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<td><strong>Other Contributor(s)</strong></td>
<td>University of Hong Kong</td>
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The size of processing unit of writing Chinese characters

in normal primary students

Jim Wai Kwan, Jenny

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2008.
Abstract

The present study aimed to investigate the size of processing unit of writing Chinese characters of normal primary students across grades. Eighty-six primary students from grade two, grade four and grade six were recruited as participants in the present study. An experimental task of delayed copying of pseudo-characters varied in stroke number, logographeme number and radical frequency was administered. Results showed a developmental change of processing unit from a small size unit (logographeme) to a large size unit (radical) from grade two to grade six students. Logographeme and radical were showed to be existed as psycholinguistic entities in grade two and grade four students and radical existed as psycholinguistic entity in grade six. Error analysis also showed prominent substitution errors with two logographemes which corresponded to a larger unit existed in real characters. It is concluded that developmental data appears to support the claim that Chinese character is hierarchically represented.
Introduction

A number of studies on the spelling errors of dysgraphic patients investigated the functional architecture of spelling in alphabetic language (Caramazza & Miceli, 1990; Caramazza, Miceli, Villa & Romani, 1987; Hillis & Caramazza, 1989; McCloskey, Badecker, Goodman-Schulman & Aliminosa, 1994). Spelling was explained as involving two processes, the formation of abstract graphemic representation and the transformation of graphemic representation to graphomotor code for spelling (Caramazza et al., 1987). The identification of basic processing unit in spelling was an important issue to be addressed during the investigation of functional architecture of spelling.

In order to understand the functional architecture of Chinese writing system, investigation on the size of processing unit in Chinese character writing was indispensable. In alphabetic script, spelling included oral spelling and written spelling (Caramazza et al., 1987). However, writing was defined as the peripheral process of motor execution of the orthographical code into the written form (Barry, 1994). In the present study, writing was used instead of spelling in discussing the structural representation of Chinese writing system.

Characteristics of Chinese script

The Chinese writing system was described as logographic, in which each Chinese character ‘corresponds to a morpheme - the minimal meaningful unit of language’ (Scholfield, 1994). A morpheme in Chinese script is usually represented by a Chinese character (Weekes,
Yin, Su & Chen, 2006). It was reported that character was the ‘building block of written
Chinese’ and all Chinese characters were written in a square-shape area (Chen, 1996). A
number of studies found that the speed in recognizing Chinese characters was affected by the
number and frequency of sub-character components, for example, number of stroke, number
of stroke pattern and frequency of radical (Chen & Allport, 1996; Peng & Wang, 1997; Taft &
Zhu, 1997). These studies supported the claim that Chinese characters have internal structures.
The complexity of a Chinese character depends on the ‘density and internal structure’ within a
square area (Li & Chen, 1997). According to database of Hong Kong Corpus of Primary
School Characters (HKCPSC), around 70% of Chinese characters are compound characters
which are made up of phonetic and semantic radicals (Leung, 2002).

Previous studies on the orthographical processing units in Chinese

Taft and Zhu (1997) argued that Chinese character recognition involved processing of
hierarchically structured levels: stroke, radical and character. A stroke is the smallest writing
unit in Chinese writing system and it was defined as ‘a line made between the points at which
the pen touches and leaves the paper’, for example, —, 丿 and 丶. (Law & Leung, 2000).
Chen and Allport (1996) found that the response time of same and different comparison task
in recognizing Chinese characters was affected by the number of stroke pattern but not the
number of stroke. Stroke pattern was argued to be the functional orthographical unit in
Chinese character recognition. However, stroke pattern was not defined clearly in that study.
The frequency of the stroke pattern was also not controlled, which may become a
confounding variable. Peng and Wang (1997) found processing time of characters with more
strokes was longer than that of characters with fewer strokes in reading aloud and lexical
decision tasks. Processing time of low frequency characters with more number of ‘bujian (部件)’ was also longer than that of low frequency characters with less number of ‘bujian (部件)’.

It was argued that processing of Chinese character involved three different levels: stroke,
‘bujian (部件)’ and character. However, one of the shortcomings of the study was the absence
of detailed explanation of the characteristics of stimuli and it was uncertain about the
definition of ‘bujian (部件)’. Taft and Zhu (1997) argued that radical played a role in
processing of Chinese character recognition since radical frequency and radical position were
found to be affecting the response time in character decision task. These studies showed
consistent argument that there were three different levels of representation in Chinese, but
there seemed to be different terminology concerning the second level of representation, which
was termed as ‘stroke pattern’ by Chen and Allport (1996), ‘bujian (部件)’ by Peng and Wang
(1997) and ‘radical’ by Taft and Zhu (1997).

Functional orthographical unit like signific and phonetic radicals was argued to be
affecting Chinese character recognition (Taft & Zhu, 1997). It was reasonable to hypothesize
that there was a level of representation which was orthographically smaller than a radical and
did not correspond to a functional unit. Law and Leung (2000) argued that ‘logographeme’
instead of ‘signific and phonetic radicals’ was the basic processing unit in writing based on
the writing errors of a Chinese dysgraphic patient in delayed copying task. ‘Logographeme’
was defined as a sub-character component spatially separated from and replaceable by other
component. It was an orthographical unit larger than a stroke, but smaller than a radical. For
example, 玉 was one of the pseudo-characters used in delayed copying task. It could be
divided into two parts, 皇帝 and 欠. For the first part 皇帝, the lower part of the sub-character
component 土 could be replaced by another component 兜 to become 兒. Therefore,
皇帝 could be further divided into two sub-character components, 皇帝 and 兎, which were
called logographemes. According to Law and Leung (2000), the argument that logographeme
was the basic processing unit in writing was supported first, by the most prominent error type
of logographeme errors in delayed copying task. Second, there was an increase of errors with
an increase of number of logographeme similar to the word length effect showed in spelling
errors of dysgraphic patients of alphabetic language (Caramazza et al., 1987; Hillis &
Caramazza, 1989). Structural representation of Chinese was also argued to be hierarchical
based on the fact that ‘in errors where two or more logographemes are involved, the
logographemes often form larger units that may appear in real characters (Law & Leung,
2000). In Taft and Zhu’s study (1997), the largest sub-character component, radical, included
both compound radical (which made up of more than one logographeme) and simple radical
(which made up of one logographeme). In the present study, radical referred to compound
radical which included phonetic and semantic radicals, which was the same as signific and phonetic radicals as stated in Law and Leung (2000). For example, using the same example 钦, it was constructed by two compound radicals 皇 and 久 which also existed in real compound characters. In a recent study by Han, Zhang, Shu and Bi (2007), Chinese character was argued to be hierarchically structured which composed of three orthographical units of different sizes: stroke, logographeme and radical.

Although structural representation of Chinese was claimed to be hierarchical based on a number of studies on the writing errors of dysgraphic patients, there were few Chinese studies on developmental change of size of processing unit of writing in normal developing children (Law & Leung, 2000; Han et al., 2007). Shen and Bear (2000) argued that there was an increase of orthographical knowledge of Chinese in Mandarin speaking children. In the study, participants were asked to have an essay writing task and the spelling errors were further used to devise a dictation task. The results showed a higher percentage of phonological errors in lower grade and a higher percentage of graphemic and semantic errors in higher grade. The study did not address the issue of sub-character processing unit in Chinese writing development. Moreover, the stimuli were not controlled for the number and frequency of sub-character components, for example, stroke number, radical frequency, which were suggested to affect the processing of Chinese characters (Chen & Allport, 1996; Peng & Wang, 1997; Taft & Zhu, 1997).
Lam (2004) argued that logographeme existed as a psycholinguistic entity in grade two, grade three and grade four students using a delayed copying paradigm. Grade four students were also hypothesized to chunk and process multiple numbers of logographemes as a larger unit based on their better performance in copying pseudo-characters with more number of logographeme than grade two students. However, stimuli used in Lam’s study (2004) only varied in number of logographeme, further investigation was required to verify the hypothesis of using a larger processing unit in higher grade students.

Objectives

Results of studies on adult population indicated that structural representation of Chinese was hierarchical. However, it is interesting to know how the structural representation of Chinese was developmentally. Therefore, the present study aimed at answering two research questions. First, was there a developmental change of size of processing unit of writing Chinese characters in normal primary students? Second, did the developmental change agree with the hierarchy mentioned above?

Characteristics of present study

In the present study, delayed copying task was administered. During delayed copying, the participants were required to have temporary storage of the graphemic representation of the pseudo-characters in graphemic output buffer. This paradigm was hypothesized to be similar to the process involved in normal writing and was adopted in the present study (Kay &
Hanley, 1994).

**Prediction**

According to the cognitive process of writing in Chinese dysgraphic patients, it was hypothesized that the structural representation of Chinese was hierarchical with three levels of representation: stroke, logographeme and radical (Han et al., 2007). Hierarchical representation implied that the development of radical representation depended on the integrity of the development of logographeme and the development of logographeme depended on the integrity of the development of stroke (Luria, 1973).

In the present study, the independent variables of stroke number, logographeme number and radical frequency were manipulated. If these orthographical units existed as psycholinguistic entities, the percentage of correctly copied pseudo-characters would be affected by manipulation of these variables and there would be main effects of stroke, logographeme or radical. The hierarchical structural representation of Chinese would be revealed in the interaction effects between grade and the repeated measures of stroke number, logographeme number and radical frequency. There would be a developmental change of processing unit from a smaller unit size to a larger unit size from lower grade to higher grade. If structural representation of Chinese was not hierarchical, the developmental order from smaller unit size in lower grade to larger unit size in higher grade would not occur. Error analysis was also implemented to provide additional information regarding the presence of
structural representation of Chinese. Caramazza et al. (1987) argued that ‘degradation of graphemic representation’ resulted in spelling errors of substitution, addition, transposition and deletion at a particular graphemic unit. Orthographical unit level at which there was highest number of errors across grades, would indicate its developmental prominence. Substitution errors of two or more number of logographemes which corresponded to a larger unit of radical as showed by the finding of Law and Leung (2000) would also be computed to find whether the structural representation of Chinese was hierarchical.

Methodology

Participants

Ninety-seven students from grade two, grade four and grade six were recruited from a local primary school in Hong Kong respectively. All students were screened by the Raven’s Standard Progressive Matrices (Raven’s) (Raven, 1986) and Hong Kong Graded Chinese Character Naming Test (CNT) (Leung, Ching-Lai & Kwan, 2008). Students who passed the two screening tests and had not received any speech and language therapy were recruited. The participants were also native Cantonese speakers. The screening helped to ensure that the participants had normal cognitive, visual perceptual and reading abilities. After screening, 26 students from grade two, 30 students from grade four and 30 students from grade six were recruited to participate in present experimental study respectively. The characteristics of participants were showed in Table I.
Table I.

*Age, gender and results of screening tests of participants in three grades*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Age</th>
<th>Gender</th>
<th>Raven's</th>
<th>CNT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (Range)</td>
<td>Number of male</td>
<td>Number of female</td>
<td>Mean of standard score (Range)</td>
</tr>
<tr>
<td>P2</td>
<td>7; 09 (7;01 - 9;06)</td>
<td>13</td>
<td>13</td>
<td>114 (96-135)</td>
</tr>
<tr>
<td>P4</td>
<td>11;00 (9;01 - 12;07)</td>
<td>18</td>
<td>12</td>
<td>106 (87-135)</td>
</tr>
<tr>
<td>P6</td>
<td>12;01 (11;02 - 13;04)</td>
<td>16</td>
<td>14</td>
<td>103 (88-117)</td>
</tr>
</tbody>
</table>

*Stimuli*

A delayed copying task was administered. One stimuli list consisted of 40 pseudo-characters was created for the present study. 20 pseudo-characters were of high stroke number (HS) and 20 pseudo-characters were of low stroke number (LS). For 20 high stroke pseudo-characters, 10 were of high logographeme number (HL) and 10 were of low logographeme number (LL). There were also 10 pseudo-characters of high logographeme number and 10 of low logographeme number for the 20 low stroke pseudo-characters. For the 10 high logographeme number pseudo-characters, five were of high radical frequency (HR) and five were of low radical frequency (LR). There were also five pseudo-characters of high radical frequency and five of low radical frequency for the 10 low logographeme number characters. Consequently, there were eight different groups of pseudo-characters (HS-HL-HR / HS-HL-LR / HS-LL-HR / HS-LL-LR / LS-HL-HR / LS-HL-LR / LS-LL-HR / LS-LL-LR), with five pseudo-characters in each group. The design of present study with examples in the eight different conditions was showed in Table II and the characteristics of pseudo-characters
varied in stroke number, logographeme number and radical frequency were showed in Table III. The pseudo-characters were composed of real radicals made up of logographemes placed in legitimate positions (Chen & Allport, 1996). According to HKCPSC, left-right structure characters make up of about 60% of Chinese characters (Leung, 2002). Therefore, all radicals were spatially arranged in this configuration to be representative.

Table II.

*Design of present study with examples in eight different conditions*

<table>
<thead>
<tr>
<th></th>
<th>HS</th>
<th></th>
<th>LS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HL</td>
<td>LS</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td></td>
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<tr>
<td></td>
<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
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<td>HR</td>
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<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
</tr>
</tbody>
</table>

Table III.

*Characteristics of pseudo-characters used in the stimuli list*

<table>
<thead>
<tr>
<th>Grade</th>
<th>P2</th>
<th>P4</th>
<th>P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of stroke</td>
<td>High: 18 (16-22)</td>
<td>Low: 13 (10-15)</td>
<td></td>
</tr>
<tr>
<td>Mean (Range)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of logographeme</td>
<td>High: 6 (3 in each radical)</td>
<td>Low: 4 (2 in each radical)</td>
<td></td>
</tr>
<tr>
<td>Type frequency of radical</td>
<td>High: 6 (3-17)</td>
<td>High: 9 (5-28)</td>
<td>High: 12 (6-40)</td>
</tr>
<tr>
<td>Mean (Range)</td>
<td>Low: 1 (1-2)</td>
<td>Low: 2 (1-4)</td>
<td>Low: 3 (1-5)</td>
</tr>
</tbody>
</table>

Construction of stimuli was based on the database from HKCPSC (Leung, 2002). Each of the 40 pseudo-characters was constructed by two radicals. Each of the radicals was composed of either two logographemes or three logographemes. Among the 40
pseudo-characters, 20 were constructed by two high frequency radicals and 20 were constructed by two low frequency radicals. All radicals were taken from familiar characters in grade two from HKCPSC (Leung, 2002). The radical frequency was calculated in type frequency, which meant the different number of character which consisted of a particular radical. Pseudo-characters with type frequency of radical above third quartile were named as the high radical frequency group and pseudo-characters with type frequency of radical below first quartile were named as the low radical frequency group. However, the boundary between the two groups of stimuli was close in order to control the three factors (stroke, logographeme and radical). Sixty five different radicals were used, 13 of them were semantic radicals and 52 of them were phonetic radicals. Fifteen radicals were also used twice. Most of the radicals can act as standalone characters (62/80).

The logographemes used in the present study were chosen from the database of HKCPSC (Leung, 2002). Only multi-stroke logographemes were selected to compose the pseudo-characters in order to avoid the ambiguity between a stroke error or a logographeme error during error analysis. A total of 71 different logographemes were used for composing the pseudo-characters. The frequency of logographemes was controlled across the eight groups of stimuli. The overall token frequency of logographeme of each radical was averaged. Token frequency was the total number of occurrence of a logographeme in all characters. The average of overall token frequency of logographeme of each radical in the high radical
frequency group was matched with that of the corresponding low radical frequency group. The pseudo-characters in each group were numbered and randomly ordered to become the stimuli list.

Procedure

The task was divided into two sessions, each lasted for around 45 minutes. Raven’s Standard Progressive Matrices together, followed by Hong Kong Graded Chinese Character Naming Test was conducted to individual participants in the same grade in the first session. In the second session, the delayed copying task was administrated on another day.

Before presenting the 40 experimental trials, there were three practice trials which served to familiarize the participants to the delayed copying task. Within the task, there were seven fillers. Each of which was presented after five experimental trials. The fillers were high frequency real characters. A total of 50 powerpoint slides, including three practice trials, 40 pseudo-characters and seven fillers were projected onto a screen through a LCD projector. All trials were presented in a 6cm x 6cm square with font style ‘biau kai’ (標楷體) at the centre of the powerpoint slide.

At start, a fixation point ‘+’ was showed at the centre of the slide to draw the participants’ attention. It was followed by the presentation of a pseudo-character or a filler for three seconds. After that, there was a slide with instruction asking the participants to read aloud three numbers, followed by three slides, each presenting a number showing for one
second. The numbers were used as distractors and the participants were asked to copy the pseudo-character presented after reading aloud the three numbers. They were encouraged to copy as much as they remembered. It took about 30 minutes to 50 minutes to complete the delayed copying task.

Results

Correct percentage analysis

The average numbers of correctly copied pseudo-characters across the three grades were computed and the results were showed in Table IV. There was a progressive increase in the number of correct response from grade two to grade six.

Table IV.

Average number of correctly copied pseudo-characters across three grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Average number of correctly copied pseudo-characters (standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>21.77 (6.81)</td>
</tr>
<tr>
<td>P4</td>
<td>32.37 (5.01)</td>
</tr>
<tr>
<td>P6</td>
<td>35.27 (2.73)</td>
</tr>
</tbody>
</table>

A $3 \times 2 \times 2 \times 2$ (grade x stroke number x logographeme number x radical frequency) factorial analysis of variance (ANOVA) with between group design of grade and within group design of repeated measures of stroke number, logographeme number and radical frequency with two levels each, was done to identify whether there were any main effects of grade, stroke, logographeme, radical and interaction effects between the variables.
The results showed a significant main effect of grade ($F(2, 83) = 54.12, p < .001$), with higher grade students performed better than lower grade students. Significant main effect of logographeme was also found ($F(1, 83) = 41.13, p < .001$), with low logographeme number better than high logographeme number. There was also a significant main effect of radical ($F(1, 83) = 62.59, p < .001$) with high radical frequency better than low radical frequency. However, no significant main effect of stroke was found ($F(1, 83) = 1.06, p = .31$).

Significant interaction effect between grade and logographeme was also found ($F(2, 83) = 11.84, p < .001$). Post hoc test (Fisher LSD test) showed a significant better performance in grade two ($p < .001$) and grade four ($p = .02$) at the level of low number of logographeme. However, no significant difference was showed in grade six ($p = .30$). At the level of high number of logographeme, grade six students showed significantly better performance than grade four students ($p = .01$), though grade four and grade six students performed similarly in copying characters with low number of logographeme ($p = .12$). The interaction effect between grade and logographeme was showed in Figure I. Although no significant interaction effect was found between grade and radical ($F(2, 83) = 2.87, p = .06$), post hoc test (Fisher LSD test) showed significant better performance with high radical frequency than low radical frequency in grade two ($p < .001$), grade four ($p < .001$) and grade six ($p = .007$). However, it was found that at the level of low radical frequency, grade six students performed significantly better than grade four students ($p = .004$), though they showed similar
performance in copying characters with high radical frequency (p = .23). The interaction
effect between grade and radical was showed in Figure II.

![Graph 1: Interaction effect between grade and logographeme](image1)

![Graph 2: Interaction effect between grade and radical](image2)

**Figure I.** Interaction effect between grade and logographeme

**Figure II.** Interaction effect between grade and radical

Post hoc analysis using Fisher LSD test also helped to compare the logographeme effect
and radical effect within each grade. For grade two, significant logographeme effect (p < .001)
and radical effect (p < .001) with similar degree of significance was showed. For grade four,
both logographeme effect (p = .02) and radical effect (p < .001) were significant but the
degree of significance of radical effect was greater than that of logographeme effect. For
grade six, significant radical effect (p = .007) but insignificant logographeme effect (p = .30)
were found.

**Error analysis**

Error analysis indicated prominent errors in the orthographical levels of logographeme
and radical. Errors were classified according to the orthographical unit size: stroke,
logographeme, radical and character. For each orthographical level, there was further error classification of error types, including substitution, addition, transposition and deletion. There were totally 16 different errors. The distribution of errors at each orthographical level across the three grades was showed in Figure III.

![Figure III. Distribution of errors at each orthographical level across three grades](image)

Logographeme substitution, radical substitution and radical deletion were the three most prominent error types across the three grades. Since radical deletion may reflect a total deterioration of the identity of grapheme or participants’ lack of motivation in an attempt to write, only logographeme and radical substitution errors were analyzed in further details. The substitution errors were classified into three error types, first error type of substitution of one logographeme, second error type of substitution of two logographemes which did not correspond to a larger unit of radical and third error type of substitution of two logographemes which corresponded to a larger unit of radical. The results showed that a number of errors of the third error type were found across all three grades. Although the percentage of errors of
the third type was similar across grades, it was found that for errors which involved two logographemes, there was an increase of third type errors from lower grade to higher grade.

The percentage of different types of substitution errors across three grades was showed in Table V.

Table V.

<table>
<thead>
<tr>
<th>Grade</th>
<th>One logographeme</th>
<th>Two logographemes which did not correspond to a larger unit</th>
<th>Two logographemes which corresponded to a larger unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>73.56%</td>
<td>11.49%</td>
<td>14.94%</td>
</tr>
<tr>
<td>P4</td>
<td>77.30%</td>
<td>7.09%</td>
<td>15.60%</td>
</tr>
<tr>
<td>P6</td>
<td>79.61%</td>
<td>5.83%</td>
<td>14.56%</td>
</tr>
</tbody>
</table>

Discussion

*Presence of logographeme and radical as psycholinguistic entities*

The present study aimed to investigate the size of processing unit of writing Chinese characters in normal primary students across grades. The results showed significant main effects of logographeme and radical, which indicated that logographeme and radical existed as psycholinguistic entities in Chinese writing system. However, no significant main effect of stroke was found. Results also showed significant logographeme effect and radical effect in grade two and grade four students, indicating that logographeme and radical existed as psycholinguistic entities in grade two and grade four students. Since there was only radical
effect in grade six, radical was thus suggested to be the psycholinguistic entity of writing in grade six students.

There was no significant stroke effect in all three grades, it was resulted from the fact that grade two students were using unit larger than stroke in their writing. Therefore, only significant logographeme and radical effects were found. However, error analysis showed that there were a small number of stroke errors across the three grades, indicating that stroke also existed as a level of representation in Chinese writing system. Similarly, the absence of significant logographeme effect in grade six was suggested to be resulted from the fact that grade six students were using unit larger than logographeme in writing. Error analysis showed that both logographeme and radical errors were the most prominent error types in grade six, which suggested that grade six students also used logographeme as the processing unit in writing.

The findings of the present study appeared to support the hypothesis of a developmental change of processing unit from a smaller orthographical unit to a larger orthographical unit.

*Co-occurrence of significant logographeme and radical effects*

Although there was co-occurrence of significant logographeme and radical effects in grade two and grade four, the degree of significance of the two effects in grade two and grade four would be different if the structural representation of Chinese was hierarchical. Since the results showed a more significant radical effect than logographeme effect in grade four than
grade two, it suggested that grade four students may be more capable than grade two students in using a larger processing unit (radical) in writing.

The correct percentage analysis did not show the developmental trend of a larger processing unit to a smaller processing unit from grade two to grade six. There was also a change of the significant main effect and significance of main effect across three grades. These results provided support to the claim that there was hierarchical representation of Chinese with three levels: stroke, logographeme and radical.

Error analysis showed a number of substitution errors of two logographemes which corresponded to a larger unit of radical in all three grades. If the representation of Chinese was non-hierarchical, there would be more number of substitution errors of two logographemes which did not correspond to a larger unit of radical. Error analysis also showed a developmental increase of substitution errors of two logographemes which corresponded to a larger unit of radical from lower grade to higher grade, indicating the shift from using a smaller processing unit (logographeme) to a larger processing unit (radical) in writing from lower grade students to higher grade students. Results from error analysis were also consistent with the hypothesis of hierarchical representation of Chinese.

**Developmental change of processing unit**

The developmental trend of increase of the size of processing unit was hypothesized to be resulted from writing practice. During writing development, children would be able to
recognize common patterns of strokes across different positions of characters, and gradually used these common patterns, known as logographeme, as processing unit in writing to increase writing accuracy and efficiency. Since logographemes were stored temporarily in the graphemic output buffer, writing performance would be affected by the word length variable, the number of logographeme in the character, as showed by the results in grade two and grade four, which was also similar to the finding of study on writing errors of a Chinese dysgraphic patient (Han et al., 2007). The change of a smaller orthographical unit (logographeme) to a larger orthographical unit (radical) from grade two to grade six was hypothesized to be resulted from the increase of orthographical knowledge. In the later stage of writing development, learning to write an increased number of characters would help the children to realize the ‘orthotactic principles’ (Masterson & Apel, 2000). Children would learn that logographemes had different positional consistency. Logographemes may occur in a restricted number of positions and have a higher positional consistency or occur in a varied number of positions and have a lower positional consistency. Logographeme which had a higher positional consistency and usually co-occurred with a limited number of logographemes may be processed as a larger unit, radical. Radical was a functional unit and most of the radicals were standalone characters with their own pronunciations. The use of radical as processing unit involved the activation and retrieval of radical and thus the writing performance would be affected by the frequency of the radical, and thus resulting in radical effect in writing as
showed in all three grades.

Results from correct percentage analysis and error analysis provided support that the structural representation of Chinese was hierarchical. However, there were co-occurrence of two psycholinguistic entities in grade two and grade four. The co-occurrence was explained by the developmental change of size of processing unit on a character-by-character basis. Writing of Chinese characters was usually taught in whole characters in word context without explicit instruction of writing Chinese characters in terms of the sub-character components (Chen & Allport, 1996). Therefore, realization of different orthographical units as psycholinguistic entities was acquired through writing development. Different logographemes had different positional consistencies and frequencies of occurrence of each logographeme with other logographemes. Logographeme which had a higher positional consistency and co-occurred with fewer number of logographemes, for example,  

\[
\text{馬} + \text{心} = \text{馬}
\]

may be easier than logographeme which had a lower positional consistency and co-occurred with more number of logographemes, for example,
to be processed as a larger unit. In the present study, although the logographeme frequency was controlled, the positional consistency of the logographeme and number of co-occurring logographeme were not controlled. Therefore, it was hypothesized that for each character, there was a developmental change of a smaller processing unit to a larger processing unit in writing for all three grades of students.

Further studies

In the present study, the percentage of accuracy in grade six students was high and there may be ceiling effect. It was suggested that the time of presentation of each pseudo-character should be reduced in higher grade students in future studies. The absence of a significant main effect of stroke was also found and it was hypothesized that the significant main effect of stroke, indicating existence of stroke as a psycholinguistic entity, may be found in earlier writing development. Further investigation on the processing unit of writing in kindergarten children was suggested. Moreover, the processing unit of writing in dyslexic children may be investigated, which may have implications for deciding appropriate treatment approach of writing for dyslexic children.
Conclusion

The present study showed that logographeme and radical existed as psycholinguistic entities in grade two and grade four students while radical existed as psycholinguistic entity in grade six students. The structural representation was suggested to be hierarchical since there was a developmental change of processing unit from a smaller orthographical unit (logographeme) to a larger orthographical unit (radical) from lower grade to higher grade.

Prominent error type of substitution of two logographemes which corresponded to a larger unit of radical also provided additional support for the claim of hierarchical representation of Chinese.
Reference


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Appendix A

Instruction of the delayed copying task

今日邀請你哋做一個抄寫測驗，等陣你哋要望住熒光幕中間嘅十字，之後會見到一個中文字，你哋要即刻記住佢，因為個字會好快消失，當個字消失之後，唔係即刻寫低嘅，我哋會一齊讀熒光幕度見到嘅三個數字，之後見到幅寫字圖畫出現嘅時候，你哋先可以攞起枝筆，寫番頭先見到嘅字出嚟。你哋見到嘅字，有啲會好似字，有啲唔似，你哋要睇清楚每一筆每一劃，然後照抄就得，淨係記得中文字其中一部分，記住都要寫低，因為都會計分。啲字有深有淺，如果個字識唔識好讀嘅話，係個測驗唔可以用擦膠，如果你寫錯咗，就用枝筆打個交叉就得。每一頁抄一個字，總共有 50 題。抄完一個字之後翻去下一頁同埋擺低筆，記住呢個測驗係唔可以翻去之前頁數複卷。
Appendix B

Stimuli list

1. 鎣
2. 鎣
3. 鎣
4. 鎣
5. 鎣
6. 鎣
7. 鎣
8. 鎣
9. 鎣
10. 鎣
11. 豈
12. 豈
13. 豈
14. 豈
15. 豈
16. 豈
17. 豈
18. 豈
19. 豈
20. 豈
21. 鬭
22. 鬭
23. 鬭
24. 鬭
25. 鬭
26. 鬭
27. 鬭
28. 鬭
29. 鬭
30. 鬭
31. 鬭
32. 鬭
33. 鬭
34. 鬭
35. 鬭
36. 鬭
37. 鬭
38. 鬭
39. 鬭
40. 鬭