Journal of Experimental Psychology: Learning, Memory, and Cognition

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Online First Publication, October 22, 2012. doi: 10.1037/a0030337

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0278-7393/12/$12.00 DOI: 10.1037/a0030337

The Advantage of Word-Based Processing in Chinese Reading: Evidence From Eye Movements

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In 2 experiments, we tested the prediction that reading is more efficient when characters belonging to a word are presented simultaneously than when they are not in Chinese reading using a novel variation of the moving window paradigm (McConkie & Rayner, 1975). In Experiment 1, we found that reading was slowed down when Chinese readers could not see characters belonging to a word simultaneously compared to when they could do so. In Experiment 2, when Chinese readers could choose whether the 2 characters in the moving window contained a word or 2 characters that did not constitute a word, they had a clear tendency to look at 2 characters belonging to a word simultaneously. The results of the current study provide strong evidence that character processing is affected by word knowledge and the processing of other characters belonging to the same word in Chinese reading, and add to a growing body of evidence demonstrating that words do have psychological reality for Chinese readers. The results also suggest that the eye movement control strategy of Chinese readers is rather flexible in that it can be adjusted online to modify the characteristics of the window.

Keywords: Chinese reading, eye movements, word processing

For readers of English, letters are identified more accurately when they are embedded within a briefly presented word than within a briefly presented nonword letter string (Reicher, 1969; Wheeler, 1970). Many models of word recognition assume that the processing of letters belonging to a word is not independent but is affected by word knowledge and by the processing of other letters belonging to the same word in English. For example, the interactive activation model (McClelland & Rumelhart, 1981) assumes that the activation of the related letter units increases more quickly when the input stimuli constitute a word than when the stimuli do not constitute a word. Letter processing is affected by word knowledge and by the processing of the letters in the same word since there are spaces between them and English readers can segment them via low-level visual information. For Chinese readers, however, there are no spaces or other explicit markers between words to mark the word boundaries. Hence, Chinese readers cannot segment words with low-level visual information. In this situation, is the characters' processing affected by word knowledge and by the processing of other characters belonging to the same word?

Chinese reading differs from English reading in many dimensions. First, there are more than 5,000 Chinese characters in contrast to 26 letters in English, and the information density in each Chinese character is much higher than in each English letter (Hoosain, 1991). Second, Chinese words are made up of characters while English words are made up of letters, and the average number of characters in Chinese words is less than the average number of letters in English words. Among the 56,008 words that are included in one published source (Lexicon of Common Words in Contemporary Chinese Research Team, 2008), 6% of Chinese words are single-character words, 72% are two-character words, 12% are three-character words, and 10% are four-character words. Less than 0.3% of Chinese words are longer than four characters. When word tokens are taken into account, 70.1% of words are one-character, 27.1% are two-character words, 1.9% are three-character words, 0.8% are four-character words, and 0.1% are words longer than four characters. Third, there are no spaces in Chinese text to separate words. Text written in Chinese is formed by strings of equally spaced box-like symbols (i.e., characters). Chinese readers thus have to depend on word knowledge to segment characters into words (Li, Rayner, & Cave, 2009). Because of these differences, findings from English cannot be directly extended to Chinese reading.

Since there are no spaces between words in Chinese text, Chinese readers have to depend on high-level knowledge to segment text into words. Even so, Chinese readers can read Chinese text without difficulty. How is this possible? A model of Chinese word recognition and word segmentation proposed by Li et al. (2009) might be able to explain this. The model assumes Chinese char-

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This research was supported by the Knowledge Innovation Program of the Chinese Academy of Sciences (KSCX2-YW-BR-6), by Natural Science Foundation of China Grant 31070904, and by National Institutes of Health Grant HD26765. We thank Raymond Bertram, Sarah White, and Jinmian Yang for their helpful comments on an earlier version of the manuscript.

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acters are processed in parallel, with the efficiency of character processing being affected by acuity and visual attention. The model follows the interactive account of word processing (McClelland & Rumelhart, 1981) and assumes that the information in the character recognition level feeds forward to the word-processing level, which activates related words. All of the activated words compete for a single winner. Meanwhile, the activity in the word-processing level feeds back to the character recognition level and affects the activities of the units in the character recognition level. More activated words provide more feedback to the character-processing level, and the activities of the characters belonging to those words increase more quickly than others. Only when the competition is complete is the word recognized and the word boundary determined. Hence, Chinese word segmentation and word recognition are a unified process. One of the key assumptions of this model is that the processing of a single character is affected by processing from higher levels and by the processing of other characters belonging to the same word. This model predicts that processing speed will be faster when characters belonging to a word can be processed simultaneously than when they cannot. We tested this prediction in the present study.

Previous studies have suggested that reading might be more efficient when characters belonging to a word are processed simultaneously than when they are processed independently. First, similar to the word superiority effect in English, Cheng (1981) found that Chinese characters were identified more accurately in a briefly presented word than in a string of briefly presented characters that did not constitute a word. Second, Li et al. (2009) found a word boundary effect. Specifically, subjects were shown four characters briefly and were asked to report as many characters as possible. These four characters constituted a four-character word in the one-word condition or two words in the two-word condition. Li et al. found that subjects reported all of the four characters very accurately in the one-word condition but could usually only report the two characters belonging to the first word in the two-word condition, suggesting that word boundary information could affect low-level processing and character report accuracy. Many models of word processing assume that increased character identification accuracy is caused by faster activation increasing speed in the character units when the characters in the stimuli constitute a word than when they do not. Hence, reading might be more efficient when characters belonging to a word are processed simultaneously than when they are not. However, there is no direct evidence for this, especially in sentence reading. Note that to do the character identification task in the word superiority studies, subjects do not need to understand the meaning of the word (although they may still do so automatically even if not asked), and they do not need to integrate the information with other parts of a sentence. These factors are different from the situation in sentence reading where semantic integration is needed.

Bai, Yan, Liversedge, Zang, and Rayner (2008) found that when Chinese readers read sentences in which spaces were inserted between words (or highlighting was used to demarcate characters or words), they read these word-based sentences as easily as normal unspaced Chinese text.[1] However, when spaces were inserted (or highlighting was used) within words (in a nonword segmentation condition), reading was slowed down. This study provided direct evidence that inserting spaces within a word in Chinese text slows down reading.

Results of local analyses in Bai et al. (2008) comparing the difference between the word condition and the nonword condition showed that the differences between these two conditions were mainly localized in eye movement measures such as total reading time and the total number of fixations. However, first fixation duration, single fixation duration, and gaze duration showed no influence of spacing. It is widely accepted (see Rayner, 1998, 2009) that some eye movement measures such as first fixation duration, single fixation duration, and gaze duration are mainly affected by early stages of processing such as visual perception and lexical access, while other measures such as total time and total number of fixations are mainly affected by late stages of processing related to integration of a word into a sentence (Rayner, 1998). Thus, it seems that the results of Bai et al. suggest that inserting extra visual markers within words (i.e., between characters so that the units are not words per se) did not affect the early stages of processing in Chinese reading but rather mainly affected later stages of reading. In summary, no previous study has provided converging evidence to support the prediction that Chinese reading is more efficient when characters belonging to a word are shown simultaneously than when they are not.

In the present study, we compared reading performance when Chinese readers were forced to view characters belonging to a word in serial (character condition) to a condition in which they could view characters belonging to a word simultaneously (word condition). The model proposed by Li et al. (2009) predicts that reading speed will be slower in the character condition than in the word condition since the interactive process will be interrupted in the character condition and, hence, character processing will benefit less from word knowledge and the processing of other characters belonging to the same word.

In the study, we used a novel variation of the moving window paradigm (McConkie & Rayner, 1975; Rayner & Bertera, 1979), which has been widely used to measure the perceptual span in reading (see Rayner, 1998, 2009; Schotter, Angele, & Rayner, 2012, for reviews). In these studies, readers can only see letters within a moving window contingent on the eye position. The information outside the window is masked so that readers cannot see/process it, and the size of the window varies across conditions. Reading performance with different window sizes is then compared to that in normal reading (i.e., when there is no window and text is presented normally). The perceptual span (or span of effective vision) is defined as the window size that did not cause any deficit in reading compared with normal reading. In English reading, the perceptual span extends about three to four letters to the left of fixation and 14–15 letters to the right of fixation. Although most studies that have examined the perceptual span have used letters as the unit of window size, a few studies have used words (Rayner, Slattery, & Bélanger, 2010; Rayner, Well, Pollatsek, & Bertera, 1982). The general finding is that the perceptual span to the left of fixation is constrained by word boundaries (Rayner, Well, & Pollatsek, 1980), but the right side is not (Rayner et al., 1982).

[1] Hsu and Huang (2000) found that reading time was reduced when spaces were inserted between Chinese words, but only when the text was quite difficult; when the text was of medium or low difficulty, inserting spaces had much less of an effect.

The purpose of the current study was not to measure the perceptual span in Chinese reading, so we did not manipulate window size. Rather, the window size was always two characters. Given that the perceptual span of Chinese readers extends one character to the left of fixation to two or three characters to the right of fixation (Inhoff & Liu, 1998), the window size in the present study was smaller than the perceptual span in Chinese reading. Certainly, reading performance should be reduced in our conditions compared with normal reading. However, that was not our interest as we were interested in the contrast between the two conditions, where the window size was identical but the content within the window was different.

In this study, all of the words in the sentences were two characters in length. Since many Chinese words are two-character words (as noted above, 72% of the words in Chinese are two-character words; when word tokens are taken into account, 27% words are two-character words), we could make up fluent Chinese sentences with only two-character words. In Experiment 1, there were two conditions depending on the content in the two-character window (see Figure 1 for examples). The two characters in the window constituted a word in the *word-window* condition but did not in the *nonword-window* (or character) condition. The model proposed by Li et al. (2009) predicts that reading performance would be better in the word-window condition than in the nonword-window condition.

In Experiment 2, we examined whether Chinese readers would choose to view two characters belonging to a word simultaneously if they had the opportunity to do so. There were also two conditions depending on the content in the moving window (see Figure 1 for examples). In the *right-character window* condition, readers could see the fixated character and the character to the right of it. In the *left-character window* condition, readers could see the fixated character and the character to the left of it. With this manipulation, readers could choose whether the two characters in the window constituted a word or not. In the left-character window condition, readers could see two characters belonging to a word simultaneously if they fixated on the second character of a word. In the right-character window condition, readers could see two characters belonging to a word simultaneously if they fixated on the first character. If Chinese readers process characters belonging to a word simultaneously, we assumed that they would tend to choose a window so that two characters in the window constituted a word so that they could maximize their reading speed. Hence, in the right-character window condition, they should fixate more frequently on the first character of a word; in the left-character window condition, they should fixate more frequently on the second character of a word. If Chinese readers did fixate on the preferred character more often, it would suggest that Chinese readers tended to view two characters belonging to a word simultaneously if they had the chance to do so.

In addition to the purpose stated above, Experiment 2 also served two other purposes. First, we tested whether showing characters belonging to a word simultaneously facilitates Chinese reading in a different setup. In Experiment 1, a single sentence was shown either as the word-window condition or as the nonword-window condition for a specific subject. In Experiment 2, subjects could view a window that contained either a word or two characters belonging to different words depending on where they looked. Hence, we could compare eye movement measures between these conditions within a sentence. Second, we investigated whether Chinese readers' eye movement control system is flexible enough so that they can develop a strategy to improve reading performance by controlling where to move their eyes during reading. Previous studies showed that eye movements were close to optimal when subjects conducted a visual search task (Najemnik & Geisler, 2005). We were interested in determining if Chinese readers could develop an optimal eye movement strategy in Experiment 2 to improve their reading performance.

Sentence

老师教导我们永远不要忘记历史。

The teacher taught us that we should never forget the history.

Word-window condition in Experiment 1

Example 1: ※※※※我们※※※※※※※※
*

Example 2: ※※※※我们※※※※※※※※
*

Nonword-window condition in Experiment 1

Example 1: ※※※导我※※※※※※※※※
*

Example 2: ※※※※※们永※※※※※※※
*

Right-character window condition in Experiment 2

Example 1: ※※※导我※※※※※※※※※
*

Example 2: ※※※※我们※※※※※※※※
*

Left-character window condition in Experiment 2

Example 1: ※※※※我们※※※※※※※※
*

Example 2: ※※※※※们永※※※※※※※
*

Figure 1. Stimuli example. The symbol * indicates the position of the eyes.

Experiment 1

Experiment 1 tested whether making Chinese readers unable to see two characters belonging to a word simultaneously would slow down their reading speed. Thus, as noted above, in one condition, Chinese readers could not view characters belonging to a word simultaneously. We compared this condition with a word-window condition in which characters belonging to a word were shown simultaneously. As noted above, we used a novel variation of the moving window paradigm in this experiment. The window size was identical (two characters) for the two conditions although the content in the windows was different.

Method

Subjects. Twenty native Chinese speakers (10 of them were female), who were students from universities in Beijing near the Institute of Psychology, Chinese Academy of Sciences, were paid to participate in the experiment. The average age was 22.5 years old. All of them had normal or corrected-to-normal vision, and all were naive regarding the purpose of the experiment.

Apparatus. Eye movements were recorded by an SR EyeLink 2000 tracker, which has a resolution of approximately 30′ of arc. Subjects read the target sentences (which were printed horizontally from left to right) on a 21-in. CRT monitor (SONY Multiscan G520) connected to a Dell PC. The eye-tracking system sampled at the rate of 2,000 Hz and provided eye movement data for further analysis via another PC. The subjects rested their heads on a chinrest to minimize head movements during the experimental trials. Viewing was binocular, but eye movement data were collected only from the right eye. The subjects were seated 58 cm from the video monitor; at this distance, one character subtended 0.8° of visual angle. The refresh rate of the CRT monitor was 150 Hz, and the resolution was 1,024 × 768. Subjects pressed a button on a button box (Microsoft SideWinder Game Pad) to answer comprehension questions that appeared periodically throughout the experiment.

Materials and design. There were 70 sentences for the experimental trials and 10 additional practice sentences.[2] Among the 70 experimental trials, 63 were 14 characters long, and seven were 16 characters long. All of the words in these sentences were two characters long, and all of the words were listed as words in a Chinese lexicon (Lexicon of Common Words in Contemporary Chinese Research Team, 2008). Three native Chinese speakers agreed that all of these sentences were valid sentences. Although we only used two-character words to construct the sentences, we did not tell subjects about this before the experiment. Immediately after the experiment, we asked them whether they noticed anything special about the material. None of them reported that they noticed that all of the words were two-character words.

As noted above, we used a variation of the moving window paradigm in Experiment 1. Subjects could only see the characters in the two-character window, and all of the characters outside the window were masked by the symbol ※. Depending on the type of window, the experimental trials were categorized into two conditions. In the word-window condition, the two characters in the window always constituted a word; in the nonword-window condition, the two characters in the window did not constitute a word. The trials in these two conditions were intermixed randomly. There were an equal number of trials in each condition, and each sentence was shown in the word-window condition for half of the subjects and was shown in the nonword-window condition for the other subjects.

Procedure. When subjects arrived for the experiment, they were given instructions for the experiment and a description of the apparatus. The eye tracker was calibrated at the beginning of the experiment, and the calibration was validated as needed. For calibration and validation, subjects looked at a dot that was presented at each of three locations horizontally arranged at the center of the display in a random order (the maximum error permitted for validation throughout the experiment was 0.5° of visual angle). Then, each subject read 10 sentences for practice and the 70 experimental sentences in a different random order but with appropriate counterbalancing procedures to ensure that an equal number of each type of window was encountered. The subjects were told to read silently and that they would periodically be asked to answer questions about the sentences. These questions were asked after about one third of the 80 sentences that were read.

Each trial started with a fixation box (1° × 1° in size) at the location of the first character of the sentence. The sentence was shown after the subject successfully fixated on the box. After reading a sentence, the subject pressed a response button on a button box to either present the comprehension question or start the next trial.

Custom-made software based on the UMass EyeTrack software[3] was used to present the two conditions. Once a reader fixated on a given character, the computer determined whether the character to the left or right should be displayed depending on the condition. This typically took about 5 ms, with a maximum of 10 ms. Subjects' phenomenological impression was that the window moved in synchrony with their eye movements.

It is important to note that if no adjustment was made, subjects would have to fixate on the first character and the last character of a sentence to see these characters in the nonword-window condition. Hence, at least one more fixation would be needed in the nonword-window condition than in the word window condition to see all of the characters in a sentence (if there was no regression or refixation). Thus, to make the two conditions more comparable, subjects were allowed to see the first three characters in a sentence when they fixated on any of these three characters in the nonword-window condition. No special adjustment was made for the last characters. That is to say, subjects had to fixate on the last character of a sentence to see it. However, in terms of eye movement data analysis, this is largely irrelevant since fixations at the beginning and the end of sentences were discarded as we only examined the fixations located on Characters 5–12. Fixations longer than 1,000 ms or shorter than 80 ms were excluded from analyses.

Data analysis. Across all of the trials, approximately 3% of the data were lost due to a track loss. Occasionally, subjects moved back to the beginning of a sentence when they had looked through the sentence. Since we were interested in first-pass reading, all of the fixations after the return sweep (a regression from the final three characters of the sentence to the beginning three characters) were discarded when we analyzed local fixation measures. An analysis of variance (ANOVA) or *t* test was carried out on each of the sets of data, using subjects (F_1 or t_1) and items (F_2 or t_2) as random effects.

Results and Discussion

Accuracy. Accuracy on the comprehension questions was high (94%), did not differ across the two conditions (*t*s < 1), and was not analyzed further.

[2] Some of the sentences were taken from Zhang, Liu, Zhao, and Ji (2012).

[3] The UMass EyeTrack software can be downloaded from the following site: http://www.psych.umass.edu/eyelab/software/

Sentence reading time (SRT). SRTs not bold longer than 10,000 ms or shorter than 100 ms were excluded from analyses.[4] This resulted in excluding 4.7% of the trials from the analyses. The number of excluded trials did not differ across conditions ($t < 1$). SRTs were longer in the nonword-window condition (M = 4,260 ms, SE = 217 ms) than in the word-window condition (M = 3,531 ms, SE = 158 ms), $t_1(19) = 6.38$, $p < .001$; $t_2(69) = 16.50$, $p < .001$ (see Table 1). This suggests that characters are not processed independently in Chinese reading and that word knowledge must play an important role, as reading time was significantly increased when Chinese readers could not view two characters belonging to a word simultaneously.

Eye movement measures. The SRT results showed that subjects needed more time to read a sentence in the nonword-window condition than in the word-window condition. To further explore what factors affected reading speed, we analyzed the eye movement measures. The slowdown in the nonword-condition was possibly caused by longer fixations, shorter saccades, or more regressions to integrate information from different fixations. To test these possibilities, we examined (a) the number of fixations, (b) the mean fixation duration, (c) saccade length, (d) regression rate, (e) fixation probability on a character, and (f) the number of fixations on each character. For all measures, there was a significant difference between the two conditions.

Specifically, (a) there were more fixations in the nonword-window condition (M = 11.89, SE = .34) than in the word-window condition (M = 10.34, SE = .38), $t_1(19) = 5.85$, $p < .001$; $t_2(69) = 14.84$, $p < .001$. (b) Fixations were longer in the nonword-window condition (M = 312 ms, SE = 10 ms) than in the word-window condition (M = 298 ms, SE = 10 ms), $t_1(19) = 3.51$, $p = .002$; $t_2(69) = 4.13$, $p < .001$. (c) Forward saccade length was longer in the word-window condition (1.68 characters, SE = .07) than in the nonword-window condition (1.64 characters, SE = .06), $t_1(19) = 2.39$, $p = .027$; $t_2(69) = 1.79$, $p = .078$. (d) There were more regressions in the nonword-window condition (8.3%, SE = .1%) than in the word-window condition (6.3%, SE = .1%), $t_1(19) = 2.12$, $p = .048$; $t_2(69) = 4.14$, $p < .001$. (e) Characters were more likely to be fixated in the nonword-window condition (M = .66, SE = .03) than in the word-window condition (M = .63, SE = .02) $t_1(19) = 4.77$, $p < .001$; $t_2(69) = 3.95$; $p < .001$. And (f) characters were fixated more often in the nonword-window condition (M = .91, SE = .05) than in the word-window condition (M = .80, SE = .04), $t_1(19) = 5.88$, $p < .001$; $t_2(69) = 7.11$, $p < .001$.

Table 1
Results of Experiment 1

Measure	Word-window	Nonword-window
Sentence reading time (ms)	3,531 (158)	4,260 (217)
Number of fixations	10.34 (.38)	11.89 (.34)
Mean fixation duration (ms)	298 (10)	312 (10)
Saccade length	1.68 (.07)	1.64 (.06)
Regression rate	.063 (.001)	.083 (.001)
Number of fixations on a character	.80 (.04)	.91 (.05)
Fixation probability on a character	.63 (.02)	.66 (.03)

Note. The numbers in parentheses are standard errors.

As is evident from the results, many factors contributed to the general slowdown in the nonword-window condition in comparison to the word-window condition. First, more fixations were made in the nonword-window condition. Second, saccade length was shorter in the nonword-window condition. Third, fixations were longer in the nonword-window condition. All of these factors suggest that character and word recognition were longer when readers could not view the characters belonging to a word simultaneously. Finally, more regressions in the nonword-window condition might be caused by a larger working memory load in the nonword-window condition. If Chinese readers cannot view characters belonging to a word simultaneously, they would need to integrate information from different fixations to recognize a word. This might cause some information loss, and so, more regressions would be needed.

Experiment 2

Experiment 1 showed that the reading time of Chinese readers increased when they could not view two characters belonging to a word simultaneously. If Chinese readers can choose whether they can view two characters in a window so as to constitute a word, will they choose to do so? From the results of Experiment 1, it is clear that viewing two characters belonging to a word simultaneously improves reading speed. In Experiment 2, there was again a two-character window on each trial. In the right-character window condition, the two-character window included the fixated character and the character to the right of it. In the left-character window condition, the two-character window included the fixated character and the character to the left of it. If Chinese readers can optimize their performance so that they always see a word within the window, in the right-character window condition, they should strive to fixate on the first character of a word; in the left-character window condition, they should strive to fixate on the second character of a word. However, in the right-character window, if they fixate on the second character of a word, they would see that character and the first character of the next word (similar to the nonword-window condition in Experiment 1). Conversely, in the left-character window condition, if they fixate on the first character of a word, they would see that character and the last character of the prior word (again, a nonword-window condition). To test whether they looked at two characters belonging to a word simultaneously, we measured fixation probability on each character. If subjects chose to view two characters belonging to a word simultaneously, the first character of the words should be fixated more frequently than the second character in the right-character window condition, but the opposite should be the case in the left-character window condition. Hence, subjects were able to view the two characters belonging to a word simultaneously if they fixated on the preferred character. As a result, first-pass fixation probability on these preferred characters should have been higher than the nonpreferred character.

Another goal of Experiment 2 was to replicate the findings of Experiment 1 in a different setup. Experiment 1 found that fixation duration was longer, saccade length was shorter, and there were more regressions in the nonword-window condition than in the word-window condition. In Experiment 2, subjects could freely

[4] This exclusion applies only to SRT.

choose where to look, so that they would see two characters belonging to a word for some fixations and would see two characters that did not make up a word for other fixations when they read a single sentence. Therefore, we could examine whether two characters in a window constituting a word would affect eye movements in a single sentence.

Method

Subjects. Twenty native Chinese speakers (15 of them were female, and the average age was 23.0 years), who were from the same participant pool as that in Experiment 1, participated in Experiment 2. None of them had participated in Experiment 1. All of them had normal or corrected-to-normal vision, and all were naive regarding the purpose of the experiment.

Apparatus. The apparatus was the same as that in Experiment 1.

Materials and design. There were 180 sentences for the experimental trials and 10 additional practice trials. Among the experimental trials, 140 sentences were 14 characters long, and 40 sentences were 16 characters long. All of the words in these sentences were two characters long. These words were listed as words in a Chinese lexicon (Lexicon of Common Words in Contemporary Chinese Research Team, 2008). The frequency and number of stokes of the first characters in the words (frequency: $M = 1{,}960$, $SD = 2{,}571$; number of strokes: $M = 7.51$, $SD = 3.09$) did not differ from those of the second characters (frequency: $M = 1{,}825$, $SD = 1{,}927$; number of strokes: $M = 7.58$, $SD = 2.80$; $ts < 1$). Three native Chinese speakers agreed that all of the sentences were valid sentences.

There were two conditions in Experiment 2 depending on the content of the moving window. As noted above, in the right-character window condition, the two-character window included the fixated character and the character to the right of it. In the left-character window condition, the two-character window included the fixated character and the character to the left of it. To make sure that subjects were familiar with the window conditions, each subject was only exposed to one of the conditions throughout the experiment. Hence, Experiment 2 was a between-subject design. Half of the subjects read the sentences in the left-character window condition, and the other half read in the right-character window condition. There were 180 experimental trials. They were divided into three blocks; each block had 60 trials. The order of trials was randomized within blocks.

Data analysis. The same method was used to analyze data as in Experiment 1. Across all of the trials, approximately 2.5% of the data were lost due to a track loss.

Results and Discussion

Accuracy. Accuracy was 95% and did not significantly differ between the two conditions ($t < 1$).

Sentence reading time. SRTs not bold longer than 10,000 ms or shorter than 100 ms were excluded from analyses. This resulted in excluding 3.2% of the trials from the analyses (see Footnote 4). A 2 (condition) × 3 (block) ANOVA was conducted on SRTs. There was a main effect of block, $F_1(2, 36) = 9.89$, $p < .001$, $\eta_p^2 = .36$, $MSE = 558{,}666$; $F_2(1, 354) = 25.57$, $p < .001$, $\eta_p^2 = .13$, $MSE = 759{,}744$. SRTs decreased gradually from Block 1 to Block 3 (Ms = 6,230 ms, 5,430 ms, and 5,199 ms, SEs = 413ms, 308 ms, and 250 ms, respectively, for the three blocks), suggesting a learning effect on reading performance. There was a hint of interaction between the two factors in the subjects analysis, $F_1(2, 36) = 2.54$, $p = 0.093$, $\eta_p^2 = .12$, $MSE = 558{,}666$, but it was not significant in the items analysis, $F_2(1, 354) = 2.15$, $p = .118$. The learning effect was greater in the right-window condition (Ms = 6,369 ms, 5,142 ms, and 4,898 ms, respectively, for the three blocks) than in the left-window condition (Ms = 6,036 ms, 5,718 ms, and 5,500 ms, respectively, for the three blocks). Reading time was shorter in the right-window condition ($M = 5{,}470$ ms, $SE = 582$ ms) than in the left-window condition ($M = 5{,}752$ ms, $SE = 341$ ms). But this effect was only significant in the items analysis, $F_2(1, 354) = 16.95$, $p < .001$, $\eta_p^2 = .05$, $MSE = 759{,}744$, but not significant in the subjects analysis ($F_1 < 1$). Compared to the SRT difference between the word-window condition and the nonword-window condition in Experiment 1, the difference in SRT between the two conditions in Experiment 2 was numerically smaller. It is not surprising that there were no major differences between the two conditions. As we show later, readers seemed to have learned to saccade to the ideal landing position so that they could see characters belonging to a word simultaneously in both conditions.

Eye movement measures. The purpose of Experiment 2 was to test whether subjects would choose to look at two characters belonging to a word simultaneously if they had the opportunity to do so. As in Experiment 1, fixations after a return sweep were not included in the analyses nor were fixations at the beginning and the end of sentences (i.e., we again examined the fixations located on Characters 5–12). As before, fixations longer than 1,000 ms or shorter than 80 ms were excluded from analyses. We report first-pass fixation probability on each character, forward saccade length, regression rate, and fixation duration. We conducted a 2 (condition: left-character window condition or right-character window condition) × 2 (character position: first character or second character of a word) × 3 (block) ANOVA for each of these measures.

First-pass fixation probability on a character. There was a main effect of condition, $F_1(1,18) = 4.44$, $p = .049$, $\eta_p^2 = .20$, $MSE = .06$; $F_2(1, 354) = 319.63$, $p < .001$, $\eta_p^2 = .47$, $MSE = .005$. Characters were more likely to be fixated in the left-character window condition ($M = .72$, $SE = .03$) than in the right-character window condition ($M = .63$, $SE = .03$). There was also a main effect of character position, $F_1(1, 18) = 6.45$, $p = .021$, $\eta_p^2 = .26$, $MSE = .006$; $F_2(1, 354) = 22.48$, $p < .001$, $\eta_p^2 = .06$, $MSE = .011$. Readers fixated more often on the first character ($M = .69$, $SE = .02$) than on the second character ($M = .65$, $SE = .02$) of a word. More importantly, there was also an interaction between character position and condition, $F_1(1, 18) = 17.21$, $p < .001$, $\eta_p^2 = .49$, $MSE = .006$; $F_2(1, 354) = 59.80$, $p < .001$, $\eta_p^2 = .15$, $MSE = .011$. The interaction reflects different patterns in the two conditions. In the right-character window condition, the first character of a word was more likely to be fixated ($M = .67$, $SE = .03$) than the second character ($M = .58$, $SE = .02$), $F_1(1, 9) = 12.74$, $p = .006$, $\eta_p^2 = .59$, $MSE = .01$; $F_2(1, 177) = 62.22$, $p < .001$, $\eta_p^2 = .26$, $MSE = .01$. In contrast, in the left-character window condition, the second character was more likely to be fixated ($M = .73$, $SE = .03$) than the first character ($M = .70$, $SE = .03$), $F_1(1, 9) = 5.30$, $p = .047$, $\eta_p^2 = .37$, $MSE = .002$; $F_2(1, 177) = 5.97$, $p = .016$, $\eta_p^2 = .03$, $MSE = .01$. These results suggest that subjects tended to choose to view two characters belonging to a word simultaneously in both conditions. It is interesting that the effect of character on fixation probability was numerically larger in the right compared to the left window condition. We discuss this in more detail later. The interaction between block and character position was significant in the items analysis, $F_2(2, 354) = 3.35$, $p = .036$, $\eta_p^2 = .02$, $MSE = .01$, but not in the subjects analysis, $F_1(2, 36) = 2.34$, $p = .111$. Fixation probability did not change that much for the first character position in the three blocks (*M*s = .692, .690, and .686, and *SE*s = .02, .03, and .03, respectively, for Blocks 1, 2, and 3). However, fixation probability differed for the three blocks for the second character position (*M*s = .673, .625, and .658, and *SE*s = .02, .03, .and 03 for Blocks 1, 2, and 3, respectively). Nothing else was significant.

Saccade length. To further confirm the finding that Chinese readers tend to choose two characters belonging to a word simultaneously when they have the chance to do so, we also analyzed outgoing saccade length as a function of fixation position within a word. As noted above, to view the two characters belonging to a word simultaneously, Chinese readers should tend to fixate on the ideal character to view the two characters belonging to word simultaneously. Hence, the saccade length should be longer when the fixated character was farther away from the ideal character of the next word.

There was a main effect of fixation position, $F_1(1, 18) = 14.44$, $p < .001$, $\eta_p^2 = .45$, $MSE = .005$; $F_2(1, 354) = 20.70$, $p < .001$, $\eta_p^2 = .06$, $MSE = .015$. Saccade length was longer when the fixation was on the first character of a word ($M = 1.59$ characters, $SE = .05$) than the second character ($M = 1.54$ characters, $SE = .06$). There was also a main effect of condition, $F_1(1, 18) = 7.68$, $p = .013$, $\eta_p^2 = .30$, $MSE = .35$; $F_2(1, 358) = 537.03$, $p < .001$, $\eta_p^2 = .60$, $MSE = .024$. Saccade length was longer in the right-character window condition ($M = 1.72$ characters, $SE = .08$) than in the left-character window condition ($M = 1.42$ characters, $SE = .08$). There was also a main effect of block, $F_1(2, 36) = 3.69$, $p = .035$, $\eta_p^2 = .17$, $MSE = .02$; $F_2(1, 354) = 18.19$, $p < .001$, $\eta_p^2 = .09$, $MSE = .021$. Saccade length increased as a function of block (*M*s = 1.52, 1.59, and 1.59 characters, *SEs* = .05, .06, and .06 characters, respectively). There was an interaction between fixation position and condition, $F_1(1, 18) = 10.57$, $p = .004$, $\eta_p^2 = .37$, $MSE = .005$; $F_2(1, 354) = 23.66$, $p < .001$, $\eta_p^2 = .06$, $MSE = .015$. In the right-character window condition, saccade length was longer when the fixation was on the first character than on the second character of a word (see Table 2), $F_1(1, 9) = 13.81$, $p = .005$, $\eta_p^2 = .61$, $MSE = .008$; $F_2(1, 177) = 35.13$, $p < .001$, $\eta_p^2 = .17$, $MSE = .02$. In contrast, the difference between the first character position and the second character position was not significant (*F*s < 1) in the left-character window condition. Finally, there was also an interaction between condition and block, which was significant in the items analysis but not in the subjects analysis, $F_1(2, 36) = 1.76$, $p = .187$; $F_2(2, 354) = 8.70$, $p < .001$, $\eta_p^2 = .05$, $MSE = .021$. Saccade length increased as a function of block in the right-character window condition (*M*s = 1.65, 1.77, and 1.75 characters, *SE*s = .07, .08, and .09 character for Blocks 1, 2, and 3, respectively), but saccade length did not change that much in the left-character window condition (*M*s = 1.40, 1.42, and 1.43 characters, *SE*s = .07, .08., and .09 characters, respectively). These results in the right-character window condition are consistent with the argument that Chinese readers tend to target the first character of a word so that they can see the two characters belonging to a word simultaneously. When subjects fixated on the first character of a word, they tended to saccade to the first character of the next word, which usually yielded a saccade that was two characters long. In contrast, when they fixated on the second character of a word, they only needed to saccade one character to fixate on the first character of the next word. Hence, saccade length was longer when the fixation was on the first character than on the second character of a word. This effect was not observed in the left-character window condition. We discuss possible reasons for this later in this section.

Regression rate. Experiment 1 showed that there were fewer regressions when the two characters in the window constituted a word than when they did not. The results in Experiment 2 also confirmed this finding. There was a hint of main effect of character position, $F_1(1, 18) = 3.84$, $p = .066$, $\eta_p^2 = .18$, $MSE = .001$; $F_2(1, 354) = 11.00$, $p < .001$, $\eta_p^2 = .03$, $MSE = .002$; fewer regressions were made from Character 1 ($M = .10$, $SE = .01$) than Character 2 ($M = .11$, $SE = .01$). There was also a main effect of condition in the items analysis, $F_2(1, 354) = 69.94$, $p < .001$, $\eta_p^2 = .17$, $MSE = .004$, but this effect was not significant in the subjects analysis, $F_1(1, 18) = 1.54$, $p = .230$. There were more regressions in the right-character window condition ($M = .12$, $SE = .02$) than in the left-character window condition ($M = .09$, $SE = .02$). There was an interaction between fixation position and condition, $F_1(1, 18) = 10.97$, $p = .004$, $\eta_p^2 = .38$, $MSE = .001$; $F_2(1, 354) = 30.90$, $p < .001$, $\eta_p^2 = .08$, $MSE = .002$. And there was a three-way interaction between condition, block, and character position, $F_1(1, 36) = 4.24$, $p = .019$, $\eta_p^2 = .20$, $MSE = .001$; $F_2(1, 354) = 2.52$, $p = .082$, $\eta_p^2 = .01$, $MSE = .002$. To interpret this interaction, we conducted two separate 2 (character position) × 3 (block) ANOVAs for the two conditions. In the right-character window condition, there were fewer regressions (see Table 2) when the fixation was on the first character than on the second character of a word, $F_1(1, 9) = 8.33$, $p = .018$, $\eta_p^2 = .48$, $MSE = .002$; $F_2(1, 177) = 32.06$, $p < .001$, $\eta_p^2 = .15$, $MSE = .003$. There was

Table 2
Results of Experiment 2

Measure	Right-character window		Left-character window	
	Character 1	Character 2	Character 1	Character 2
Probability of fixation	.67 (.03)	.58 (.02)	.70 (.03)	.73 (.03)
Fixation duration (ms)	314 (11)	324 (9)	344 (11)	335 (9)
Forward saccade length	1.71 (.10)	1.62 (.11)	1.40 (.10)	1.40 (.11)
Regression rate	.10 (.01)	.13 (.02)	.094 (.01)	.086 (.02)

Note. The numbers in parentheses are standard errors.

also an interaction between block and character position, $F_1(2, 18) = 4.23$, $p = .031$, $\eta_p^2 = .32$, $MSE = .001$; $F_2(1, 177) = 3.49$, $p = .032$, $\eta_p^2 = .04$, $MSE = .003$. Fewer regressions were made from Character 1 ($M = .10$, $SE = .02$) than Character 2 ($M = .13$, $SE = .03$). However, the difference was smaller in Block 1 ($M = .01$, $SE = .02$) than either Block 2 ($M = .04$, $SE = .02$) or Block 3 ($M = .04$, $SE = .02$). In contrast, there was a hint that there were more regressions when the fixation was on the first character than on the second character of a word in the left-character window condition, $F_1(1, 9) = 2.76$, $p = .131$; $F_2(1, 177) = 3.26$, $p = .073$, $\eta_p^2 = .02$, $MSE = .002$. These results confirm the findings of Experiment 1 that regressions were more likely to occur when Chinese readers could not see two characters belonging to a word simultaneously.

Fixation duration. The fixation duration data in Experiment 2 also confirmed those in Experiment 1. Fixation durations were shorter when the characters in the window constituted a word than when they did not. There was a main effect of condition in the items analysis, $F_2(1, 354) = 118.77$, $p < .001$, $\eta_p^2 = .25$, $MSE = 710$, but this effect was not significant in the subjects analysis, $F_1(1, 18) = 2.29$, $p = .148$. Fixation duration was shorter in the right-character window condition ($M = 319$ ms, $SE = 10$ ms) than the left-character window condition ($M = 340$ ms, $SE = 10$ ms). There was also a main effect of block, $F_1(2, 36) = 14.57$, $p < .001$, $\eta_p^2 = .45$, $MSE = 602$; $F_2(1, 354) = 79.26$, $p < .001$, $\eta_p^2 = .31$, $MSE = 710$. Fixation durations decreased as a function of block (*Ms* = 346 ms, 324 ms, and 317 ms, *SE*s = 9 ms, 7 ms, and 7 ms, respectively), suggesting a learning effect on fixation durations. There was also an interaction between fixation position and condition, $F_1(1, 18) = 7.40$, $p = .014$, $\eta_p^2 = .29$, $MSE = 326$; $F_2(1, 354) = 23.74$, $p < .001$, $\eta_p^2 = .06$, $MSE = 527$. In the right-character window condition, fixations were shorter when the fixation was on the first character of a word ($M = 314$ ms, $SE = 11$ ms) than on the second character of a word ($M = 324$ ms, $SE = 9$ ms; see Table 2), $F_1(1, 9) = 8.76$, $p = .016$, $\eta_p^2 = .49$, $MSE = 165$; $F_2(1, 177) = 9.55$, $p = .002$, $\eta_p^2 = .05$, $MSE = .469$. In contrast, in the left-character window condition, fixation duration was longer when the eyes fixated on the first character ($M = 344$ ms, $SE = 11$ ms) than on the second character of a word ($M = 335$ ms, $SE = 9$ ms). However, the difference was only significant in the items analysis, $F_1(1, 9) = 2.03$, $p = .188$; $F_2(1, 177) = 14.24$, $p < .001$, $\eta_p^2 = .07$, $MSE = 585$. These results are generally consistent with those in Experiment 1, which showed that fixation durations were shorter when Chinese readers could see two characters belonging to a word simultaneously.

In summary, Experiment 2 confirmed the findings of Experiment 1. Fixation durations were longer and there were more regressions when two characters belonging to a word were not presented simultaneously than when they were. More importantly, consistent with the predictions of the Li et al. (2009) model, the results of Experiment 2 showed that Chinese readers looked at two characters belonging to a word simultaneously when they had chance to do so. In the right-character window condition, they were more likely to fixate on the first character of a word; in the left-character window condition, they were more likely to fixate on the second character of a word (although the effect was smaller than that in the right-character window condition). Fixating on these ideal positions resulted in two characters belonging to a word being shown simultaneously. Note that although subjects had a clear tendency to target the ideal characters so that two characters belonging to a word were presented simultaneously, they seemed largely unaware of this. Immediately after the experiment, we asked whether they used any strategy in the experiment, and none of them reported that they had targeted the ideal character.

The results in the left-character window condition and the right-character window condition were clearly different. Although Chinese readers saw two characters belonging to a word simultaneously in both conditions, they did so more frequently in the right-character window condition than in the left-character window condition. Fixation durations were shorter and the regression rate was lower when the characters in the window constituted a word than when they did not in both conditions. However, the differences were significant in the right-character window condition but either marginally significant (for regression rate) or not significant (for fixation duration) in the left-character window condition. Furthermore, forward saccade length was longer when the fixated character was farther away from the ideal fixation character of the next word than when it was closer in the right-character window condition, but there was no sign of a difference for the left-character window condition. All of these results suggest that Chinese readers were less likely to view two characters belonging to a word simultaneously in the left-character window condition than in the right-character window condition. A likely explanation of this difference between the two conditions might be because Chinese readers recognize a word more efficiently when they fixate on the first character of a word than when they fixate on the second character.

There is some evidence supporting the view that Chinese readers recognize a word more efficiently when they fixate on the first character of a word than when they fixate on the second character. First, the perceptual span in reading is asymmetric and is smaller to the left of fixation than to the right (see Rayner, 1998, 2009; Schotter et al., 2012, for reviews). This is the case for both English reading (McConkie & Rayner, 1975; Rayner & Bertera, 1979; Rayner et al., 1980) and Chinese reading (Inhoff & Liu, 1998). Second, Li and Pollatsek (2011) found that presenting the first character of a word facilitates the perception of the second character of a word but that presenting the second character does not facilitate the perception of the first one. In the left-character window condition, Chinese readers always fixated on the second character of a word when the two characters in the window constituted a word. This might have made word recognition less efficient than when the first character of a word was fixated. Third, the view is also supported by the data from Experiment 1 in the current study. In the word-window condition of Experiment 1, first fixation duration was shorter when the eyes fixated on the first character position within a word (285 ms, $SE = 11$ ms) than on the second character position (318 ms, $SE = 7$ ms), $t_1(19) = 4.17$, $p < .001$; $t_2(69) = 6.56$, $p < .001$. This suggests that word recognition is easier when the eyes fixate on the first character of a two-character word than on the second one. This finding is interesting in the context of the optimal viewing position (OVP) effects in alphabetic languages (O'Regan & Jacobs, 1992; O'Regan, Lévy-Schoen, Pynte, & Brugaillère, 1984), which showed that word recognition is more efficient in isolated word recognition when the eyes fixate near the word center. This latter finding is also different from Japanese reading, where reading times such as gaze duration and total time were longer when the eyes fixated at word beginning than word center and word ends (Sainio, Hyönä, Bingushi, & Bertram, 2007). The difference might be caused by processing differences across different languages. In English, there are spaces between words. In Japanese, although there are no spaces between words, different kinds of characters (hiragana and kanji) are different in shape, and they can provide some word boundary information. However, in Chinese reading, there are no spaces between words. These differences might have caused the unique properties in Chinese reading. Alternatively, these differences may be due to the specific task condition of the experiment, namely, that all words used were two characters long. However, we acknowledge that the exact reason for the differences needs further investigation.

Hence, these fixation position effects might have been confounded with the word-based processing effect and made word recognition efficiency not so high when two characters belonging to a word were shown simultaneously in the left-character window condition. As a result, Chinese readers were less likely to view two characters belonging to a word simultaneously in the left-character window condition than in the right-character window condition.

General Discussion

Using a novel variation of the moving window paradigm, we tested whether reading performance is better when characters belonging to a word are presented simultaneously than when they are not. In Experiment 1, Chinese readers could not see two characters belonging to a word simultaneously in the nonword-window condition but could do so in the word-window condition. There were differences between the two conditions in both the SRT measures and the eye movement measures. Compared with the word-window condition, in the nonword-window condition (a) reading time was longer, (b) mean fixation duration was longer, (c) saccade length was shorter, and (d) there were more regressions. In Experiment 2, when Chinese readers could choose between two characters in the moving window that contained a word or two characters that did not constitute a word, they had a clear tendency to look at two characters belonging to a word simultaneously. It is also interesting to note that the effect of characters on fixation probability was numerically larger in the right-character window condition compared to the left-character window condition.

These results are consistent with one of the predictions of the Li et al. (2009) model of word recognition and word segmentation in Chinese reading, which suggests that characters are not processed independently but are affected by word knowledge and the processing of characters belonging to the same word. By interrupting Chinese readers from processing characters within words simultaneously, reading performance was greatly reduced.

The results can be explained in the Chinese word recognition model by Li et al. (2009). In the word-window condition, only two characters belonging to a word can be seen. Hence, there are many advantages in this condition. First, characters belonging to other words do not interfere with the recognition of the shown word, so the word can win the competition very quickly. Second, the activation of the two character units belonging to a word are fed forward to the word level simultaneously, resulting in faster settlement of the competition at that level, which makes word recognition faster. Third, character recognition is facilitated by the information that is fed back from the word recognition level, so that character recognition efficiency is increased. These factors benefit reading to a greater extent in the word-window condition than in the nonword-window condition, and hence, we observed increased reading performance and shorter fixation durations in the word-window condition.

The results of the current study confirmed our prediction that forcing Chinese readers to view two characters belonging to a word in different windows makes word-based processing more difficult and consequently decreases reading fluency. Another potential reason for decreased reading fluency under the nonword-window condition is related to the extra burden it creates for working memory. When two characters belonging to a word are presented simultaneously, the processing of characters could benefit from the processing of the other characters and word knowledge and can be encoded and stored at the word level. However, when they cannot be processed simultaneously—as is the case in the nonword-window condition—characters have to be processed one by one and stored at the character level. In this situation, Chinese readers would have to keep characters activated across fixations and integrate character information across two views, placing an extra burden on working memory. The working memory hypothesis was supported by our data: Compared with the word-window condition, in the nonword-window condition, saccade length was shorter, and regression rate was higher. Note that although an extra load on working memory might cause more regressions during Chinese reading, it is not likely that it causes the reduction of fixation durations. That is, some studies explored whether working memory load or working memory capacity affects fixation durations during reading and found no reliable evidence to support this position (Kennison & Clifton, 1995; King & Just, 1991).

The results of Experiment 2 showed that Chinese readers could develop a strategy to process words in one fixation very quickly by directing their eyes to a position from which they could view two characters belonging to a word simultaneously. This provides further evidence that Chinese readers process characters belonging to a word simultaneously in natural sentence reading since, in this experiment, they could freely choose which part of the text would be processed together. It is also of some interest that most of the measures we examined did not yield interactions with block, suggesting that from the very first block on, readers effectively adapted their eye movement strategy. This suggests that the eye movement control strategy of Chinese readers is so flexible that it can be adjusted to modify the characteristics of the window very quickly.

The finding that reading is more efficient when characters belonging to a word are shown simultaneously in Chinese reading has implications for linguistic research on Chinese. Some Chinese linguists argue that Chinese characters are the basic unit in written Chinese (H. J. Wang, 2007; J. Wang, 2009; Xu, 1994, 2005). They argue that the concept of a word is mostly borrowed from Indo-European languages and that the concept may not be applicable in Chinese. These theories are supported by many linguists since, historically, the Chinese writing system consisted of one-character words. However, in modern Chinese, many words are two or more characters long. Thus, we would argue that the benefit of presenting words simultaneously should be taken into account in linguistic theories on the Chinese language.

In the current study, we used only two-character words to construct the stimulus sentences and the window size was always two characters long. Some of the effects in the current study may have been caused by this setup. For example, in Experiment 2, subjects tended to look at an ideal position within words. Although our subjects did not notice the fact that the sentences were constructed only of two-character words, they did use a strategy implicitly so that they could land their eyes on the ideal character so that they could view two characters belonging to a word simultaneously. Using words with the same length was essential in Experiment 2 so that participants could develop that strategy. The sentences used in the present study thus led to a highly predictable word length of the upcoming words. Things may be very different in natural sentence reading where there is a variation regarding the length of the words in sentences. Besides, there are no explicit markers (like spaces) to mark word boundaries. Hence, it is very hard for Chinese readers to predict the length of the upcoming word, and an eye movement target selection strategy such as subjects used in Experiment 2 is very unlikely to be extended to that situation. Further studies are needed to explore how the conclusions in the current study might be extended to sentences with words of varying length.

In English, the concept of a word is relatively easy to define: Words are the letter strings between the spaces. However, the word concept is not so well defined in Chinese given that there are no spaces between words. Characters that form a word no doubt co-occur much more frequently than characters that do not form a word; hence, two characters that form a word are likely to facilitate character processing for each component character more than if a nonword was fixated. Thus, as noted above, the present studies provide a different type of support for the view that words have psychological reality in Chinese reading.

The results of the current study show that presenting characters belonging to the same word simultaneously facilitates Chinese reading, provide strong evidence that character processing is affected by word knowledge, and add to a growing body of evidence (Bai et al., 2008; Cheng, 1981; Rayner, Li, Juhasz, & Yan, 2005; Rayner, Li, & Pollatsek, 2007; G. L. Yan, Tian, Bai, & Rayner, 2006) that has demonstrated that words have psychological reality for Chinese readers. First, in Chinese reading, word frequency (G. L. Yan et al., 2006) and word predictability (Rayner et al., 2005) affect fixation times on target words, suggesting that word properties affect word processing during Chinese reading. Second, Li, Liu, and Rayner (2011) found that the saccade length leaving a long word is longer than leaving a short word, suggesting that the length of the fixated word affects the planning of following saccades. Third, M. Yan, Kliegl, Richter, Nuthmann, and Shu (2010) found that the duration of the first fixation in two-fixation cases was longer than the durations of single fixations. Li et al. also found that the first fixation on a word was longer than the second fixation. These results suggest that word length is an important factor influencing when to move the eyes. All of these results suggest that words have psychological reality in Chinese reading. The results of the current study go beyond the previous studies by showing that reading is facilitated when characters belonging to a word are presented simultaneously.

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Received January 11, 2012
Revision received July 30, 2012
Accepted August 1, 2012 ■