 112*(1), 43-59.

Perfetti, C. A., & Tan, L. -H. (1999). The constituency model of Chinese word identification. In J. Wang, A. W. Inhoff, H. -C. Chen (Eds.), *Reading Chinese script: a cognitive analysis* (pp. 115-134). Mahwah: Lawrence Erlbaum Associates.

Raven, J. C. (1986). *Hong Kong supplement to guide to the standard progressive matrices.* Hong Kong: Education Department.

Sears, C. R., Hino, Y., & Lupker, S. J. (1999). Orthographic neighbourhood effects in parallel distributed processing models. *Canadian Journal of Experimental Psychology, 53*(3), 220-229.

Shu, H. (2003). Chinese writing system and learning to read. *International Journal of Psychology, 38*(5), 274-285.

Shu, H., & Anderson, R. C. (1999). Learning to read Chinese: the development of metalinguistic awareness. In J. Wang, A. W. Inhoff, & H. C. Chen (Eds.) *Reading Chinese script: A cognitive analysis* (pp. 1-18). Mahwah: Erlbaum.

Taft, M., & Zhu, X. -P. (1997). Submorphemic processing in reading Chinese. *Journal of*

Experimental Psychology: Leaning, Memory, and Cognition, 23(3), 761-775.

Taft, M., Zhu, X. -P., & Peng, D. -L. (1999). Positional specificity of radicals in Chinese character recognition. *Journal of Memory and Language, 40,* 498-519.

Tainturier, M. J., & Rapp, B (2001). The spelling process. In B. Rapp (Ed.), *Handbook of cognitive neuropsychology: what deficits reveal about the human mind* (pp. 263-289). Philadelphia: Psychology.

Wu, N. -N., Zhou, X. -L., & Shu, H. (1999). Sublexical processing in reading Chinese: a development study. *Language and Cognitive Processes, 14,* 503-524.

Yu, B., & Cao, H. (1992). A new exploration on the effect of stroke number in the identification of Chinese characters. *Acta Psychologica Sinica, 24*(2), 120-126 (in Chinese).

Zhang, D. -C., Zhang, H. -C., Zhou, X. -L., Shu, H. (1999). Production of Chinese characters under dictation. *Applied Linguistics, 29*(1), 67-70 (in Chinese).

Zhou, X. -L., Lu, X. -M., & Shu, H. (2000). The nature of sublexical processing in reading Chinese: phonological activation of semantic radicals. *Acta Psychologica Sinica, 32*(1), 20-24 (in Chinese).

Zhou, X. -L., & Marslen-Wilson, W. (1999). The nature of sublexical processing in reading Chinese characters. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(4), 819-837.

Appendix A

Stimuli Used for Grade One Students

High AF		Low AF	
High PF	Low PF	High PF	Low PF
鼻	言	髦	無
表	馬	鼻	爺
身	黑	面	爭
罕	眉	奉	家
鼻	言	髦	爭
隶	鬲	鼻	爸
长	冒	毛	豢
罕	犀	春	虛

Appendix B

Stimuli Used for Grade Four Students

High AF		Low AF	
High PF	Low PF	High PF	Low PF
金	臭	弊	隶
罕	隼	爭	寘
鳥	舁	畫	肩
虛	眉	鼠	隸
金	皐	豐	隶
罟	爸	鼠	隶
鳥	癸	弊	辰
亞	屏	奉	隸

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