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Interword spacing effects on reading Mandarin Chinese as a second language

Yun Yao
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Abstract
This study tested the effects of interword spacing on the speed and comprehension of readers of Mandarin Chinese as a second language (CSL) of different proficiency levels and from typologically different orthographic backgrounds. Unspaced and spaced reading tasks were used to examine whether participants whose first languages (L1) were written in a spaced fashion read texts differently than those whose L1 was written in an unspaced fashion, and to determine whether interword spacing had different effects on the performance of CSL intermediate and advanced readers. The results showed that readers whose L1s were written in spaced fashion were not affected by the interword spaces, while readers whose L1 was written in unspaced fashion, especially those at the advanced level, were slowed down by the artificially added interword spacing in texts in Chinese as a second language (L2). It is hypothesized that the different effects of interword spacing on participants from different orthographic backgrounds are due to cross-language transfer from L1 to L2 reading.

Interword spacing is employed by the majority of the world's orthographies to mark word boundaries. However, it is not used by many languages written with Chinese-derived scripts (e.g. Chinese and Japanese) or Brahmi-derived scripts (e.g. Thai and Laotian; Nakanishi, 1980).

Chinese orthography has never employed interword spacing in either horizontal or vertical texts throughout its history. Classical Chinese is known to have been a monosyllabic language (Feng, 1997). Most of the characters represented free morphemes, and words were usually mono-morpheme (Hoosain, 1991). Although two-syllable combinations can be found in the earliest documents, monosyllabic words dominated in language use, as seen in the example of Mencius (c. 300 BC), where only 0.94% of the total words used were two-syllable combinations (Feng, 1997). Since characters functioned as words and served as dominant orthographic framing units in Classical Chinese, there was little need to insert spaces between them.

However, two-syllable words appeared in large numbers during the Han dynasty. In a 100 AD book, Critical Essays (Lunheng) written by Wang Chong (27–97 AD), 2.25% of the total words were disyllabic combinations, indicating a significant change compared with earlier books. The Analects of Confucius (c. 550 BC), for example, contains only 1.15% disyllabic words (Feng, 1997). The development of disyllabicity has been a robust tendency throughout Chinese history (Wang, 1980). It is estimated that in modern Chinese there are more than 60,000 words consisting of two or more characters (Sun et al., 1985). That is to say, about 70–80% of
all the Chinese words are made up of at least two characters (Yu et al., 1985). Due to this diachronic change from monosyllabic to disyllabic words, many characters can no longer be used alone as free morphemes. For example, as seen in 1, pèng (朋), which used to be an independent word in Classical Chinese, is no longer a free morpheme. It is usually used together with yǒu (友) to form a disyllabic word pèngyǒu (朋友) ‘friend’. Similarly, as seen in 2, the original meaning of yīn (姻) —‘bridegroom’s father’ is rarely used in modern Chinese. Instead, it is commonly used together with hūn (婚) to form a disyllabic word hūnyīn (婚姻) ‘marriage’.

(1) Yǒu pèng zì yuán fāng lái 有朋自远方来 Have-friend-from-far away-come ‘Friends come from far away’
(2) Xù zhī fù wéi yīn 婚之父为姻 Bridgroom-REL-father-be-yin ‘Bridegroom’s father is called yīn’

Since word boundaries are not explicitly marked in modern Chinese, readers need to discern whether a character is a word itself or only a part of a word. A string of characters, thus, can be segmented in different ways, creating correspondingly different meanings. Such phenomena exist in the English language as well, as seen in 1, ‘a green house plant’ can refer to a plant in a greenhouse or to a houseplant that is green (thank to an anonymous reviewer for this example). However, the ambiguity goes away as soon as interword spaces are inserted properly, as seen in (2) and (3).

(1) a green house plant
(2) a greenhouse plant (a plant in a greenhouse)
(3) a green houseplant (a houseplant that is green)

Unlike English, interword spacing information is not available in Chinese. Therefore, word frequency plays an essential role in determining how character texts should be segmented. However, when the frequencies of competing combinations are similar, the ambiguity of the sentence becomes higher (Hsu and Huang, 2000b). For example, as seen in 1, in the Mandarin sentence Huá shēng zhǎng zài wū hòu de tián lǐ (花生长在屋后的田里), the first three characters huá shēng zhǎng (花生长) can be interpreted as either huá shēngzhǎng ‘flowers grow’ (as in 2) or huāshēng zhǎng ‘peanuts grow’ (as in 3), depending on where the interword spacing is inserted (Hsu and Huang, 2000b).

(1) Huá shēng zhǎng zài wū hòu de tián lǐ 花生长在屋后的田里
(2) (Huā) shēngzhǎng zài wū hòu de tián lǐ 花生长在屋后的田里 flowers-grow-in-house-behind-field ‘Flowers grow in the field behind the house’
(3) (Huāshēng) zhǎng zài wū hòu de tián lǐ 花生长在屋后的田里 Peanuts-grow-in-house-behind-field ‘Peanuts grow in the field behind the house’

Learners of Mandarin Chinese as a Second Language (CSL) do not have enough Chinese language experience to rely upon when deciding which combination of characters is most frequently used, and so are likely to segment strings of characters in inappropriate ways, which not only may slow down their reading speed, but may also negatively affect their comprehension. When coming across a sentence Tā xǐ huān xué shēng cí (他喜欢学生词), beginners may well parse it into Tā xǐhuan xuéshēng cí he-like-student-word, as opposed to Tā xǐhūăn xuéshēngcí he-like-study-new word ‘He likes studying new words’, and thus may have difficulty understanding the sentence. Interword spacing, therefore, is sometimes employed in East Asian language pedagogy, as seen in the example of the elementary Japanese textbook Nakama I (Makino et al., 1998).

Zhang (1998) advocates the introduction of interword spacing in Chinese texts in order to significantly facilitate natural language processing. First of all, interword spacing makes automatic pinyin-character conversion possible at word-unit level, and in turn accelerates the development of Chinese text-to-speech recognition. Since more than 6,000 high-frequency characters correspond to less than 1,300 syllables, it is almost impossible to convert individual pinyin syllables to characters. However, the conversion becomes much easier at the level of word-units, since only 10% of the 20,000 Chinese high-frequency words are homophones (Hu, 1992). In addition, inserting interword spaces
also facilitates the conversion between traditional Chinese characters and simplified Chinese characters. Computer-assisted automatic conversion becomes unreliable in situations where one simplified Chinese character corresponds to more than one traditional Chinese characters. For example, the simplified Chinese character hou (后) corresponds to two traditional characters—hou (后) as in wanghou (王后) 'queen' and hou (後) as in ranhou (然後) 'afterwards.' Such problems are solved if words instead of characters serve as the orthographic framing units in Chinese texts. Zhang also points out that computer-assisted Chinese-to-English translation is more accurate if spaced Chinese texts are used.

However, Chinese word segmentation is sometimes difficult. Without consistent and clear-cut conventions, inserting interword spaces in Chinese texts may result in confusion. Yang (2006) points out that employing interword spaces gives rise to a number of problems. First of all, it is very difficult to reach a consensus on where to insert spaces. For example, rerenaonao (热热闹闹) hot-hot-noisy-noisy ‘lively’ can be parsed into either re re nao nao (热/热/闹/闹) or re renao nao (热/热/闹/闹), and it is difficult to determine which way of parsing is necessarily better than the other (Dong, 1997). Yang (2006) also suggests that employing interword spaces may result in further writing difficulties, since Chinese speakers would be forced to stop and decide where to insert spaces whenever writing down a word.

Therefore, among Chinese linguists there still exists substantial debate on whether interword spacing should be introduced to Chinese orthography and if so, how it should be inserted. More research should be done to investigate how interword spaces would affect orthographic processing for both Chinese native speakers and second language learners and the corresponding pedagogical implications.

1 Literature Review

As seen in Table 1, a multitude of studies investigating the comparative effects of the introduction of interword spacing on reading behaviors reveal that interword spacing does affect reading speed and eye movements.

2 Interword Spacing Effects on Reading Indo-European Languages

As seen in Table 1, the current literature on this topic shows two opposing views. Analogous data indicate that interword spacing plays an essential role in reading languages written with the Roman alphabet, for it not only provides readers with effective guidance in eye movements, but also groups strings of letters into meaning-conveying units. Several studies (Pollatsek and Rayner, 1982; Rayner et al., 1998) showed that eliminating interword spacing negatively affected reading for English native speakers. Perea and Acha's (2009) results also indicated that Spanish texts without interword spaces caused disruption in terms of word identification and eye movement control for native readers.

However, as shown in Table 1, data generated by other experiments reveal different results. Yang and McConkie's study (2004) found that replacing interword spaces with random letters did not influence native English speakers’ onset times of saccades, nor did the absence of spaces make their saccade length different from that with space-delimited non-words. Epelboim et al. (1994) study investigating both native and nonnative readers of English suggests reconsideration of the claim that emphasized interword spacing as a guide to eye movement. They found that the subjects’ comprehension level, percentage of regressions, number of saccades, and oculomotor pattern were approximately the same in both spaced and unspaced conditions.

Rayner and Pollatsek (1996) had serious reservations concerning Epelboim et al. conclusions and pointed out that the sample size of that experiment was too small, since there were only seven subjects in the experiment. They believed that although readers may be able to read unspaced texts, space information still played an essential role in saccades programming. In their own experiment (Rayner et al., 1998), native speakers were instructed to read English materials that were either normal text
in which the space information was unavailable (either removed or replaced by x), or text in which there were interword spaces and the words were flanked by x. The findings indicated that the absence of space information not only interfered with word identification, but also affected eye movement control.

### 3 Interword Spacing Effects on Reading Other Languages

#### 3.1 Japanese

As seen in Table 1, Sainio et al. (2007) examined the role that interword spaces played in reading Japanese. Native readers’ eye movements were observed when they read pure hiragana text and mixed kanji-hiragana text, both in spaced and unspaced conditions. The results showed that interword spacing facilitated reading both texts. Nevertheless, the subjects’ eye movements were influenced by interword spaces only when they read hiragana texts. The authors claim that this was due to the redundancy of adding interword spaces in mixed kanji-hiragana texts, since the visually salient kanji provided readers with effective segmentation cues.

#### 3.2 Thai

Thai–English bilinguals and English monolinguals participated in an experiment conducted by Winskel et al. (2009). As shown in Table 1, observations of the subjects’ eye movements when reading Thai and English texts with and without interword spaces suggested that spacing information facilitated word recognition, but did not influence eye movement or lexical segmentation in reading Thai texts, although it had clear effect on eye movements when subjects read English texts.

#### 3.3 Chinese

Although Chinese native speakers do not have interword spaces available as parsing aids when

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Table 1 Previous research on interword spacing effects

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Indo-European languages</th>
<th>Other languages</th>
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<tr>
<td></td>
<td>Language</td>
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<td>On speed or comprehension</td>
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<tr>
<td>Bai et al. (2008)</td>
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<td>Bassetti (2009)</td>
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<td>Everson (1986)</td>
<td>N/A</td>
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<td>Gao (2006)</td>
<td>N/A</td>
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<td>Gao (2008)</td>
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<td>Hsu and Huang (2000a)</td>
<td>N/A</td>
<td>Chinese</td>
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<td>Hsu and Huang (2000b)</td>
<td>N/A</td>
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<td>Liu et al. (1974)</td>
<td>N/A</td>
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<tr>
<td>Peng and Su (2009)</td>
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<td>Spanish</td>
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<td>Pollatsek and Rayner (1982)</td>
<td>English</td>
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<td>Rayner et al. (1998)</td>
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<tr>
<td>Sainio et al. (2007)</td>
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<td>Winskel et al. (2009)</td>
<td>English</td>
<td>+</td>
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<tr>
<td>Yang and McConkie (2004)</td>
<td>English</td>
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+ indicates positive effects were observed, whereas – indicates negative effects were observed.
reading, research has shown that they do not read Chinese more slowly than their English counterparts read English. Fixation times were found to be approximately the same for both languages. Saccadic lengths were found to be shorter for the Chinese language, and Chinese passages actually were read even faster, if saccadic lengths were not measured in terms of physical distance, but in terms of number of words covered in one eye movement (Sun et al., 1985).

As seen in Table 1, Liu et al. (1974) study was probably the first to investigate whether adding interword spaces would facilitate Chinese reading. They used seven-character sentences with interword spacing and the same sentences with no spacing as stimuli and compared the times required by native speakers to read the sentences. No facilitation effect was observed when interword spaces were placed in the reading materials. This phenomenon might have resulted from the fact that subjects were not used to the experimental spaced text. Another possible explanation offered by Hoosain (1992) was that the predetermined word boundaries exerted disruptive influence on subjects’ reading comprehension because different individuals had different ideas about word boundaries.

Everson (1986) investigated how Chinese readers were affected when texts were spaced into word-units. His data demonstrated that subjects who had acquired different degrees of automaticity with reading Chinese tended to use different strategies when reading. Native readers and L2 beginners did not show significant difference in processing the language material under either textual spacing condition, whereas the advanced L2 learners were disrupted by the artificial spacing condition. Comparisons of the eye movement behaviors of the three groups suggested that they employed different attention allocation strategies. For both textual conditions, the L2 beginners had to fixate more frequently and for longer duration, and they were found to regress over previously read text at a high percentage rate. The native readers, on the other hand, did not show a difference in either textual spacing condition because of the flexibility of their reading strategies. As for the advanced L2 readers, they were found to fixate significantly more times when reading passages in the spaced condition, but their fixation frequency patterns were similar to those of native readers when reading unspaced Chinese passages.

Bai et al. (2008) observed native Chinese readers’ eye movements as they read both spaced and unspaced texts. Global and local measures suggested that ordinary Chinese texts without interword spaces were as easy to read as those with spaces, but texts with spaces between characters that yielded non-words and texts with spaces between every character caused longer reading times.

Data generated in Gao’s (2008) study, in which sentences ranging from 15 to 19 characters long were used as stimuli, again demonstrated that interword spacing provided no significant facilitation effects for both native and nonnative Chinese readers of beginning, intermediate, and advanced language proficiency. On the other hand, an earlier experiment conducted by Gao (2006) showed that the introduction of interword spacing improved CSL learners’ reading speed when they read long texts, although it did not affect their reading comprehension when short texts were used as stimuli. Different results yielded by the above two studies (Gao, 2006, 2008) suggest that the length of the stimuli used may have had significant influence on what strategies readers chose to employ and how they processed the reading materials.

Hsu and Huang’s (2000a) experiment showed that interword spacing significantly improved Chinese native speakers’ performance when reading from a video display terminal. There were three levels of interword spacing in the stimuli they used—the conventional spacing, as seen in 1, half-character spacing, as seen in 2, and whole-character spacing, as seen in 3 (Hsu and Huang, 2000a). They found that both half-character interword spacing and whole-character spacing significantly reduced subjects’ reading time and enhanced their comprehension. In addition, the fact that the number of questions answered correctly for text with half-character spacing was significantly greater than that for text with whole-character spacing suggested that the optimal interword spacing should be wider than that of unspaced texts and narrower than whole-character spacing. The results of the study indicated that explicitly

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marking word boundaries may be beneficial to Chinese readers.

(1) 文艺不但在创作上是人的表现，……
   (conventional).
(2) 文艺不但在创作上是人的表现，……
   (half-character).
(3) 文艺不但在创作上是人的表现，……
   (whole-character).

In another study, Hsu and Huang (2000b) conducted a series of experiments to investigate interword spacing effects on native Chinese readers. In experiment 1, text read aloud by TV broadcasters and college graduates was analyzed by a sonogram detector. The fact that interword intervals were significantly longer than intercharacter (within a word) intervals confirmed the psychological reality of interword spacing in speech. The results of the second experiment showed that separating the characters of a word led to longer reading times, although it did not affect accuracy. Experiment 3 indicated that interword spacing significantly reduced reading times for high-ambiguity sentences, but not so much for low-ambiguity sentences. Hsu and Huang (2000b) concluded that adding interword spacing in Chinese texts would enhance reading performance because it would help readers to process a string of characters more quickly and reduce the chance of misinterpretation.

Bassetti’s (2009) study was one of the few experiments conducted to compare the effects of explicit demarcation of Chinese word boundaries on the reading processes of native and nonnative readers. She had both groups perform two sentence–picture verification tasks and found that interword spacing facilitated pinyin reading for nonnative readers but not for the native readers. No significant interword spacing effects on character reading were observed for either group.

Peng and Su (2009) compared the eye movement of Korean students when they read spaced and unspaced Chinese texts. The results suggest that the reading efficiency of Korean students improves considerably when word boundaries are explicitly marked. They therefore concluded that using spaced texts in Chinese textbooks would facilitate Korean students’ learning of Chinese.

4 Summary of the Previous Studies

As shown above, a growing body of scholarship has illustrated the essential role that interword spacing plays in reading languages written with the roman alphabet: Interword spacing not only provides readers with effective guidance in eye movements, but also groups strings of letters into meaning-conveying units (Pollatsek and Rayner, 1982; Rayner et al., 1998; Perea and Acha, 2009). Yang and McConkie (2004) and Epelboim et al. (1994), on the other hand, report that reading behaviors were similar in both spaced and unspaced conditions. The discrepancy in results may be due to the different methodologies and participant populations involved in different studies. In Yang and McConkie’s (2004) study, interword spaces were replaced by random letters, which may have caused a different effect than simply deleting interword spaces.

Hsu and Huang (2000a, 2000b), Gao (2006), Sainio et al. (2007), Winskel (2009), and Peng and Su (2009) suggested that interword spacing facilitated Japanese and Thai speakers’ reading process, whereas Liu et al. (1974), Everson (1986), Bai et al. (2008), Gao (2008), and Bassetti (2009) reported that interword spacing did not seem to be significantly facilitative for reading normally unspaced scripts. The mixed findings may also be attributed to a multitude of factors, including the target languages investigated, the underlying subject populations, the stimuli used, the modality of measurements, etc. On the whole, previous research shows that interword spacing has facilitative effects when ambiguous texts and long texts are involved, but not so much for shorter and less ambiguous texts. Moreover, interword spacing also appears to function differently in different unspaced orthographies (i.e. Chinese, Japanese, and Thai) and have different effects on native and nonnative readers.

Nevertheless, interword spacing effects on reading L2 orthographies other than languages written with the roman alphabet, especially unspaced orthographies such as Chinese, Japanese, and Thai, have not been as well documented. The majority of the studies described above examined the
reading processes of native speakers. Only six studies (Everson, 1986; Epelboim et al., 1994; Gao, 2006, 2008; Bassetti, 2009; Peng and Su, 2009) involved second language learners. Few studies have looked at the interaction effect of interword spacing and participants’ language proficiency (Everson, 1986; Gao, 2006, 2008; Peng and Su, 2009). No studies have compared the effect of interword spacing on CSL readers coming from spaced and unspaced L1 orthographic backgrounds.

5 The Present Study

In the light of the limitations of the previous research, the present study addressed the following three research questions:

(1) Does the introduction of interword spacing facilitate the reading process of nonnative Chinese readers?
(2) Does the introduction of interword spacing have the same effects on CSL learners of different proficiency levels?
(3) Does the introduction of interword spacing have the same effects on CSL learners coming from different orthographic backgrounds? Are the effects of interword spacing on second language reading dependent on the spacing characteristics of the reader's native orthography?

5.1 Design

A 2 (native orthography background) × 2 (Chinese proficiency level) × 2 (text type) design was used to investigate the effects of L1 orthographic background, Chinese language proficiency level, and interword spacing on Chinese reading. The 102 participants were divided into two groups based on their L1 orthographies: the spaced L1 group included those whose native languages were written in spaced fashion (N=53) and the unspaced L1 group consisted of those whose native language was written in unspaced fashion (N=49). As for Chinese proficiency level, the participants were assigned to two categories: intermediate learners (N=48) and advanced learners (N=54).

All the participants were asked to read one spaced Chinese text and one unspaced text. Their performance was measured in terms of reading speed, which was calculated by number of characters read per second, and accuracy rate, which was calculated by percentage of correct responses to comprehension questions asked about the readings.

5.2 Participants

A total of 102 international students enrolled in Chinese language programs at either Beijing Language and Culture University or East China Normal University participated in the study and received payment for their participation.

These participants included two groups:

(1) Fifty-three CSL learners whose native languages were written in spaced fashion. Among this group, there were 2 Arabic speakers (3.77%), 26 English speakers (49.06%), 2 French speakers (3.77%), 2 Indonesian speakers (3.77%), 3 Italian speakers (5.66%), 1 Mongolian speaker (1.89%), 2 Portuguese speakers (3.77%), 12 Russian speakers (22.64%), 2 Spanish speakers (3.77%), and 1 Urdu speaker (1.89%).

(2) Forty-nine CSL learners whose native language was written in unspaced fashion (i.e. forty-nine native speakers of Thai).

As shown in Table 2, the participants were assigned to an intermediate group (N=48) and an advanced group (N=54) according to their scores on a Chinese proficiency test given before the experiment. As seen in Examples 1 and 2, the test was administered in the written modality and was divided into a vocabulary section and a grammar section, with each section consisting of fifteen multiple choice questions. The mean score on the test was 23.49%. Participants who scored less than 15.00% were classified as intermediate learners, and those scoring above 15.00% were classified as advanced learners. The mean score on the test was 9.20% for the intermediate group, and 36.20% for the advanced group. According to the questionnaires filled out by the participants, the average length of the advanced group's Chinese study was 32.48 months, and 12.58 months for the intermediate group.
Example 1. 昨天你为什么迟到? (Vocabulary Section)

A B C D
没来 报名 睡过头了 来晚了

Example 2. 我昨天买了一 ______ 车。 (Grammar section)

A B C D
件 块 辆 条

In order to assess the unspaced L1 group’s experience with spaced texts and the possible relation between their English proficiency and performance when reading spaced Chinese texts, they were asked to take an English proficiency test after the experiment. As seen in Example 3 and 4, the test was also administered in the written modality and was divided into a vocabulary section and a grammar section, with each section consisting of 15 multiple choice questions. On average they scored 28.50%, with the intermediate group scoring 33.50% and the advanced group scoring 25.06%.

Example 3. ‘Stigma’ means _______. (Vocabulary section)

A. mark of shame or disgrace
B. lack of seriousness
C. treachery, breaking of faith
D. a group or band of people

Example 4. When I graduate from college next June, I ______ a student here for five years. (Grammar section)

A. will have been B. have been
C. has been D. will have

An ANOVA test was used to compare the performance of the different groups of participants in the Chinese proficiency test, with native language background and proficiency level as the independent variables, and their scores as the dependent variable. No significant difference was observed in language proficiency between the spaced and unspaced L1 group (p = .9521), but the advanced learners scored significantly higher than the intermediate learners (p < .001). No interaction effect between participants’ L1 background and proficiency was observed (p = .8931).

5.3 Stimuli

As seen in the Appendix A, the experimental stimuli were two 750-character-long articles written based on a second year Chinese textbook Chinese Link: Zhongwen Tiandi (Wu et al., 2008). The articles were of a comparable level of difficulty in terms of sentence complexity, propositional complexity, word frequencies, and character frequencies.

All the participants were familiar with the topics covered in the material but none of them had read these particular articles before. Two native Chinese speakers collaborated to segment the texts into word units by inserting interword spaces according to the ‘syntactic word’ criterion: A word is the smallest form that can independently occur in a syntactic form class slot (Packard, 2000). The articles and the corresponding comprehension questions were pre-tested with seven native speakers and two nonnative speakers in the pilot study and then refined prior to the main experiment.

As seen in Table 3, there were two versions of each article – spaced and unspaced – and correspondingly two different versions of the Chinese reading test (see Appendix A). The two articles were counterbalanced in the different versions of test in order to reduce potential confounding caused by possible
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5.4 Procedure
After completing the Chinese proficiency test, the participants had 90 s to read each article. After 90 s, participants were asked to stop reading the first article and circle the last character they read. Participants were then given 90 s to answer the corresponding fifteen comprehension questions. Participants were explicitly told prior to the experiment that they would have to answer questions after they read the articles, and their reading strategies were thus expected to be consistent across different articles. After submitting the answer sheets, the same procedure was repeated for the second text. The entire experiment thus lasted about 20 min. All tests were administered individually or in small groups at the participants’ universities in Beijing and Shanghai, China.

6 Results
Table 4 presents the means and standard deviations for the two dependent variables—reading speed and accuracy rate—across the spaced and unspaced L1 group.

Data from the 102 participants were analyzed using two random-effects generalized least squares (GLS) regression tests in Stata. Random-effects models were used because they have important advantages over traditional methods of repeated-measures analysis. According to Gueorguieva and Krystal (2004), the basic benefits of the random-effects model are that it is much more flexible than a repeated-measures ANOVA, is unaffected by randomly missing data, and improves statistical power, for it not only uses all available data, but also appropriately accounts for correlation between repeated measurements on the same individual and has larger flexibility to model time effects.
In the present study, repeated-measures data were strongly correlated, since the values of sequential observations of the same participant were close to one another. In addition, two participants only completed part of the experiment. Therefore, the flexibility of the random-effects model made it the preferred choice here.

The dependent variable in the first test is reading speed, which was measured by characters read per second. Accuracy rate, measured by percentage of comprehension questions answered correctly, is the dependent variable in the second test. In both models, participant is a random-effect factor, and fixed-effect factors include: participants’ native orthography (0 if spaced, 1 if unspaced), Chinese proficiency level (0 if intermediate, 1 if advanced), text type (0 if unspaced, 1 if spaced), and the interaction effects among the three variables.

Table 5 shows the results of the regression test for the effects on reading speed. As expected, the advanced participants read significantly faster than the intermediate learners.

After running the regression, planned post hoc tests were performed to investigate the potential difference in the average speed of the spaced L1 group and the unspaced L1 group across the two spacing conditions. As seen in Fig. 1, the unspaced L1 group's average reading speed for the unspaced text was significantly higher than that for the spaced text ($p = .0030$). Their speed was 0.24 characters per second slower when the interword spaces were added. The spaced L1 group's average reading speed, on the other hand, was 0.04 characters per second faster when the spaces were added.

Planned post hoc tests were also conducted to examine whether the artificial interword spaces had

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>SE</th>
<th>z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native orthography</td>
<td>-0.17</td>
<td>0.38</td>
<td>-0.45</td>
<td>.653</td>
</tr>
<tr>
<td>Proficiency level</td>
<td>1.75</td>
<td>0.36</td>
<td>4.92</td>
<td>&lt;.0001***</td>
</tr>
<tr>
<td>Text type</td>
<td>-0.02</td>
<td>0.14</td>
<td>-0.14</td>
<td>.886</td>
</tr>
<tr>
<td>Text type*Native orthography</td>
<td>0.003</td>
<td>0.21</td>
<td>0.01</td>
<td>.989</td>
</tr>
<tr>
<td>Native orthography*Proficiency level</td>
<td>0.23</td>
<td>0.52</td>
<td>0.45</td>
<td>.655</td>
</tr>
<tr>
<td>Text type*Proficiency level</td>
<td>0.12</td>
<td>0.20</td>
<td>0.60</td>
<td>.549</td>
</tr>
<tr>
<td>Text type<em>Native orthography</em>Proficiency level</td>
<td>-0.50</td>
<td>0.29</td>
<td>-1.74</td>
<td>.082</td>
</tr>
</tbody>
</table>

***$p<.001$.

![Fig. 1](image_url)
different effects on advanced learners and intermediate learners. As seen in Fig. 2, the advanced learners’ reading speed was significantly higher in the unspaced condition ($p = .0087$), whereas the intermediate learners behaved similarly in both conditions ($p = .9058$).

Additional analysis demonstrates that the advanced learners whose native orthography was unspaced (i.e. Thai speakers) were mainly responsible for the difference. As seen in Fig. 3, the introduction of the interword spaces slowed down their average reading speed by 0.40 characters per second ($p = .0074$), but did not affect the speed of the intermediate learners ($p = .4908$).

Table 6 displays the results of the regression for the effects on accuracy rate. Again, as expected, a main effect was found for proficiency level, with the average accuracy rate of the advanced learners being significantly higher than that of the intermediate learners. However, post hoc tests indicate that the introduction of interword spaces and its interaction with participants’ native orthographies and proficiency levels did not have significant effects on their accuracy rate. This is likely due to the fact that reading speed is a more direct measurement of processing difficulty than accuracy rate. Therefore, it can capture subtle differences in text processing difficulty, such as that caused by differences in interword text spacing.

Additional statistical analysis showed that the participants’ scores on the Chinese proficiency test significantly correlated with the length of...
their Chinese study \((r=0.54, p<.001)\), with their reading speed \((r=0.78, p<.001)\), and with their accuracy rate \((r=0.31, p<.001)\) as measured in the main experiment, suggesting that allocating participants into proficiency levels according to the results of the proficiency test was a valid procedure.

### 7 Summary and Discussion

The experimental results may be summarized as follows. First, artificially added interword spaces have different effects on CSL learners coming from typologically different orthographic backgrounds. Although the introduction of interword spacing significantly slowed the reading speed of CSL learners whose native language is written in an unspaced fashion (i.e. native speakers of Thai), the introduction of interword spacing did not affect the reading speed of those whose native languages are written with word spacing. Second, the advanced learners who were native speakers of languages with unspaced orthography were significantly slowed down by the artificial interword spaces, whereas the intermediate readers were unaffected. Third, with regard to reading comprehension accuracy, the introduction of interword spacing did not affect CSL learners’ reading performance.

Comparisons of the interword spacing effects on learners from different orthographic backgrounds show that previous reading experience and habits may affect L2 reading speed. Since there are no interword spaces in Thai orthography, interword spaces may be considered relatively ‘marked’ for Thai native speakers, and the slower performance of Thai L1 speakers on spaced L2 Chinese texts may be due to negative cross-language transfer from L1 to L2 reading. Thai readers, due to their experience in reading their L1, are unaccustomed to reading texts that demarcate word boundaries using spacing. Therefore when Thai readers encounter Chinese texts with word boundaries demarcated using spacing, their reading speed is naturally slower as they attempt to extract meaning from the text. Native readers of spaced orthographies (i.e. Arabic, English, French, Indonesia, Italian, Mongolian, Portuguese, Russian, Spanish, and Urdu), on the other hand, are accustomed to reading texts with space-demarcated word boundaries, and so do not find artificially-spaced Chinese texts as cognitively challenging as appears to be the case for the unspaced L1 group.

A closer look at the performance of CSL learners of different proficiency levels again confirms the effect of previous reading experience on reading speed. Since the advanced learners had been working with the unspaced Chinese texts for a longer time and might have developed their own strategies for demarcating word boundaries while reading, the artificial interword spacing appeared to be disruptive and significantly slowed their speed. This may explain why the introduction of interword spacing did not affect the reading speed of the intermediate learners, who were still in the process of developing Chinese-specific L2 reading strategies.

As for the possible relation between the unspaced L1 group’s experience with spaced languages (e.g. English) and interword spacing effects on their Chinese reading performance, their scores on the

### Table 6 Effects on accuracy rate (percentage correct in comprehension questions)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>SE</th>
<th>z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native orthography</td>
<td>-0.03</td>
<td>0.03</td>
<td>-0.85</td>
<td>.393</td>
</tr>
<tr>
<td>Proficiency level</td>
<td>0.08</td>
<td>0.03</td>
<td>2.80</td>
<td>.005**</td>
</tr>
<tr>
<td>Text type</td>
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<td>0.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Text type*Native orthography</td>
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<td>0.04</td>
<td>-0.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Native orthography*Proficiency level</td>
<td>0.03</td>
<td>0.04</td>
<td>0.77</td>
<td>.442</td>
</tr>
<tr>
<td>Text type*Proficiency level</td>
<td>0.02</td>
<td>0.04</td>
<td>0.58</td>
<td>.562</td>
</tr>
<tr>
<td>Text type<em>Native orthography</em>Proficiency level</td>
<td>0.01</td>
<td>0.05</td>
<td>0.16</td>
<td>.873</td>
</tr>
</tbody>
</table>

**p<.010.
English proficiency test accounted for no additional variance. If lack of familiarity with word-spaced orthography is the reason for slower performance of the Thai speakers with the spaced Chinese orthography, there was likely to be a smaller spacing effect for those Thai speakers who scored higher on the English proficiency test. The fact that this did not happen suggests that lack of experience with English orthography is not the reason for slower overall performance of the Thai speakers with spaced Chinese orthography.

7.1 Pedagogical implications and recommendations for future research

The findings of this study suggest that it may be more effective to design different lesson plans and curricula catering to the individual needs of CSL learners coming from different orthographic backgrounds. In the realm of Chinese reading pedagogy, attention has long been given to ‘characters’ per se, as seen in the emergence of a wide variety of instructional materials designed specifically for the CSL learners whose first languages use orthographies related to Chinese character orthography (e.g. Japanese speakers) and for those who have little previous exposure to Chinese characters (e.g. English speakers). On the contrary, the layout of Chinese texts and its corresponding pedagogical implications have received relatively little consideration. According to the results of this study, artificially spaced Chinese texts could be employed in elementary Chinese reading classes designed for learners from spaced orthographic backgrounds, so that they would not have to deal with the difficulty of adjusting to a typologically different writing system (i.e. Chinese characters) and the difficulty of getting used to word boundary differences at the same time. However, CSL learners should not be exposed to spaced texts for a prolonged period of time and the transition between spaced and unspaced texts should be well-planned and systematic. Such instructional materials, on the other hand, may not be necessary for advanced CSL learners and those from unspaced orthographic backgrounds.

This study raises a number of questions which would benefit from additional research. Readers’ individual reading habits could be a confounding factor in this study, since all the participants had been reading ordinary unspaced Chinese texts since they started to learn Chinese and had never been exposed to artificially spaced Chinese texts before the experiment. A similar study comparing the performances of Chinese children (e.g. first graders) and CSL beginners, who also would have minimal experience reading Chinese texts, would be one possible way to control for this potentially confounding factor. A follow-up eye-tracking study may be a profitable next step to provide a more sensitive measure of L2 learners’ ability to parse Chinese texts.

In addition, the comprehension questions were timed in this study, which potentially confounded the issue of whether the participants did not understand the texts or they did not have enough time to answer the questions. The measurements used in this experiment (characters per second, percentage of multiple choice questions answered correctly) could also be further refined to reduce sources of additional error variance. More precise measurements would allow for a more detailed and accurate analysis.

Another way to improve on the present study concerns the participants’ native orthographic backgrounds. Although whether their native orthographies were spaced or unspaced was predicted to have a significant effect on how CSL learners processed spaced and unspaced Chinese texts, the fact that the members of the spaced L1 group came from different language backgrounds (e.g. Arabic, English, French, Indonesian, Italian, Mongolian, Portuguese, Russian, Spanish, and Urdu) whereas all the members of the unspaced L1 group were native Thai speakers might have influenced the results of the experiment. A comparison between the L2 Chinese reading performance of native Vietnamese and Thai speakers could be adopted in future research, since both languages have similar characteristics but differ in spacing conventions.

Funding

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Acknowledgements

I wish to thank Prof. Jerome Packard and Prof. Joseph Robinson for insightful suggestions and kind help throughout the project. I would especially like to thank my colleague Yaqiong Cui for helping me with stimulus generation, subject recruitment, and experiment administration. I am also grateful to the editors and the anonymous reviewers for their constructive comments on an earlier version of this article.

References


Appendix A

Article #1 (the spaced version)

去年暑假的时候，我的美国朋友爱伦和他女朋友小美一起来我的家乡——天门旅行了。这是他们第一次来中国，所以他们既激动又兴奋。我跟他们说天门有很多好吃的小吃，也有很多好玩儿的地方，他们高兴地说这次非吃遍天门，玩遍天门不可！于是我陪他们一起在天门逛了好几天。

我们先去了中山公园。那天是星期天，去中山公园玩儿的人特别多，我们玩了差不多两个小时左右，还拍了很多照片。中午十二点半，我们去了南京路。南京路是我们天门最有名的商业街，离中山公园很近。从中山公园往东走，经过两条大街再向北拐就是了。南京路上有各种各样的商店，爱伦和小美买了很多送给美国朋友的礼物，我们还在这儿的一家很有名的老字号小吃店吃了午饭。爱伦和小美特别喜欢天门的小笼包和炒饭。

第二天，我们去了中华园。这天来中华园玩儿的人也不少，但我们都很兴奋，还在太平湖划了船。下午的时候，我带他们去了离中华园不远的天门大学，天门大学是我们天门最好的大学。小美说天门大学太漂亮了，这里的大学生活一定很愉快。我们还看到了很多在天门大学学中文的留学生。他们有的在和中国朋友聊天，有的躺在草地上看书，还有的在练习武术。小美现在也正在学中文，她觉得中文虽然越学越难，可是却越学越有意思。她说以后有机会一定要来天门大学继续学中文。晚上，我还邀请了他们到新世界那儿的酒吧去坐坐，他们都觉得感觉好多了！

后来，我们还去爬了西山，因为在西山上可以看到天门的全景。爱伦还听人们说“没到过西山就是没到过天门”，所以他们一定要去爬爬西山。那天的天气可真是太热了，可是我们不但一点儿都不觉得累，反而越玩越有精神呢！小美听我说到了秋天，整个西山都会变成红色的时候，她觉得有一点儿可惜。

爱伦和小美要回美国的前一天晚上，我请他们到我家来吃晚饭。我和妈妈做了很多菜，有鸡鸭鱼肉，也有传统小吃，还有妈妈的拿手好菜……摆了满满一桌。我们吃着、说着、笑着，高兴得连时间都忘了。爱伦和小美很感谢我的热情招待，还邀请我一有机会一定要去美国走走呢！
Comprehension Questions

1.  My American friends仑伦和他的女朋友小美什么时候来天门旅行的？
   A 今年春天  B 今年秋末  C 今年夏天  D 今年秋天

2.  仑伦和小美第一次来中国，他们感觉怎么样？
   A 他们觉得天门的风景很美丽  B 他们觉得天门很美
   C 他们觉得既兴奋又激动  D 他们觉得很有精神

3.  仑伦和小美为什么说要吃遍天门，玩遍天门？
   A 因为天门的东西很便宜  B 因为来天门旅行的人很多
   C 因为我和他妈妈做饭做得很好吃  D 因为我和他们说天门有很多好吃的小吃，也有很多好玩儿的地方

4.  我们在中山公园玩儿了多长时间？
   A 一个小时左右  B 两个半小时左右  C 一个半小时左右

5.  我们在哪儿拍了很多照片？
   A 太平湖  B 西山  C 中山公园  D 中华园

6.  天门大学在哪儿？
   A 中华园里边  B 中山公园里边  C 中华园附近  D 中山公园附近

7.  小美为什么想去天门大学学习中文？
   A 中文虽然越学越难，却越学越有意思  B 小美觉得那里的大学生活很愉快
   C 小美在天门大学有很多中国朋友  D 天门大学不仅可以学中文，还能练习武术

8.  仑伦和小美在哪儿买了很多送给美国朋友的礼物？
   A 南京路  B 西山  C 我家  D 中山公园

9.  请选出正确的一项
   A 仑伦觉得中华园非常漂亮  B 小美特别喜欢吃小笼包和炒面
   C 第二天上午，我们一起去天门大学  D 南京路在中山公园的东边

10.  在哪儿可以看到天门的全景？
    A 南京路  B 中山公园  C 小吃店  D 西山

11.  他们为什么一定要去爬西山？
    A 因为西山是天门最高的地方  B 因为没有去过西山就是没有去过天门
    C 因为西山上不太热  D 因为西山上的景色很漂亮

12.  仑伦和小美爬西山的时候感觉怎么样？
    A 他们觉得天气太热了，所以没有精神  B 他们很感谢我带他们去西山玩儿
    C 他们不但不觉得累，反而更有精神  D 他们觉得西山很没意思

13.  秋天的时候，西山会怎么样？
    A 西山上会有很多人  B 西山会变得很凉快  C 西山会变成红色
    D 西山上会有很多小吃店

14.  我和妈妈是怎么招待仑伦和小美的？
    A 我和妈妈去机场接仑伦和小美  B 我和妈妈陪仑伦和小美聊天
    C 我和妈妈给仑伦和小美买了很多礼物  D 我和妈妈做了很多手抓米

15.  仑伦和小美觉得天门怎么样？
    A 他们俩都特别喜欢天门，其中最喜欢中华园。  B 伦伦觉得在天门购物很方便，也很愉快
    C 他们俩不仅喜欢天门的风景，也喜欢那儿的小吃  D 小美很喜欢天门，所以她决定要申请那儿的暑期班

Article #2 (the spaced version)

三月 五日 是 我们 大学 的 百年 校庆。我们 的大学 已经 有 一百年 历史 了，我们 也 已经 毕业了 十 年 了。同学们 当中 不少 人 己经 有 整整 十年 没有 见过面 了。这次 校庆 不 能 不 说 是 一个 好 机会，所以 大家 很早 就 约好，来 学校 里 聚会。

那天，我 见到了 很多 同学。同学们 来自 四面八方，有的 就 在 这里，有的 是 从 国外 专门 回来 参加 百年 校庆 的。同学们 见了面 以后 都 非常 高兴，脸 上 都 挂着 微笑。张建国 和 李月华 都 是 我们 经济 系 的 同学。他们俩 以前 经常 吵架，没 想到 他们俩 一 到 美国 就 结婚了，还 生了 三个 孩子。张建国 现在 是
一位有名的工程师，工作特别忙，不过多年来他一直坚持锻炼身体，哪怕 是 刮风下雨，也天天去户外运动。李月华看起来倒不太有精神，因为她得一面工作，一面照顾孩子。高伟当年特别爱打篮球，常常不来上课，也从不写作业。所以 他 经常让我把作业借给他。最后的毕业考试他 也 差点不及格。再加上这几年经济不景气，他曾 一直也没找到一份好工作。这次聚会看到 他 一个个都事业有成，家庭幸福，他“唉”了一声，说道：“早知今日，何必当初呢！”

我们见了面以后的第一件事就是一起去看了以前教过我们的王教授。我们都在他 的 中国历史、东亚文化、和日本文学，我还特别喜欢他的“韩国电影”那门课。十年过去 了，王教授的头发都白了，可还是那么健康，那么有精神，而且他连我们的名字都记得很清楚，我们都感到很感动。

我们学校的 变化也 非常大，很多地方 我们都不认识了。校园里的高楼 以前 多了很多，我们 都 找不到以前 上过课的教学楼了。以前我们常常去学习的图书馆比以前大了两倍，我们以前住过的宿舍都变成了漂亮的公寓楼。还有很多打篮球的运动场也变成了一个很大的体育场，在里面可以打篮球、打网球，还可以游泳呢。

但是有的地方可 一点儿都没有 变，还记得我们当年最喜欢去“味好美”饭馆吃饭，那儿的菜很好吃，其中，上海小笼包 和春卷，是我们最喜欢吃的 小吃。我们这次也去那里吃饭了！这家饭馆还和以前一样，只是 比以前更大了，来吃饭的人也更多了。我们吃着好吃的饭菜，回想这以前的大学生活，觉得好像回到了以前一样。

Comprehension Questions

1. 我们的大学已经有多少年历史了？
   A 五十年  B 七十年  C 一百年  D 一百二十年

2. 同学们见了面以后觉得怎么样？
   A 因为我们有十年没见过面了，所以不知道要说什么
   B 因为我们很久没见过面了，所以都不认识了
   C 我们都很高兴，脸上挂着微笑
   D 我们都老了很多

3. 请选出正确的一项
   A 张建国和李月华有两个孩子
   B 张建国和高伟现在在美国工作
   C 张建国的专业是工程
   D 李月华的专业是经济学

4. 为什么李月华看起来没有张建国那么年轻？
   A 李月华没有坚持锻炼身体
   B 李月华现在是有名的工程师，工作太忙
   C 李月华得一面工作，一面照顾孩子
   D 李月华去了美国以后常常和张建国吵架

5. 为什么高伟感叹“早知今日，何必当初”？
   A 时隔多年，同学们都变了
   B 高伟当年毕业考试差点不及格
   C 高伟很后悔当年没有努力读书
   D 这些年经济很不景气，找工作很难

6. 同学们见了面以后的第一件事是什么？
   A 去我们以前打篮球的运动场
   B 去看新的图书馆
   C 去“味好美”饭馆吃饭
   D 去看以前教过我们的王教授

7. 王教授曾经教过我们哪些课？
   A 中国文化，日本文学，韩国电影和东亚历史
   B 日本文学，韩国电影，中国历史和东亚文化
   C 日本文化，中国历史，东亚文学和韩国电影
   D 韩国历史，中国文学，日本电影和东亚文化

8. 王教授现在怎么样？
   A 虽然王教授的头发都白了，可是他还是很有精神
   B 王教授的身体不太好
   C 王教授已经记不清楚我们的名字了
   D 王教授已经退休十年了

9. 请选出正确的一项
   A 我们以前常常去读书的图书馆没有变
   B 我和同学们一起去看了我们以前上过课的教室
   C 我们已经毕业了十年了
   D 现在的体育馆不能游泳
10. 我们以前住过的宿舍现在怎么样了？
A 现在可以在宿舍里打篮球、打网球，也可以游泳
B 宿舍已经变成一个漂亮的公寓楼了
C 宿舍里现在有一个图书馆
D 宿舍的楼下现在有一家不错的中国饭馆。

11. 学校里有什么没有变？
A “味好美”饭馆 B 运动场 C 宿舍 D 图书馆

12. 我和同学们以前最喜欢去哪里吃饭？
A 宿舍 B 食堂 C “味好美”饭馆 D 咖啡馆

13. 关于“味好美”饭馆，下面哪一项是正确的？
A “味好美”饭馆现在和以前一样大
B “味好美”饭馆的菜不好吃
C 在“味好美”饭馆可以打网球
D 去“味好美”饭馆吃饭的人比以前更多了

14. 请选出不正确的一项：
A 同学们有的住在这里，有的是从国外回来的
B 我和同学们约好在学校里聚会
C 我们吃着好吃的饭菜，
   想着以前的大学生活，好像回到了以前一样
D 我们的学校没怎么变

15. 作者的心情怎么样？
A 看到大家都变了，觉得有些惋惜
B 看到校园发生了这么大的变化，感到很惊讶
C 时隔多年再次见到了老师同学，既激动又高兴
D 吃到了以前最爱吃的小吃，觉得心里很温暖