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Reading, Writing, and Animation in Character Learning in Chinese as a Foreign Language

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Abstract: *Previous studies suggest that writing helps reading development in Chinese in both first and second language settings by enabling higher-quality orthographic representation of the characters. This study investigated the comparative effectiveness of reading, animation, and writing in developing foreign language learners' orthographic knowledge of Chinese and found that, for learners with existing orthographic knowledge, the three learning conditions facilitated character learning in different ways: Writing and animation both led to better form recognition, while reading produced superior meaning and sound recalls. In addition, the effect of animation in meaning recall was also better than writing. In developing the skill of reproducing characters from memory, writing was superior. Implications for the teaching and learning of Chinese characters are offered.*

Key words: *animation, Chinese characters, orthographic knowledge, reading, writing*

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The Chinese writing system is often considered to be "logographic," although this general term is not entirely accurate. A logographic language is one in which each word is represented by a distinct symbol, while the basic orthographic units in Chinese are characters instead of words, which usually consist of two or more characters. As characters represent morphemes and they are typically monosyllabic, some have chosen to refer to it more accurately as the morphosyllabic writing system (DeFrancis, 1989; Perfetti & Zhang, 1995). The Chinese writing system is said to present the highest contrast to languages such as English: Whereas English has a linear structure, the Chinese character is composed of a number of strokes interwoven in a square-like form. In addition, while the relationship between spelling and pronunciation is transparent in alphabetic languages, the Chinese script has little or no systematic grapheme-phoneme correspondence. Thus, learning Chinese orthography is often identified as the greatest challenge for learners of Chinese as a foreign language (CFL) (e.g., Everson, 1998; Ke, Wen, & Kotenbeutel, 2001). A large number of studies by researchers specializing in CFL, reading, and educational psychology, summarized below, have investigated a variety of methods to help learners overcome these difficulties. This study approached the issue of non-alphabetic reading using theoretical foundations and experimental methods based in both cognitive and behavioral sciences and addressed the question of how to help learners who have an alphabetic first language background best develop reading and writing skills in Chinese.

Existing Research

CFL researchers have attributed learners' difficulty in learning characters to the need to retain and rapidly retrieve the three aspects of a character: the shape (graphic form or orthography), the sound (phonology), and the meaning (semantics) (Shen, 2004). The decomposition of character identification skills into these three elements is consistent with the lexical constituency model, which claims that a high-quality lexical representation is complete and accurate and provides strong links among these three interlocking constituents (Perfetti & Tan, 1998, 1999; Tan & Perfetti, 1998). A topic of key interest to both researchers and instructors is how to facilitate learners' development of orthographic knowledge, which can be defined as a thorough understanding of characters as the logical composition of radicals[1] and strokes and, in addition to having such structural knowledge, the establishment of strong form-sound and form-meaning links when processing the written language.[2] Traditionally, learning to read and write characters has been accomplished through rote repetition (Fan, Tong, & Song, 1987; Packard et al., 2006); however, the increasing availability of modern technology has given rise to discussions of changes in pedagogical decisions in two different aspects. On the one hand, some scholars have argued that the need to actually write characters by hand is diminished with the increasing reliance on electronic communication, rendering handwriting practice an inefficient use of learners' time (e.g., Allen, 2008). On the other hand, researchers have explored the possibility of utilizing modern technology such as stroke sequence animation programs as computer-assisted language learning tools in character learning (e.g., Jin, 2003, 2006; Zhu & Hong, 2005).

Although the extent to which writing from memory should be emphasized as a pedagogical goal could differ from program to program (Everson, 2011), CFL research (e.g., Ke, 1998) and the reading literature have suggested a close relationship between reading and writing skills. In alphabetic languages where the grapheme-phoneme correspondence is present, the role of phonology is thought to be crucial in one's reading process. For instance, Rayner, Foorman, Perfetti, Pesetsky, and Seidenberg (2001) reported that phonics instruction

helped beginning readers learn new words. Meanwhile, researchers have argued that visual-orthographic skills may be more crucial in learning Chinese characters than in learning an alphabetic language (e.g., Huang & Hanley, 1994; Leck, Weekes, & Chen, 1995). Tan, Spinks, Eden, Perfetti, and Siok (2005) suggested that due to the linguistic differences between Chinese and alphabetic languages and the different processing mechanisms of Chinese and English words, reading in Chinese depends on writing while reading in English does not. In first language (L1) literacy studies, Tan et al. (2005) and Chan, Ho, Tsang, Lee, and Chung (2006) found that the reading skills of Chinese children, including those with normal reading and writing skills as well as children with dyslexia, are highly correlated with the ability to copy characters. In addition, writing practice can be especially important for CFL learners, because, unlike L1 children who typically acquire the orthographic representation by connecting it to a word that already exists in their vocabulary, CFL learners in a curriculum following the three modes of communication, i.e., interpersonal, interpretative, and presentational, often learn to read at the same time that they are learning to speak and therefore have to connect unfamiliar orthographic symbols to concepts that are not yet established in the spoken form in their second language (L2) vocabulary. This unique situation may force learners to rely heavily on the visual form of the words to access the lexicon (M. Wang, Perfetti, & Liu, 2003). That is, for learners whose native language is alphabetic, the first step in learning characters should be to develop sensitivity to each character's visual-orthographic structure. This notion is supported by results in several CFL surveys in which learners identified applying orthographic knowledge or attending to a character's form as the most relied-on learning methods (Ke, 1998; Shen, 2005).

Writing is said to be a supportive encoding method that directly mediates reading by developing orthographic awareness for L1 children (e.g., Tan et al., 2005). However, the extent to which writing facilitates reading for L2 learners has not been fully investigated. A functional brain imaging study found that learning through writing characters, when compared to writing pinyin, a standard phonetic system for transcribing the sound of characters into Latin script, led to greater activation in the bilateral superior parietal lobules and bilateral lingual gyri, which are regions of the brain that are distinctively involved in the reading networks of Chinese (Cao et al., 2012). Cao et al. (2013) also compared three encoding methods: reading, writing, and visual chunking, i.e., showing the compositional chunks in a character one by one. They found no significant differences among the three methods in their behavioral results, but their event-related potential (ERP) measures, which recorded electrical activities of the brain in response to a character, detected evidence of orthographic enhancement functions through the writing and visual chunking instructions. Guan, Liu, Chan, Ye, and Perfetti (2011) showed an advantage of writing in developing L2 learners' form recognition and meaning recall when brief character viewing time was allowed in learning through writing and through learners mentally recalling the character after reading. While these studies established that writing benefits reading, it is yet unclear how powerful the effect is in a realistic learning situation if learners are allowed the same amount of time in writing and in carefully studying the characters by viewing. From a practical point of view, because writing is time-consuming and labor-intensive, is it worthwhile to devote significant time to writing or could a learner benefit equally well if he or she chose to simply pay attention to the character and its form, sound, and meaning?

In terms of teaching and learning practices, Shen (2004, 2010) discussed the ways in which cognitive processing might affect the L2 learning of characters. For instance, Shen (2004) reported that

instructor-guided elaboration of the characters' etymology and radical functions resulted in better recall and memory retention than did rote memorization of characters. Rote memorization used in Shen (2004) consisted of passive viewing of the character without writing. While those studies have significant implications for classroom pedagogy, successful learning outcome essentially depends on the availability of skilled instructors and classroom time. If, as the aforementioned reading research indicates, writing supports lexical memory through the mediation of the character's orthography, it is possible that learners can benefit from self-learning through writing characters and be encouraged to engage in writing exercises outside the classroom.

Meanwhile, some CFL studies have examined the role of stroke sequence animation in character learning. Jin (2003) compared three types of multimedia presentations focusing, respectively, on radical formations, stroke sequences, and pronunciation (pinyin) and reported that radical formation was a more effective method than stroke presentation, which in turn led to better performance than pinyin presentation. Zhu and Hong (2005) compared four learning conditions: character presentation with or without stroke animation and with or without voice pronouncing the character. They reported that learners who learned characters with voice and with animation performed significantly less well than those who learned characters with voice but without animation. At the same time, Zhu and Hong acknowledged that the negative effect of animation was only found in conditions where learners were overwhelmed by the amount of input to their visual modality, i.e., when the character's pinyin, meaning, and an English paragraph explaining the mnemonic cues were simultaneously on display. In other words, results from these studies on the effect of presenting characters using animation are not consistent, and it is possible to hypothesize that stroke animation may have a similar effect as writing in developing orthographic knowledge. That is, because there is a research-based "psychomotor basis" for requiring handwriting to be carried out only with the defined set of basic stroke forms with certain directions of movement and correct sequence rules (Law, Ki, Chung, Ko, & Lam, 1998, p. 272), stroke sequence instruction may help direct learners' attention to the exact spatial orientation and compositional relations of even the smallest component in a character, thus helping learners to establish better orthographic representations. This suggests that, if characters are learned through animation, the perceptual information about written stroke order may also be part of the character's mental representation, and recognition can be facilitated because such representation may involve the coupling of the visual and the sensory motor systems, as in learning by writing (Guan et al., 2011).

Due to the critical importance of helping CFL learners to read and write characters, and thus the ongoing effort to find an effective way to teach Chinese characters, coupled with the changing realities offered by modern technology, this study investigated the effectiveness of writing in comparison with reading and stroke sequence animation in developing CFL learners' receptive knowledge and productive skills in reading and writing Chinese characters and specifically addressed the following questions:

1. How do the three encoding methods—reading, writing, and animation—support orthographic form representation, as typically measured by accuracy rates and reaction time in computerized lexical decision tasks? What is the ranking of their comparative effectiveness?
2. Do reading, writing, and animation also enhance the meaning and sound representation aspects of orthographic knowledge development? Which method of the three is the most effective?
3. What impact do reading, animation, and writing have on the development of learners' productive skills, specifically their ability to recall and reproduce the character's form from memory?

Specifically, to what extent does the use of animated stroke order programs offer an innovative method that can potentially replace traditional handwriting?

Methods

Participants

Participants for this project were recruited from a pool of CFL students who had completed 20 weeks (approximately 150 hours) of previous instruction in Chinese and were enrolled in the second semester of the first-year Chinese language course sequence at a university in the northeastern United States. Based on a survey of language background conducted before the experiment, heritage learners and learners whose native language was other than English did not participate in the experiment. The remaining thirty-six participants, whose native language was English and who reported having no substantial experience learning Chinese prior to enrolling in their current language program, were randomly assigned to one of three groups to allow for counterbalancing of the three learning conditions. All participants experienced the three learning conditions, while the sets of target characters in each condition differed for participants in the different groups.

All participants were taught in a curriculum following the three modes of communication, in which listening and speaking aspects of interpersonal, interpretive, and presentational modes are developed simultaneously with the reading and writing skills. The participants had prior knowledge of pinyin, general rules of stroke order, and an existing vocabulary of about 450 characters. Copying characters was regularly assigned as homework, and writing characters from memory was also required on weekly dictation quizzes.

Materials

Sixty Chinese characters that had not been taught at the time of the experiment and that had identical or near-identical forms in the traditional and the simplified systems were selected as experiment materials;[3] a complete list is included in the Appendix. The characters were divided into three sets (a, b, and c), with 20 characters in each set. The sets of characters were matched by (1) average stroke numbers, which were 9.95, 10.05, and 10, $F(2, 57) = 0.007$, $p = 0.993$; (2) average English translation frequency (Brysbaert & New, 2009), $F(2, 57) = 0.349$, $p = 0.707$; (3) average number of chunks as defined by the Chinese Orthography Database (Chen, Chang, Chou, Sung, & Chang, 2011), which were 3.15, 3, and 2.95, respectively, $F(2, 57) = 0.208$, $p = 0.813$; and (4) structural configuration—half of the characters had a left-right structure, and the other half had an up-down structure. Below and in the Appendix, *a1 to a20, b1 to b20*, and *c1 to c20* each refer to the 20 characters in character sets a, b, and c.

Procedures

The experiment had a within-subject design in which each participant learned a set of 20 characters in two sessions in each of the three conditions, with 40 minutes in the first learning session and 20 minutes in the second session, resulting in a total of six learning sessions for each participant. For example, if a participant in one of the three participant groups learned character set a1 to a20 in the reading condition, he or she learned b1 to b20 in the animation condition and c1 to c20 in the writing condition. A participant in another group may have learned b1 to b20 in the reading condition, c1 to c20 in the animation condition, and a1 to a20 in the writing condition. To control potential transfers of learning strategies from one condition to another, all participants experienced the reading condition first, as it is unlikely that learners would develop any specific strategies during reading that would potentially affect their learning in the other two conditions. The sequence of animation and writing conditions was counterbalanced, with half

of the participants in each group experiencing animation before writing and the other half experiencing writing before animation.

Pretest

A written pretest was conducted to ensure that participants did not have substantial prior knowledge of the characters used in the experiment. The pretest required participants to write the meaning and the pinyin for the characters that they recognized and was conducted immediately before a participant experienced a given learning condition.

Main Experiment

In the main experiment, participants learned each character on individual computers in research labs on the campus of their institution. E-prime software (Schneider, Eschman, & Zuccolotto, 2002) was used to display the materials and to record computerized data. In all three conditions, the initial display on the screen involved a three-second exposure to the character's form, sound, and meaning during which the character's form was shown on screen for one second, followed by a one-second pinyin display and a female native speaker's voice pronouncing the character, and then a final one-second display of the character's English translation. After this initial exposure, the screen differed for each learning condition, which lasted for 15 seconds. In the reading condition, the character itself was on display statically for 15 seconds, and participants were instructed by a prompt on the screen to study the character's form carefully. They were instructed to refrain from any kind of hand movement and did not control the screen display in any way. In the animation condition, a movie showing how the character was written stroke-by-stroke was played three times within the 15 seconds. Similar to the reading condition, participants viewed the screen display without engaging in any hand movement, and the movie display was completely controlled by the computer program. In the writing condition, the screen displayed instructions that asked participants to write the characters from memory three times and that they should stop writing when hearing a beep. The total instructional time for each character was 18 seconds (three seconds of exposure and 15 seconds of learning). The process was repeated three times for each character, which allowed participants approximately one minute to study each character, before the program moved on to the next character. The E-prime program randomized the sequencing of the 20 characters in each learning session. After participants had a chance to learn all 20 characters, the 20-minute, 20-character procedure was repeated a second time, resulting in a 40-minute first session in each condition. During the second session in each condition, participants completed the same sequence of activities on the same set of 20 characters prior to taking the posttest.

Posttests

At the end of participants' second learning session in each condition, they carried out three tasks on the computer: a lexical decision task, a sound-matching task, and a meaning-matching task. They then took a written pinyin/meaning posttest in the same format as the pretest and a character form production test. In the character form production test, they were asked to write down the characters based on the pinyin and English translation prompt. These assessments are described below.

The lexical decision task has been used regularly in reading research to assess participants' visual-orthographical representation of characters (e.g., Peng, Li, & Yang, 1997; Taft, Zhu, & Peng, 1999; M. Wang et al., 2003, among others). Reaction time (RT), i.e., how much time is needed for participants to make a judgment from the onset of the stimulus to their responses, as well as accuracies in judgment, were the primary measures in this task. Faster RT and higher accuracy indicated more refined orthographic form representation, in which case a printed character was perceived as

having the logical composition of radicals and strokes to their full specification. Learners decided whether a stimulus shown on a screen was a real character and were instructed to press one of the keys on the keyboard to indicate their decision. They were asked to make a decision as quickly and accurately as they could. The stimuli included a mixture of the 20 characters learned in that session, 10 familiar characters, i.e., characters that were taught to the learners prior to the experiment as part of their curriculum, and 10 novel characters, i.e., non-experiment material characters that were beyond the learners' curriculum. Half of the stimuli were real characters and half were pseudo-characters, which were formed by adding, deleting, or moving a stroke from one location to another within a character. Participants had a total of three seconds to make a decision regarding the stimulus before the screen displayed the next trial. They completed several practice items before the real task started.

Participants then carried out a sound-matching task. In each trial, a character's form was presented for one second, followed by a pinyin display and a female native speaker's voice pronouncing the sound. Participants had three seconds to decide whether the pinyin/sound matched the character.

The final computerized task was a meaning-matching task. After a character was presented for one second, an English translation appeared on the screen and participants had three seconds to decide if the character correctly matched the pinyin or meaning. Both matching tasks contained 40 items, with 20 of the characters matched correctly to their pinyin or meaning, and the remaining mismatched. Half of the matched and unmatched items were from the materials in that learning condition, while the remaining half were drawn from familiar characters that the participants had learned in their regular curriculum prior to the experiment sessions.

In these computerized tasks, the E-prime software recorded the learners' RTs as well as their accuracy rates. For data analysis, only the participants' responses on the learning materials were included, and the RT analysis was based on correct responses.

In the written pinyin/meaning tests, two scoring schemes were used for the character's pronunciation, including a syllable-only scheme (referred to as the "syllable" scheme below) in which a score of 1 was given to each response that was correct in its syllable presentation, regardless of the correctness of its tone, and a pinyin-with-tone scheme (referred to as the "pinyin" scheme below), in which a score of 1 was given only when the response was correct in both syllable representation and tone. When scoring the participants' responses to the character's meaning, the researchers assigned them a score of either 1 or 0. For the form production test, both a strict and a nonstrict scoring scheme were used. In the former, a score of 1 was assigned to each character that was written exactly in the target-like form and a score of 0 to all other responses. In the latter (nonstrict) scoring scheme, complete character responses received a score of 1, and a score of 0.5 was assigned to responses that were partially correct. A score of "partially correct" was assigned if either of the following conditions were fulfilled:

1. It had a complete chunk, or several chunks, arranged appropriately in a space that made up at least ½ proportion of the whole character. For instance, for a target character such as 熊, a response such as 能 was assigned a score of 0.5, but a response such as 灬 would receive 0.
2. It was recognizable as the original character, with no more than two strokes deleted, added, or misplaced. The strict scoring would reflect the extent to which learners could accurately reproduce the character's orthography from memory, and the nonstrict scoring scheme reflected a common CFL scoring practice in some situations.

Delayed Tests

Approximately four weeks after learners completed the learning sessions, delayed

tests including a pinyin/meaning test and a form production test were administered. In coding the data, one researcher coded the complete set of data and a second researcher independently coded one third of the responses. Interrater reliability in all other cases was 100%, and reliability in the nonstrict scoring scheme for the form production tests was 97.7%.

Results

A one-way repeated-measures analysis of variance (ANOVA) with learning condition as an independent variable was conducted on each measure. When the difference reached significance, pairwise comparisons with Bonferroni adjustment were reported. Table 1 shows the means and standard deviations of participants' scores in the written tasks at different testing points, including the pretest, posttests, and delayed tests. In the pretest, participants knew very little about the characters' sound and meaning, with less than 1% correct responses in all cases. None of the mean differences among conditions in the pretest reached statistical significance (syllable: $F(2, 70) = 2.168$, $p = 0.122$; pinyin: $F(2, 70) = 1$, $p = 0.373$; meaning: $F(2, 70) = 1.788$, $p = 0.175$).

Table 2 presents the descriptive statistics in participants' accuracy rates and RTs in the computerized tasks. As Table 2 indicates, the writing condition produced the most rapid form recognition, as measured by lexical decision times. However, in the measure of meaning-matching, the reading condition produced the best result.

Orthographic Representation: A Writing Advantage

For the lexical decision task, the RT means were 1,450, 1,252, and 1,191 milliseconds for reading, animation, and writing, respectively, with a significant difference among conditions, $F(2, 70) = 16.301$, $p < 0.001$, $\eta_p^2 = 0.318$. Pairwise comparisons revealed that reading produced longer RTs than animation ($p = 0.001$) as well as writing ($p < 0.001$), though the 63-millisecond difference between the animation and the writing conditions was not significant ($p = 0.479$). Accuracy differences produced a parallel ordering of writing (0.84), animation (0.80), and reading (0.77), but these differences did not reach significance, $F(2, 70) = 2.218$, $p = 0.116$.

Sound and Meaning Representation: A Reading Advantage

Participants' sound and meaning representations were measured by accuracies and RTs in the sound-matching and meaning-matching tasks, as well as accuracies in written pinyin and meaning production tests. Results showed that in sound recall in the written pinyin production test, the effect of reading was more beneficial than both of the other two conditions. In meaning recall, reading was more effective than writing in the computerized task, and it also led to the highest accuracies in written meaning production, while animation also produced higher scores than writing in the written meaning production.

For the sound-matching task, the differences in mean RTs and accuracies were not significant, $F(2, 70) = 1.381$, $p = 0.258$ for RTs and $F(2, 70) = 0.568$, $p = 0.569$ for accuracies.

For the meaning-matching task, the mean RTs shown in Table 2 were not significantly different among the conditions, $F < 1$. The mean accuracy rates, however, were significantly different among conditions, $F(2, 70) = 5.975$, $p = 0.004$, $\eta_p^2 = 0.146$. Pairwise comparisons showed that reading produced higher accuracy than writing ($p = 0.009$).

The written posttest revealed a similar advantage in reading. Specifically, in pinyin production, reading produced more accurate pronunciation recall than both writing and animation. In meaning production, the advantage of reading was followed by animation, while both were more effective than writing. The details are revealed below.

First, using the syllable scoring scheme for pronunciation recall, the mean scores in

TABLE 1

Mean Score and Proportion of Target-Like Responses in Written Tests in Each Condition ($n = 36$)

	Reading		Animation		Writing	
	Mean Score (S.D.)	%	Mean Score (S.D.)	%	Mean Score (S.D.)	%
Pretest						
Syllable	0.06 (0.23)	0.28	0.17 (0.45)	0.83	0.03 (0.17)	0.14
Pinyin	0.03 (0.17)	0.14	0.00 (0.00)	0.00	0.00 (0.00)	0.00
Meaning	0.03 (0.17)	0.14	0.08 (0.28)	0.42	0.00 (0.00)	0.00
Immediate						
Syllable	11.25 (4.92)	56.25	9.56 (5.94)	47.78	9.67 (5.18)	48.33
Pinyin	10.00 (5.54)	50.00	8.36 (5.71)	41.81	8.25 (5.37)	41.25
Meaning	14.94 (4.30)	74.72	12.94 (4.96)	64.72	11.11 (5.31)	55.56
Character (strict)	8.81 (4.67)	44.03	9.33 (4.95)	46.67	12.42 (4.51)	62.08
Character (nonstrict)	11.08 (4.65)	55.42	10.78 (4.43)	53.89	12.96 (4.54)	64.79
Delayed						
Syllable	1.39 (1.68)	6.94	1.44(1.68)	7.22	1.39 (1.68)	6.94
Pinyin	0.88 (1.33)	4.44	0.88 (1.28)	4.44	0.58 (1.08)	2.92
Meaning	1.94 (2.51)	9.72	1.92 (2.26)	9.58	1.44 (1.93)	7.22
Character (strict)	1.31 (1.74)	6.53	1.39 (1.76)	6.94	1.64 (1.87)	8.19
Character (nonstrict)	1.85 (2.19)	9.24	1.90 (2.24)	9.51	1.96 (2.03)	9.79

Note: The mean score and standard deviations (shown in parentheses) are reported based on a score of 1 for each target-like response. The percentage reflects the proportion of target-like responses out of all 20 items in each condition.

TABLE 2

Means and Standard Deviations of Accuracy and Reaction Time in Computerized Tests ($n = 36$)

	Reading	Animation	Writing
Accuracy Rate			
Lexical decision	0.77 (0.12)	0.80 (0.13)	0.84 (0.10)
Sound-matching	0.76 (0.14)	0.75 (0.15)	0.78 (0.14)
Meaning-matching	0.86 (0.12)	0.82 (0.17)	0.77 (0.16)
Reaction time (m.s.)			
Lexical decision	1,450 (304)	1,252 (306)	1,191 (223)
Sound-matching	1,259 (248)	1,211 (242)	1,200 (309)
Meaning-matching	964 (209)	971 (193)	977 (209)

Note: The means and the standard deviations (shown in parentheses) for accuracy were calculated using the proportion of correct responses, e.g., 0.80 stands for 80% accuracy rate. Reaction time statistics are in milliseconds.

reading, animation, and writing were 11.25, 9.56, and 9.67, $F(2, 70) = 4.445$, $p = 0.015$, $\eta_p^2 = 0.113$. Pairwise comparisons showed that the reading condition significantly outperformed both the animation condition ($p = 0.020$) and the writing condition ($p = 0.052$). Next, using the pinyin scoring scheme, the results were largely the same, and the mean scores were 10.00, 8.36, and 8.25 in reading, animation, and writing, $F(2, 70) = 4.627$, $p = 0.013$, $\eta_p^2 = 0.117$. Reading outperformed animation ($p = 0.031$) as well as writing ($p = 0.041$).

The next measure was participants' scores in the meaning production test. The means in the meaning production test in reading, animation, and writing were 14.94, 12.94, and 11.11, $F(2, 70) = 11.352$, $p < 0.001$, $\eta_p^2 = 0.245$. Pairwise comparisons revealed that reading produced the most beneficial outcome, outperforming both writing ($p = 0.001$) and animation ($p = 0.026$), while animation also marginally outperformed writing ($p = 0.057$).

Form Production: A Superior Writing Effect

This section reports participants' response accuracies when they were asked to produce characters from memory when pinyin and meaning prompts were given. Results demonstrated that the effect of writing in developing the form production skill was superior. With the strict scoring scheme, the means in reading, animation, and writing were 8.81, 9.33, and 12.42, respectively, $F(2, 70) = 15.040$, $p < 0.001$, $\eta_p^2 = 0.301$. In pairwise comparisons, writing outperformed both reading ($p < 0.001$) and animation ($p < 0.001$). The differences were replicated with the nonstrict scoring scheme, in which case the means were 11.08, 10.78, and 12.96, $F(2, 70) = 6.238$, $p = 0.003$, $\eta_p^2 = 0.151$. Pairwise comparisons revealed that writing led to better performance than animation ($p = 0.012$) and reading ($p = 0.020$).

Delayed Tests: Retention Loss

Finally, in the delayed tests, the mean scores were low in all measures and in all conditions. As statistics in Table 1 indicate, there were massive reductions in the proportion of target-like responses from the posttests to the delayed tests in general, and the proportional knowledge retained in all conditions fell below 10%. None of the differences among the three conditions were statistically significant, $F < 1$ for syllable; $F(2, 70) = 1.243$, $p = 0.295$ for pinyin; $F(2, 70) = 1.168$, $p = 0.317$ for meaning; $F < 1$ for strict scoring form production; and $F < 1$ for nonstrict scoring form production.

Significant and marginally significant pairwise comparisons are summarized in Table 3. The results are categorized according to the different aspects of orthographic knowledge that they respectively measure.

Discussion

Orthographic Form Representation

Interpretations in this section were derived from results in the lexical decision task. As can be predicted by findings in previous studies showing the positive influence of writing on reading (Cao et al., 2012; Guan et al., 2011; Tan et al., 2005), the present data indicated that learning characters through writing led to better performances than reading. In addition to replicating the beneficial outcome of writing found in previous studies, results showed that learning through animation also facilitated character recognition. Through learning by writing as well as by animation, learners could more quickly identify the visual input as a legal character or reject an illegal character. Although they did not achieve the significance level of $\alpha = 0.05$, accuracy rates in the writing and animation conditions were also higher than reading. In addition, writing led to slightly higher accuracy and faster decisions than animation, though this difference was not significant. According to those previous studies, writing helps reading due to two potential

TABLE 3

Differences Between Learning Conditions

Measures	Task	Results
Orthographic representation measure	Lexical decision task—reaction time	W < R *; A < R *
Sound and meaning information measures	Meaning-matching—accuracy rate	R> W *
	Syllable in written test	R > W†; R > A *
	Pinyin in written test	R > W*; R > A *
	Meaning in written test	R > A*; R > W*; A > W†
Character production measures	Strict grading	W > A*; W > R*
	Nonstrict grading	W > A*; W > R*

Notes: R, W, and A refer to reading, writing, and animation, respectively. For results in the lexical decision task, " < " indicates shorter reaction time and therefore better performance. For results in all other measures, " > " means higher accuracy or higher score.
* indicates a statistically significant result at $p < 0.05$.
† indicates marginal significance with $0.05 < p < 0.06$. No other differences reached $p < 0.1$.

factors. First, knowing that they will be prompted to write, participants are engaged by the analysis of internal structures of printed characters during learning (Guan et al., 2011). Cao et al. (2013) further found that that the amplitude of P100, an ERP indicator of early visual attention, was greater when L2 learners learned characters by writing than by reading. Second, the process of writing adds a sensory-motor representation to the visual representation of the character and the motor-related memory trace is activated in character recognition, instantiating perceptual-motor information such as the stroke sequence (Guan et al., 2011, p. 514).

Both these writing-related factors allow the character's orthographic form to be represented in a high quality, in the sense that all radicals and strokes are fully specified (Perfetti, 2007; Perfetti & Hart, 2002), and these two factors may apply to animation as well as writing. First, compared to viewing a static image, writing and animation both draw learners' attention to the internal visual-spatial features of the character. As Chinese characters are composed of strokes packed into a square shape with no clear initial positions, readers need to compute the configural properties and strokes of characters in a fast and nonserial way (Tan, Hoosain, & Siok, 1996). In writing, learners actively decompose a complete orthographic form and reconstruct the characters from the bottom up by orienting each stroke correctly in space. In animation, the display helps learners decompose the characters so that they can better visualize the types of strokes involved and their relative positions to each other. In reading, the complex graphic form is presented as a whole and learners need to process the orthography more holistically. There is much evidence in the reading literature that in character processing, subcharacter components including stroke

analysis are involved, and in character recognition or lexical memory, activation spreads through the hierarchy from lower to higher levels, i.e., from stroke shapes and combinations to radical units' locations and relationships and then to character units (Peng et al., 1997; Perfetti & Liu, 2006; Perfetti, Liu, & Tan, 2005; Perfetti & Tan, 1998, 1999; Taft & Chung, 1999; Taft & Zhu, 1995, 1997; Taft et al., 1999). In both writing and animation, learners' attention is directed to the bottom-level components of a character (i.e., strokes and their features) as well as how they position together to hierarchically compose a character. Thus, the writing and animation conditions enhance low-level feature processing, and the visual-orthographic representation established in these conditions is much more precise or refined than in learning through reading.

In addition to the finding that greater attention to form leads to higher-quality form representation, previous studies suggested that writing facilitates reading by mediating the neural network. Specifically, in Cao et al.'s (2012) lexical decision task, they found evidence that character writing, as compared to pinyin writing, led to greater interaction with sensory-motor information during character recognition. Animation presentation may also have a beneficial effect in that it is an "implicit" writing process that is also mediated by stroke sequence and the learning experience involves viewing a movie with dynamic and sequential information. At the same time, results of the present study suggested that the positive effects of writing are not completely provided by learners viewing an animation presentation of writing strokes. As revealed by results in the character form production test, which is discussed later, results of the animation and writing conditions in this study were similar for recognition measures but were different for form production measures. Actual writing supports the learning of an orthographic representation through both attention to orthographic form and the addition of sensory-motor components that encode the production of stroke sequences; however, viewing an animation of writing appears to support mainly attention to orthographic form, with less support for sensory-motor components that function in actual writing.

Pronunciation and Meaning

Contrary to what might be expected in the light of both Guan et al. (2011) and Cao et al. (2012), whose results suggested that writing should enhance form-meaning links through the mediation of higher-quality orthographic form representation, in the current project, reading produced better accuracy than both writing and animation in the computerized meaning-matching task. That the present findings instead favored reading over writing in measures of meaning learning may reflect differences in the proficiency of the learners. In this study, participants were in their second term of Chinese instruction and were likely to have included learners with greater radical awareness compared with the participants in previous studies, which had a mix of first- and second-term learners. Compared to participants in Guan et al. (2011), who possessed knowledge of 50–150 characters, the present participant group had acquired considerably more characters prior to the experiment. Whereas Guan et al. (2011) reported that the characters used in their study did not contain radicals that had been previously taught, in this study, learners had received explicit instruction on several radicals that can be a facilitating aid in their learning of the new characters' meanings. Those included radicals such as 女 "female" (as in 妻 *qī* "wife"), 氵 "water" (as in 汗 *hàn* "sweat" or 源 *yuán* "source"), 衣 "cloth" (as in 袋 *dài* "bag"), 口 "mouth" (as in 咕 *gū* "to rumble" or 呼 *hū* "to call"), 日 "sun" (as in 晨 *chén* "morning"), and 扌 "hand" (as in 握 *wò* "to hold" or 搞 *gǎo* "to do").

Writing may be more effective for learners who have little radical knowledge to rely on when linking the character's form with its meaning than for more experienced learners who have such knowledge to

support the orthographic representations of new characters. CFL learners approaching the end of their first year's learning can consciously apply their radical knowledge in learning new materials and even in guessing the meaning of unfamiliar characters based on the semantic radical cues (Jackson, Everson, & Ke, 2003; Ke, 1998; Shen & Ke, 2007). For these more experienced learners, having to write may interfere with their being able to analyze the new character using their existing knowledge of radicals.

The results of this study are consistent with the assumption that learners make use of characters' components. Intermediate-level subcharacter components, including radicals, can be an extremely useful aid in learning the character's meaning (Shen, 2005, 2010; Su, 2010; Taft & Chung, 1999). More than 95% of the commonly used characters are compounds containing semantic radicals (Dictionary of Chinese Character Information, 1988), as were most of the characters included in the learning materials in the present experiments. Although they are far from 100% reliable, semantic radicals can provide useful cues to the meaning of the whole character (Feldman & Siok, 1999, p. 20). CFL learners often rely on the graphemic, semantic, and phonetic aspects of the radicals to learn characters (e.g., Ke, 1998; Shen, 2005), and that radical knowledge correlates with word reading skills or the memory retention of vocabulary knowledge (Shen & Ke, 2007; Su, 2010). In this study, participants could best apply their radical knowledge in the reading condition, when the complete character's image was continuously available to them throughout the learning time after the initial form-sound-meaning exposure. Other meaning learning strategies were also more available during the character availability period provided by reading. For example, learners often created their own idiosyncratic stories in order to associate the character's meaning with the form (e.g., McGinnis, 1999). In contrast, when participants' attention is fully engaged by the stroke sequences of the graphic form, there is little opportunity for these meaning-directed strategies.

Performance on the pronunciation-matching task was lower than on the meaning task. This greater difficulty with pronunciation, compared with meaning, has been consistently reported in CFL studies (e.g. Guan et al., 2011; Liu, Wang, & Perfetti, 2007; Shen, 2004). Although the computerized tests showed no condition differences, reading produced better pronunciation recall in the later written task. The explanation for this is parallel to that for the meaning task: Reading allows learners to study the character form and its components so that they can form links to pronunciation as well as to meaning.

The results provided further evidence for the trade-off in different learning conditions. Animation appeared to allow control of the trade-off in that it strongly supports characters' visual-orthographic representation in a way that is comparable to writing, while its support for the form-meaning link is stronger than that provided by writing though weaker than that offered by reading. The presence of partial character images on the screen during animation may still enable learners to access potential subcharacter meaning cues, although to a lesser extent as compared to full character exposure. Thus, animation is more like writing in its support of form and more like reading in its support of meaning. In sum, the three conditions facilitated different aspects of orthographic knowledge development.

Form Production

Although writing led to poorer performance in the pinyin/meaning posttest, it still enabled learners to recall and reproduce the character's form better when both the pinyin and the meaning prompts were available. Meanwhile, although in reading learners achieved the highest mean score in the pinyin/meaning posttests, their performances in the production test were poorer than writing and no different from animation. This indicates that even for learners

who regularly practice writing as part of their study, their knowledge of the form-sound and form-meaning links does not automatically lead to form production skills. The difference between writing and the other two conditions was significant in both scoring schemes, with little difference between the two scoring schemes in writing (12.42 in strict scoring and 12.96 in non-strict scoring). That is, learners' refined orthographic representation developed through writing consistently transferred to productive skills. At the same time, while animation led to comparable beneficial results with writing in the lexical decision task, it was no more advantageous than reading when it came to form production, suggesting that the visual-orthographic representation developed through animation may still be less robust than that developed through writing.

Memory Retention

There was considerable retention loss over the four-week interval, after which differences among all conditions were minor. The generally low proportional knowledge retained in all conditions suggests a "floor" effect. The disappearance of an advantage associated with a particular learning condition in the delayed tests is also consistent with previous studies on Chinese character learning (e.g., Shen, 2004; A. Y. Wang & Thomas, 1992). In other words, to achieve long-term lexical memory, repeated practice is needed, regardless of the initial method that one adopts in learning.

Conclusion and Pedagogical Implications

This study investigates how reading, animation, and writing support character learning. First, previous research results were replicated, confirming the importance of writing in developing visual-orthographic representations. Second, the present results suggest that using animation to present stroke sequences could induce a similar beneficial effect in developing learners' sensitivity to Chinese orthography. In addition, the findings indicate that for experienced learners with existing orthographic knowledge, form-sound and form-meaning connections are most effectively established when the visual form of the character is continuously available for study. Thus, reading and writing/animation benefit different aspects of lexical representation. Finally, the refined orthographic representation developed through writing was also reflected in more accurate form production.

This study was guided by the goal to make connections between the reading theories and CFL practices. These results should assist practitioners in making informed decisions about best practices for helping learners to read or write in Chinese. Some potential implications are explored below.

Writing for Novice Learners

One of the crucial questions that the project attempted to address is, given that the necessity to rely on handwriting for communication has abated in the modern world, whether students should still be asked to engage in writing practice. The current study indicates that the benefit of writing goes beyond its significance in developing the skills of writing from memory itself. Learners did not achieve the same degree of sensitivity to a character's orthography by reading, even when they were allowed the same amount of time to study a particular character. Because developing awareness of the structural properties of characters is helpful for word recognition and attaining ultimate reading competence (Everson, 2011, p. 263), writing should be a beneficial learning activity for CFL learners, especially because it not only develops production skills, as that may not be the goal of all language curricula, but it can improve their reading skills. For novice learners, such writing could take the simple form of "copying characters," a practice traditionally employed in Chinese children's L1 literacy development and frequently assigned for beginning learners in many CFL programs.

The present research offers evidence for such a traditional practice. It is important to note that beginning learners need to differentiate characters from visual symbols and establish the orthographic awareness that characters have a logical structure, which can be facilitated by writing characters. In addition, many common Chinese characters are relatively similar in orthography from an alphabetic reader's point of view. Examples include 我 "I" and 找 "look for," 蓝 "blue" and 篮 "basket," and 己 "already" and 已 "self," which are often required sight words for first-year learners, as are commonly encountered words like 士 "soldier" and 土 "land," 未 "not" and 末 "end," and 耍 "play" and 要 "want". In addition, some common radicals also strongly resemble each other, e.g., 犭 and 扌, 艹 and 廾, 辶 and 辶, 礻 and 衤, and 阝 and 阝. Among 3,000 common Chinese characters, Zhang (2012) identified 445 sets of orthographically similar characters and 171 sets of words that share similar-looking radicals and argued that these characters can mostly be distinguished from one another by their stroke features, including stroke numbers, stroke shape, compositional relations, and spatial features. Zhang (2012) further declared that learner errors with these characters are related to the holistic features of the form and the learners' processing strategies in recognition. As results in this study suggest, writing characters can establish accurate form representation and encourage learners' attention to the details in characters' orthographic structure, thus preventing confusion and obstacles that may otherwise arise in their lexical and reading development.

Writing for Experienced Learners

Some suggestions can also be put forward for learners of a higher proficiency. The present research, in comparison with those of previous studies, also illustrates that the comparative effect of different learning methods is dependent on learners' prior experience with the Chinese writing system. That is, while writing should be viewed as especially helpful for alphabetic readers who need practice to develop insight into characters' structures, research has reported that experienced learners are capable of relying on existing orthographic knowledge including structural decomposition and radical knowledge to strengthen lexical memory (e.g., Shen & Ke, 2007). Thus, introduction of characters' etymology, analysis of radicals, and explanation regarding the general principles that make up the Chinese writing system, such as the structural regularity of characters' components, would all support character learning and help students make connections between new materials and familiar characters.

In addition to such explicit orthographic instruction, writing activities can continue to be encouraged for intermediate or higher-level learners, while one should consider incorporating writing with actual communication tasks and achieving other pedagogical goals within the three communicative modes. Activities may include writing letters or short essays, taking notes in information gap activities, or group work. While copying characters is often abandoned as an obligatory exercise for learners who have developed increasing comfort and experience with the orthography, and such decisions are probably well justified, it is important to remember that the amount of time that adult L2 learners engage in writing can never be comparable to the hours that Chinese L1 children spend in their learning, and thus students in CFL classrooms cannot be expected to master Chinese writing quickly (Everson, 2008, p. 101). The present results also confirm that students with a few months' experience have not developed the ability to transfer receptive skills to productive ones. Thus, writing should be continuously encouraged, though with different intensities and taking different formats than writing exercises required of beginning learners.

Technology and Character Learning

Another practical question explored in this study is if and how technology can be used

effectively to aid learning. Results show that both writing and animation can be more successful learning methods than reading to ensure that learners attend to lower-level orthographic features. While stroke animation programs cannot replace writing in developing productive skills, such programs may offer a useful alternative if one simply seeks to help students develop higher levels of reading proficiency. Compared to writing, animation affords many accessible and flexible learning opportunities, thanks to the increasing accessibility of portable devices and downloadable applications. While requiring learners to write with the correct stroke sequence may consume excessive classroom time, animated practice can be unrestricted by space or time. Animation also led to better form-meaning associations than writing in this study. Because experienced learners can learn the characters' meaning and possibly sound better when the complete grapheme is available to them, a potentially beneficial pedagogical tool is stroke animation software with a complete transparent frame throughout the whole movie display. Many such programs are publicly available, e.g., Estroke by Eon Media Ltd. Some e-learning platforms were built with such animation support (e.g., Chen, Chien, & Chang, 2013). Figure 1 demonstrates how the animation displays in some of these programs differ from the one used in our experiment.

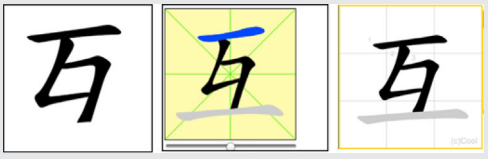
The complete character frame exposure can allow learners to use existing knowledge, including knowledge of radicals, to make meaning and sound connections, and animation helps them disentangle the strokes within the square, making it possible for them to distinguish orthographically similar forms. In other words, these programs may provide the advantages offered by both reading and writing practice in enhancing the acquisition of orthographic knowledge including form, sound, and meaning. Therefore, findings in this project encourage the use of computer-assisted learning technologies within and beyond the classroom.

The Role of Writing in Reading Development

It is hoped this research can encourage instructors to consider instrumental and methodological choices with research-informed findings, and with students' needs, classroom time considerations, and technology availabilities taken into consideration. Some researchers (e.g., Xu & Jen, 2005) previously proposed a "pen-less" curriculum in which the writing component is completely absent. Evidence in this study points to the possibility of considering the role of writing not only as a practice to help students develop the ability of writing from memory, but as an exercise for learners to develop orthographic knowledge, character learning, and reading skills. While *reading skill* refers mostly to character identifications in this research, it is important to note that such lower-level reading processes are

FIGURE 1

Animation Display with and without Frames



From left to right are presentation in the experiment, *Estroke* presentation, and presentation in Chen, Chien, & Chang (2013)'s E-learning platform, respectively.

often considered to provide the foundations for reading comprehension (Gough, 1984; Harris & Sipay, 1990). As LaBerge and Samuels (1985) pointed out, efficient reading is essentially achieved through automatic word recognition, or character recognition in this case, because rapid character or word identification allows more attentional capacity to be devoted to comprehending the meaning of the text. Thus, the project can also be considered as a step forward in the investigation of Chinese L2 reading processes in general.

Retention and Review

In line with previous studies (e.g., Shen, 2004), results in the project also point to an issue in lexical memory retention. Regardless of the original learning methods, retention is difficult to maintain. The rapid memory loss should draw language instructors' attention to the necessity of cycling learned materials regularly for review. It is unfortunate that, despite instructors' general awareness of the importance of review activities, there is little research focusing on how to help learners retain the characters' form, sound, and meaning representations after initial acquisition. Pavlik, Bolster, Wu, Koedinger, & MacWhinney (2008) made an effort in this direction by examining the learning of Chinese vocabulary with an intelligent tutoring system within a model that identified the optimal practice schedule for refreshing learning. Though informative, Pavlik et al.'s study is theoretically oriented, and its implications in foreign language teaching practices need to be tested. For instance, how to schedule reviews in optimal cycles may depend on several factors, including learners' proficiency, the amount of new materials learned, and the amount of time spent in initial learning. It is also worth exploring what varieties of review activities lead to desirable outcomes. While such investigations go beyond the scope of this research, evidence is presented for the critical value of regular reviews to maintain learned knowledge for continuous development in character learning and in reading in general.

Limitations and Future Directions

Some obvious limitations of the study should be acknowledged and explored in future research. First, given the small sample size and the specific participant population involved, the generalizability of these findings should be drawn with caution. The study was carried out among adult CFL learners. Given that the literature has suggested that heritage learners' reading capacities are quite comparable to CFL learners due to their limited exposure to the written language (Koda, Zhang, & Yang, 2008), it is possible to hypothesize that the current findings may be applicable to heritage learners. But how different encoding methods affect heritage learners should be directly investigated in future studies. Second, in this study, animation was used without a complete character frame to make the learning conditions more comparable to writing; for the purpose of teaching, it would be meaningful to assess more directly if using animation within character frames can offer an advantage. Last but not least, although the present results suggest that writing and animation support reading by achieving rapid character recognition, this study did not directly address the development of reading skills beyond character learning. While it is obvious that sensitivity toward a character's orthography accelerates reading speed and comfort, it is worth exploring how to help learners achieve instant sound and meaning retrieval at the word level and develop their ability in making inferences from context to achieve word recognition in reading at the text level. For instance, Everson and Ke (1997) pointed out that the lack of visible boundaries between words in Chinese written text imposes great challenges even for intermediate-level CFL learners, most likely because those learners' perception of words is negatively influenced by their experience with the English word

morphology (Bassetti, 2005). Reading at the text level can similarly be facilitated by practices (e.g., writing) that develop an in-depth understanding of Chinese orthography and morphology, and instructions on deriving morphological and phonological information from characters to retrieve meanings of words are also necessary. As Everson (2011, pp. 256, 264) pointed out, much of the current research involves beginning learners, and there is much ground to be covered in the understanding of reading strategies, including reading beyond the word and sentence levels, by higher-level learners. Future research can address best practices to develop reading skills at different proficiency levels.

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Notes

1. Radicals are subcharacter components that are composed of a series of strokes. They are the "smallest meaningful orthographic units that play semantic or phonetic roles in compound characters" (Shen & Ke, 2007, p. 99).
2. In this article, *orthographic knowledge* refers specifically to having accurate lexical representations, including knowledge of the character's form (orthography), sound, and meaning. In discussions of L1 or L2 development, the term *orthographic knowledge* can be more generally defined. For instance, Ho, Yau, and Au's (2003) model of orthographic knowledge development considered orthographic knowledge as consisting of characters' configuration knowledge (i.e., recognize a character as square patterns different than drawings), structural knowledge (i.e., break down a character into different radicals), positional knowledge (e.g., differentiate pseudo-characters from non-characters), radical information knowledge (e.g., acquire specific information about individuals radicals), functional knowledge (e. g., apply correct phonetic/semantic radicals to spell pseudo-characters), and the amalgamation of all the above.
3. A few characters, i.e., a20 塔, b2 充, b10 墓, and c4 苦, do not have exactly the identical forms in the traditional and the simplified system. The stroke numbers are based on the traditional form, and the traditional form was used in the experiment presentation.

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APPENDIX

Learning Materials

Group	Character	S#	C#	Pinyin	Configuration	English	Frequency
a1	秀	7	2	xiù	U-D	beautiful	14266
a2	命	8	4	mìng	U-D	life	40629
a3	妻	8	2	qī	U-D	wife	17795
a4	皇	9	2	huáng	U-D	royal	1185
a5	某	9	2	mǒu	U-D	some	88089
a6	盒	11	4	hé	U-D	case	14403
a7	悉	11	2	xī	U-D	to know	291780
a8	曾	12	4	zēng	U-D	ever	36170
a9	聚	14	5	jù	U-D	to collect	1020
a10	熊	14	5	xióng	U-D	bear	2928
a11	扔	5	2	rēng	L-R	to throw	6570
a12	改	7	3	gǎi	L-R	to change	12258
a13	股	8	2	gǔ	L-R	share	3545
a14	注	8	3	zhù	L-R	record	4365
a15	砍	9	2	kǎn	L-R	to cut	11718
a16	修	10	4	xiū	L-R	study	2501

(Continued)

APPENDIX (Continued)

Group	Character	S#	C#	Pinyin	Configuration	English	Frequency
a17	推	11	2	tuī	L-R	to push	3598
a18	剩	12	4	shèng	L-R	remains	890
a19	傲	13	4	ào	L-R	proud	4265
a20	塔	13	5	tǎ	L-R	tower	1165
b1	互	4	2	hù	U-D	mutual	368
b2	充	5	2	chōng	U-D	full	8512
b3	奇	8	4	qí	U-D	surprise	4534
b4	冠	9	4	guān	U-D	hat	3273
b5	染	9	3	rǎn	U-D	to catch	6911
b6	晨	11	2	chén	U-D	morning	22389
b7	寄	11	5	jì	U-D	to send	9169
b8	善	12	4	shàn	U-D	good	133117
b9	筷	13	3	kuài	U-D	chopsticks	93
b10	墓	14	4	mù	U-D	grave	1340
b11	汗	6	2	hàn	L-R	sweat	1115
b12	咕	8	3	gū	L-R	to rumble	139
b13	拜	9	3	bài	L-R	to bow	1034
b14	倒	10	3	dǎo	L-R	to fall	6044
b15	缺	10	2	quē	L-R	to lack	905
b16	偶	11	2	ǒu	L-R	even	44672
b17	握	12	3	wò	L-R	to hold	22273
b18	硬	12	2	yìng	L-R	hard	15700
b19	煤	13	3	méi	L-R	coal	335
b20	福	14	4	fú	L-R	happiness	1249
c1	兵	7	2	bīng	U-D	arms	3050
c2	享	8	3	xiǎng	U-D	to enjoy	4222
c3	炎	8	2	yán	U-D	hot	9682
c4	苦	9	3	kǔ	U-D	bitter	15700
c5	突	9	2	tū	U-D	suddenly	2854
c6	宵	10	3	xiāo	U-D	night	44168
c7	益	10	4	yì	U-D	advantage	1125
c8	袋	11	3	dài	U-D	bag	4796
c9	基	11	3	jī	U-D	base	1804
c10	筒	12	4	tǒng	U-D	pipe	989
c11	引	4	2	yǐn	L-R	to make	70775
c12	呼	8	4	hū	L-R	to call	43931
c13	括	9	2	kuò	L-R	to include	568
c14	俗	9	2	sú	L-R	common	2275
c15	值	10	3	zhí	L-R	to cost	2801
c16	跌	12	2	diē	L-R	to drop	6661
c17	殿	13	5	diàn	L-R	hall	2649
c18	搞	13	2	gǎo	L-R	to do	312915
c19	源	13	4	yuán	L-R	source	1437
c20	境	14	4	jìng	L-R	area	3821

"S#" and "C#" refer to the number of strokes and the number of chunks in a character, respectively. "U-D" stands for an up-down configuration, whereas "L-R" stands for a left-right configuration.