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Word properties of a fixated region affect outgoing saccade length in Chinese reading

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ABSTRACT

In two experiments, we investigated how forward saccades are targeted in Chinese reading. In Experiment 1, the critical region was a 4-character string which was either a word (one-word condition) or two 2-character word phrases (two-word condition). In Experiment 2, the critical region was either a high frequency word or a low frequency word. The outgoing saccade length from the last fixation on the critical region was longer in the one-word condition than the two-word condition in Experiment 1 and was longer in the high frequency condition than in the low frequency condition in Experiment 2. These results indicate that the properties of words in a fixated region affect the length of the outgoing saccade. We propose a processing-based strategy for saccade target selection in Chinese reading in which readers estimate how many characters they can process on each fixation, and then program their next saccade so that the eyes fixate somewhere beyond them. As a consequence, the easier the processing of the fixated region is, the longer the outgoing saccade is.

1. Introduction

In English reading, readers' eyes typically land on a location on a word, which is halfway between the beginning and the middle of the word. This location is called the *preferred viewing location* (PVL, Deutsch & Rayner, 1999; McConkie et al., 1988; Rayner, 1979). The PVL is close to the *optimal viewing position* (OVP, O'Regan & Jacobs, 1992), which is the fixation point from which identification of the word is most efficient. Although the PVL is close to the OVP, it is merely the mean fixation location and is close to the modal location as well. If one plots the frequency of initial fixations as a function of the position of letters in a word, the curve is typically quadratic with a peak slightly to the left of the word center (McConkie et al., 1988; Rayner, 1979). Most importantly, its single-peaked nature indicates that readers in English (and other alphabetic languages) have a targeting strategy for saccades in which they are attempting to land on or near the middle of a word. A detailed model of such a strategic process based on a large data set was constructed by McConkie et al. (1988) and was successfully incorporated into the E-Z Reader model to fit the data of English sentence reading (Reichle et al., 1998). Clearly, this is feasible because the spaces between words in English help to demarcate the boundary of words (Rayner, Fischer, & Pollatsek, 1998), so that readers know the location and the length of words and can plausibly send their eyes to the preferred viewing location.

However, in Chinese script, the text is formed by strings of equally spaced boxlike symbols called characters. There are many other differences between Chinese and English. There are 2500 characters that are frequently used in Chinese[1] in contrast to the 26 letters in English; and the information contained in each Chinese character is much higher than that in each English letter. In addition, Chinese words are shorter than English words (measured in terms of orthographic units). 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 2-character words, 12% are 3-character words, and 10% are 4-character words. Fewer than 0.3% of Chinese words are longer than 4 characters. When word tokens are taken into account, 70.1% of words are 1-character words, 27.1% are 2-character words, 1.9% are 3-character words, 0.8% are 4-character words, and 0.1% are words longer than 4 characters. Most importantly, there are no spaces demarcating words in Chinese, and readers have to utilize their lexical knowledge to segment characters into words (Li, Rayner, & Cave, 2009). Thus, without the aid of spaces between words, how do Chinese readers determine where to send their eyes?

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[1] National Linguistics Work Committee of China (1988). *List of Frequently Used Characters in Modern Chinese.*

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Unlike the consistent evidence of the word-based strategy used in English (which is indicated by the PVL curve), there is disagreement about whether Chinese readers adopt the same strategy. Yang and McConkie (1999) claimed that there was no preferred viewing location in 2-character words. Tsai and McConkie (2003) found that the PVL curves for both Chinese words and characters were flatter than for English words with the same length. They thus concluded that their results provided no evidence for a word-based strategy.

Yan et al. (2010) examined saccade target selection strategies in Chinese reading and found a PVL curve that peaked at the word beginning (based on corpus analyses of 2-, 3-, and 4-character words). They further divided the data into two parts based on how many fixations there were on a word; they found that the PVL curve peaked at the word center when there was only one fixation on a word, but peaked at the word beginning when there was more than one fixation on a word. They proposed that Chinese readers target their eyes on the word center if they could segment the word with parafoveal vision, but target on the word beginning if they could not. Hence, they proposed that people use a word-based strategy to select their saccade target in Chinese reading.

Li, Liu, and Rayner (2011) examined the saccade target selection problem in Chinese reading with a different paradigm. They embedded either a 2-character word or a 4-character word in the same sentence frame, so that the sentences were identical except for the target words. They analyzed a 4-character region of interest (ROI), which contained (a) the whole target word in the 4-character condition or (b) the target word as well as two characters following the target word in the 2-character condition. (The sizes of the ROI were identical for the two conditions.) If Chinese readers select the word center as the target for their initial saccade, the PVL curve in the 4-character condition should be further to the right than in the 2-character condition. However, the PVL curves were almost identical in the two conditions. These results did not support a saccade target selection strategy based on the length of the upcoming word in Chinese reading.

Li, Liu, and Rayner (2011) also obtained the PVL curve of Chinese readers which peaked at the word beginning, which was consistent with Yan et al. (2010). However, they argued that this kind of PVL curve did not necessarily support the view that Chinese readers target their eyes at the beginning of the next word and thus use a word-based strategy to select their saccade target. The eyes may fixate at the center of the next word by chance. Since word perception is more efficient when eyes fixate at the center of a word (O'Regan, 1981; O'Regan & Lévy-Schoen, 1987), the word can be processed with a single fixation in this situation and another fixation on the same word is not necessary. To make the point, Li, Liu, and Rayner (2011) did a simulation that assumed a constant distance strategy. That is, even though the simulation did not assume Chinese readers saccade to any specific position of a word, they found a PVL curve for initial fixations on the region that peaked at the word beginning. Further, when they divided the data set into two parts based on the number of fixations on a word as Yan et al. (2010) did, the same simulation also predicted a PVL curve that peaked at the beginning of a word for the first of multiple fixations, and predicted a PVL curve peaked at the center of a word for single fixations. Thus, those PVL curves cannot be used to argue that Chinese readers target their eyes on word center if they could segment the word with parafoveal vision, and target on the word beginning if they cannot.

Do Chinese readers really adopt a constant saccade length strategy during reading? According to the Lexicon of common words in contemporary Chinese research team (2008), most Chinese words consist of two characters (72% of all the words). Because word length is thus quite predictable, moving the eyes a constant distance forward on each saccade (undoubtedly with some variability) is a reasonable strategy since word length is so regular. Consequently, the probability of the eyes landing on each character would be the same and the PVL curve will be flat, as Yang and McConkie (1999) and Tsai and McConkie (2003) found. However, the findings from more recent studies showed that Chinese readers do not use this strategy when they read Chinese text. Yan et al. (2010) made a simulation of a fixed-amplitude strategy, and this simulation cannot explain that skipping probability is affected by word predictability, word length or word frequency. Hence they concluded that Chinese readers do not use a constant saccade length strategy. Li, Liu, and Rayner (2011) found that saccades leaving the target ROIs were different between the two conditions, suggesting that saccade length is not constant. In other words, there is evidence that Chinese readers do not simply employ a constant saccade length strategy when planning saccade targets.

If Chinese readers do not use a word-based strategy or a constant length strategy when selecting a saccade target, what strategy do they adopt? We propose that during Chinese reading, readers might estimate how many characters they are processing efficiently on that fixation and then send their eyes somewhere to the right of those characters. We call this strategy a *processing-based strategy*. Using this strategy, the processing difficulty of the fixated word or words should affect the saccade length of the fixation off of that word or words. The easier the processing, the longer the outgoing saccade length is. The processing-based strategy differs from a word-based strategy in that it does not assume that Chinese readers target any specific position within a word. It differs from the constant length strategy in that it assumes that saccade length is affected by the processing difficulty of the current word or words.

In the present study, instead of examining whether properties of a word or region of text affect *incoming* saccades, we examined whether the properties or processing difficulty of the fixated word or words affect *outgoing* saccade length in two experiments. In Experiment 1, we manipulated word length and in Experiment 2, we manipulated word frequency.

In Experiment 1, the length of the target ROI was 4 characters for both the one-word condition and the two-word condition. In the one-word condition, the target word consisted of a 4-character word; in the two-word condition, the target was a two-word phrase that consisted of two 2-character words. The targets in the two conditions had similar semantic meanings and they were embedded in the same sentence frame. Thus, the length of the ROI was identical in the two conditions, and the information in the ROI was meaningful. In Chinese, the 4-character word was easier to process than two 2-character words. Li, Rayner, and Cave (2009) showed that given a limited presentation duration, Chinese readers could only report the first two characters in the two-word condition although they could report all of the four characters when these four characters constituted a word in the one-word condition. This can also be confirmed if reading time on the target ROI is longer in the two-word condition than in the one-word condition in the current study. So we predicted that the outgoing saccade length should be longer in the one-word condition than in the two-word condition.

As we mentioned above, Li, Liu, and Rayner (2011) did find that the outgoing saccade length was longer in the 4-character condition than in the 2-character condition. However, that study was not designed to study this question, and there was a confound in that estimate: the length of the target words was different in the two conditions. Thus, when calculating the saccade length leaving the target word, they used, as the "launch site", a position on a 4-character ROI aligned to the right boundary of the target word. In the 4-character condition, the ROI contained the 4-character target word, but in the 2-character condition, the ROI contained the 2-character target word and 2 characters before the target word.

For the 2-character condition, the two characters before the 2-character target word constituted a word in some cases, but constituted two words in other cases. Hence the ROI could include 2 or 3 words in the 2-character condition. This might have caused some difference between the two conditions when calculating the outgoing saccade length. Experiment 1 was designed to investigate whether the effect of word length on outgoing saccade length was caused by this difference between the two conditions. The ROI contained either one word or two words in the one-word or two-word condition, respectively.

In Experiment 2, we manipulated the frequency of the 2-character target words and explored how word frequency affects outgoing saccade length. Studies in both English reading (Inhoff & Rayner, 1986) and Chinese reading (Yan et al., 2006) showed that fixation durations on the high frequency words were shorter than that on the low frequency words, suggesting high-frequency words are easier to process than low-frequency words. Hence, we predicted that the outgoing saccade length would be longer in the high-frequency word condition than in the low-frequency word condition.

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty-seven native Chinese speakers, who were students at universities in Beijing, were paid to participate in the experiment. All of them had normal or corrected-to-normal vision, and all were naive regarding the purpose of the experiment. The data of six participants were excluded because of eye tracking failure.

2.1.2. Apparatus

Eye movements were recorded by an SR EyeLink 2000 tracker. Participants read the sentences (which were printed horizontally from left to right) on a 21-in. CRT monitor connected to a DELL PC. The eye-tracking system samples at a rate of 2000 Hz and provides eye movement data for further analysis via another PC. Although the EyeLink 2000 system is able to compensate for head movements, the participants 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 participants were seated 58 cm away from the video monitor; at this distance, one character subtended 1° of visual angle. The characters were in the 20-point Song font and white color, and the background color was black.

2.1.3. Materials

The materials consisted of 48 sentence frames (or 96 sentences in total). Initially, 48 sets of 4-character words were selected as target words from the *Contemporary Chinese Dictionary* in a manner that none of the continuous subsets of characters in these 4-character word form a word. These target words were then embedded in 48 sentences, ranging from 25 characters to 36 characters long, which were obtained from an online corpus[2]. The target words were always in the middle of a sentence so that they were at least five characters from the beginning or the ending of the sentence. Forty-eight sets of two 2-character word phrases (consisted of 4 characters) which had a similar meaning to the corresponding 4-character words were then selected, and these words were embedded in the sentences at the same position as the corresponding 4-character words. The first word in the 2-word phrase was not the beginning segment of any 4-character words. Thus we created two types of 4-character string: a 4-character word and a two 2-character word phrase. We refer to the 4-character word as the one-word condition and the two 2-character word phrase as the two-word condition (see Fig. 1 for an example). As in English, word frequency is highly correlated with word length. The frequencies of longer words are usually lower than that of shorter words. Hence, we could not control word frequencies in these two conditions well. The frequency of the target word in the one-word condition was .60 occurrences per million (*SD* = .07). The frequency of the first word in the two-word condition was 50.77 (*SD* = 11.30) occurrences per million, and the second word was 34.88 (*SD* = 8.75) occurrences per million. We will discuss the influence of this factor on saccade length in the Section 4.

One-word condition
坏习惯坏思想必须要防微杜渐才能促进个人的健康全面发展。
Bad habits and thoughts must be hindered in order to get a healthy development.

Two-word condition
坏习惯坏思想必须要适时遏制才能促进个人的健康全面发展。
Bad habits and thoughts must be prevented timely in order to get a healthy development.

Fig. 1. An example of the stimuli used in Experiment 1. The target word is underlined in the example (but not during the experiment).

2.1.4. Procedure

When participants arrived for the experiment, they were given instructions for the experiment and a description of the apparatus. The eye tracker was calibrated and validated at the beginning of the experiment; then additional calibration and validation was conducted whenever needed. For calibration and validation, participants looked at a dot that was presented in three positions of a horizontal line in a random order. Then each participant read the 48 experimental sentences in a random order. They saw only one condition with each sentence frame and saw an equal number of each type of target word. The participants were told to read silently, and that they would periodically be asked to answer comprehension questions about the sentences. These questions were asked after about one third of the sentences.

Each trial started with a fixation box ($1° \times 1°$ in size) at the location of the first character of the sentence. The sentence was shown after participants successfully fixated on the box. After reading a sentence, the participant pressed a response button on a button box to start next trial.

2.1.5. Analyses

We excluded the trials in which there were eye blinks in the target ROI or there were more than three eye blinks in a single trial. In total, approximately 4% of the trials were excluded. Fixations longer than 1000 ms or less than 80 ms were truncated. When analyzing reading time, trials that were more than three standard deviations (*SD*s) from the mean value were excluded from analysis. When analyzing saccade length, saccades longer than five characters were excluded because such a long saccade length is usually due to a track loss or an eye blink. For eye movement measures, we employed *first fixation duration* (the duration of the first first-pass fixation on the target word), *gaze duration* (the sum of all first-pass fixations on the target word before moving to another word), *refixation probability* (the probability that readers make more than one fixation in the first pass reading on the target word), and the *outgoing saccade length*. The outgoing saccade length is the distance between the last fixation on the ROI and the first fixation on the region to the right. Since processing is easier for the

[2] http://ccl.pku.edu.cn:8080/ccl_corpus/index.jsp?dir=xiandai. Center for Chinese Linguistics PKU.

4-character word than for the two 2-character words, we predicted that there should be a longer outgoing saccade length, because of the shorter reading time and the lower probability of refixation in the one-word condition than in the two-word condition.

2.2. Results and discussion

2.2.1. Accuracy

For the one-word condition and the two-word condition, the average accuracy to the comprehension questions was 93.5% and 91.6%, respectively. There was no significant difference ($t < 1$), indicating that the participants could understand the sentences equally well.

2.2.2. Eye movement measures

Table 1 shows the eye movement measures associated with the target words.

The outgoing saccade length was significantly longer in the one-word condition than in the two-word condition, $t_1(20) = 3.50$, $p = .002$; $t_2(47) = 2.60$, $p = .012$, which was consistent with our prediction and indicated that the properties of the fixated word affected the planning of upcoming saccade. The launch site of these outgoing saccades was 1.97 characters (counted from the right boundary of the target ROI) in the one-word condition, and was 1.88 in the two-word condition. Although the launch site was numerically further to the left in the target ROI in the one-word condition than the two-word condition, the difference was not significant, $t_1(20) = 1.57$, $p = .132$; $t_2(47) = 1.20$, $p = .235$.

One may argue that the differences in outgoing saccade length between the two conditions may be an artifact since the launch site in the two-word condition was numerically further away from the right boundary of the ROI. Hence, the longer outgoing saccade length in the one-word condition may be just an artifact because of the launch site difference between the two conditions. This possibility is unlikely since the launch site difference between the two conditions was not significant. However, to completely exclude this possibility, we calculated the length of all of the saccades launched from each character in the ROI. As shown in Table 2, the length of the saccades launched from each character was longer in the one-word condition than the two-word condition. The differences were significant for the saccades launched from all of the positions, $t_1s(20) > 4.00$, $ps < .001$; $t_2s(47) > 2.75$, $ps < .010$, except the first character position, $t_1(20) = 1.58$, $p = .131$; $t_2(47) = 1.07$, $p = .292$. These results indicate that the longer outgoing saccade length in the one-word condition was not caused by the launch site differences between the two conditions.

Although there was virtually no difference between the two conditions in first fixation duration ($ts < 1$), the gaze duration was significantly shorter in the one-word condition than the two-word condition, $t_1(20) = -4.70$, $p < .001$; $t_2(47) = -3.52$, $p < .001$. This reflects the fact that the refixation probability was smaller in the one-word condition than in the two-word condition, $t_1(20) = -3.67$, $p = .002$; $t_2(47) = -2.18$, $p = .034$. These results indicate that the processing was easier in the one-word condition than in the two-word condition.

These results are consistent with the view that Chinese readers use a processing-based strategy to select a saccade target. According to this view, Chinese readers estimate how many characters they can process efficiently on each fixation and move their eyes beyond them. If the characters they fixate are easier to identify, they will make a longer saccade. Processing is more difficult in the two-word condition than in the one-word condition, and the saccade length was longer in the one-word condition than the two-word condition.

Table 1
Eye movement measures for the target words in Experiment 1.

	One-word condition	Two-word condition
Outgoing saccade length (in characters)	2.87 (0.21)	2.68 (0.21)**
First fixation duration	281 (21.20)	279 (20.84)
Gaze duration	502 (51.14)	585 (62.06) **
Refixation probability	69.4% (8.73%)	77.1% (7.40%)**

Note: The unit for all of the time measures is ms. SEs are shown in parentheses.
* $p < .05$.
** $p < .01$.

Table 2
Forward saccade length (in characters) launched from different positions in the target ROI in Experiment 1.

Launch site	One-word condition	Two-word condition
1st Character	2.56 (0.20)	2.48 (0.18)
2nd Character	2.67 (0.21)	2.46 (0.18) **
3rd Character	2.70 (0.21)	2.43 (0.19) **
4th Character	2.81 (0.20)	2.61 (0.21) **

Note: SEs are shown in parentheses.
* $p < .05$.
** $p < .01$.

3. Experiment 2

The number of words in the target ROI was different between the two conditions in Experiment 1. In the one-word condition, the target area contained only one word, but in the two-word condition the target area contained two words. In Experiment 2, we controlled the number of words in the target region and made it identical across two conditions. We manipulated word frequency and explored how word frequency affects outgoing saccade length. Previous studies have shown that high frequency words are easier to process than low frequency words (Inhoff & Rayner, 1986). We predicted that the outgoing saccade length would be longer in the high frequency word condition than in the low frequency word condition.

3.1. Method

3.1.1. Participants

Twenty-three native Chinese speakers, who were students at universities in Beijing, were paid to participate in the experiment. All of them had normal or corrected-to-normal vision, and all were naive regarding the purpose of the experiment. None of the participants had participated in Experiment 1. The data of two participants were excluded because of eye tracking failure.

3.1.2. Apparatus

The apparatus was identical to that in Experiment 1.

3.1.3. Materials

There were 72 sentence frames, each with 2 target words. The predictability of the target word was low so that they are not predictable from context (lower than 0.05 based on a norming study with 8 participants). All of the target words were 2-character words. Two target words were fit into each sentence frame, generating two sentences. One of the target words was high frequency (above 50 occurrences per million) and the other word was low frequency (below 5 occurrences per million). Thus there were two conditions depending on the frequency of the target word: the high frequency (HF) condition and the low frequency (LF) condition (see Fig. 2 for an example). The average frequencies and *SDs* (in parentheses) for HF

High frequency word condition
面容慈祥的迪斯尼先生正拉着可爱的米老鼠的小手向朋友们挥手致意。
Mr. Disney with a kind face was waving to friends while holding the little hand of the lovely Mickey Mouse.

Low frequency word condition
面容慈祥的迪斯尼先生正拉着可爱的米老鼠的小手向访客们挥手致意。
Mr. Disney with a kind face was waving to visitors while holding the little hand of the lovely Mickey Mouse.

Fig. 2. An example of the stimuli used in Experiment 2. The target word is underlined in the example (but not during the experiment).

and LF words were 128.96 (9.92) and 2.84 (0.17) per million occurrences, respectively. The target word was neither in the beginning nor in the final three characters of a sentence.

3.1.4. Procedure

The procedure was identical to that in Experiment 1.

3.1.5. Analyses

About 1.5% of the trials were excluded from analyses due to a track loss or eye blink. Fixations longer than 1000 ms or less than 80 ms were truncated. Data points that were more than three standard deviations (*SDs*) from the mean value were excluded from analysis. When analyzing saccade length, only the saccades that were shorter than 5 characters were analyzed. Paired sample *t*-tests were carried out on first fixation duration, gaze duration, outgoing saccade length, and refixation probability.

3.2. Results and discussion

3.2.1. Accuracy

For the HF condition and the LF condition, the average accuracy to the comprehension question was 95.6% and 93.3%, respectively, $t(20) = 1.55$, $p = .137$, indicating that participants understood the sentences equally well.

3.2.2. Eye movement measures

Table 3 shows the eye movement measures associated with the target word and the results of paired sample *t*-tests on those measures.

The outgoing saccade length was significantly longer in the HF condition than in the LF condition, $t_1(20) = 3.12$, $p = .005$; $t_2(71) = 2.63$, $p = .010$, which was consistent with our prediction. The launch site of these outgoing saccades was 1.47 characters in the HF condition, and was 1.46 in the LF condition, and the difference was not significant, $ts < 1$.

The first fixation duration was significantly shorter in the HF condition than the LF condition in the item analyses, and the effects were marginal across subjects, $t_1(20) = -1.89$, $p = .073$; $t_2(71) = -2.30$, $p = .025$. Consistent with Experiment 1, gaze duration was significantly shorter in the HF condition than in the LF condition, $t_1(20) = -3.36$, $p = .003$; $t_2(71) = -4.03$, $p < .001$. The refixation probability was less in the HF condition than in the LF condition in the item analyses, and the effects were marginal across subjects, $t_1(20) = -2.00$, $p = .059$; $t_2(71) = -2.16$, $p = .034$. These results showed that the processing of high frequency words was easier than the processing of low frequency words.

Table 3
Eye movement measures for the target word in Experiment 2.

	HF word	LF word
Outgoing saccade length (in characters)	2.93 (0.15)	2.77 (0.18)**
First fixation duration	255 (16.11)	267 (16.53)*
Gaze duration	282 (21.27)	316 (21.54)**
Refixation probability	12.4% (5.28%)	16.2% (5.53%)*

Note: The unit for all of the time measures is ms. SEs are shown in parentheses.
* $p < .05$.
** $p < 0.01$.

The results of Experiment 2 showed that the frequency of the fixated word affected the planning of upcoming saccade. More specifically, the easier the processing of the fixated word is, the longer the outgoing saccade length is. The results of Experiment 2 provided clear evidence for a processing-based strategy on saccade target selection.

4. General discussion

In two experiments, we found that the properties of the fixated ROI affected the outgoing saccade length from the last fixation on the region. In Experiment 1, the 4-character ROI included two words in the two-word condition, but included one word in the one-word condition. The key results were that the outgoing saccade length was longer in the one-word condition than in the two-word condition while the gaze duration on the region was shorter in the one-word condition. In Experiment 2, the region contained one of two target words with different word frequencies, and they were embedded in the same sentence frame. Again, the outgoing saccade length was longer in the high frequency word condition than in the low frequency word condition while the gaze duration was shorter in the high frequency word condition. These results support a processing-based strategy for saccade target selection in which the more characters Chinese readers could process on a fixation, the farther to the right, they would program their saccade.

In Experiment 1, one might argue that there was a confound as the frequencies of the initial word in the critical region were not controlled: the mean frequencies of the 4-character words in the one-word condition were lower than those of the frequencies of either of the 2-character words in the two-word condition. This seems very unlikely to be a contributing cause for the longer saccade lengths leaving the target ROI, however. That is, the results of Experiment 2 showed that saccades leaving a high frequency word were longer than those leaving a low frequency word, which is obviously opposite to what would be predicted by this frequency difference.

This leaves open the question of why the Li, Liu, and Rayner's (2011) data could be fit with a model that assumed a constant distance strategy. We think that the difference between the present situation and their study is the following. They manipulated the characteristics of the region that the reader was about to enter. Apparently, Chinese readers' saccades into the region were not influenced by the characteristics of the region that they were about to enter (or at least not those that were manipulated in that experiment). Given the results of the current experiments, we believe that the material in the region prior to the critical region that they were studying did influence where the saccades landed. However, because the difficulty of the material in this region was not varied, this was not assessed in their experiment. We do not wish to get enmeshed in a discussion of whether the fundamental unit in Chinese is the word or the character (Chen, 1996; Chen & Zhou, 1999) as suggested by some Chinese linguists (Wang, 2007, 2009; Xu, 1994, 2005). However, we think there is quite a bit of evidence indicating that "word" is a real unit in Chinese reading for determining the difficulty of text and thus how long regions of text are fixated (Bai et al., 2008; Li et al., in press; Li & Logan, 2008; Li & Pollatsek, 2011; Li, Rayner, & Cave, 2009; Zang et al., 2011). A likely reason that these word length manipulations have no effect is not that words have no psychological reality for Chinese readers. Instead, it is more probable that because the boundaries are not physically marked (as in most alphabetic languages), they cannot make the computation of where the boundary is in the time window they would need to in order to efficiently plan a saccade. Thus such a strategy to use word boundary information would be quite counterproductive for skilled Chinese reading.

In contrast, the present experiments manipulated characteristics of the region that the reader was currently fixating prior to the saccade. It seems more likely that this text can and will control aspects of eye movement control, given that is relatively fully processed prior to initiating the saccade. We should note that Li, Liu, and Rayner (2011) did observe a small, but non-significant difference in the location of refixations in their experiment, consistent with the above distinction.

The finding that outgoing saccade length is affected by the properties of the fixated word is not unique to Chinese reading. Rayner et al. (2004) found that the outgoing saccade length was slightly longer for high-frequency target words than for low-frequency target words. White and Liversedge (2006) also found that saccades launched from word n to word $n+1$ were significantly shorter when word n was infrequent compared to when it was frequent, although they found that this foveal processing difficulty did not modulate the orthographic effect (correctly spelled vs. misspelled word beginnings) of word $n+1$. Perea and Acha (2009) found that the length of the outgoing saccade of the target word was significantly longer in normally written sentences than in alternating**bold** unspaced sentences, and was significantly longer in alternating**bold** unspaced sentences than in "regular" unspaced sentences (i.e., without any clue for where word boundaries were). Because the processing of spaced script was easier than unspaced script, and regular unspaced sentences was harder than alternating unspaced sentences, this is consistent with our results that processing difficulty affects the outgoing saccade length.

The results of the current study clearly show that the properties of the fixated word affect upcoming saccade length. But when does this take place? One possibility is that Chinese readers fully process all the material within the perceptual span and then compute where to target the saccade. This possibility seems to be unlikely because it would seem to slow the reading process quite considerably. The second possibility is that they make some sort of partial computation of the fixated material (an estimate of how much they will be able to process) and make their saccade on the basis of that. The E-Z Reader model makes a similar assumption: it assumes that partial activation of the word allows the frequency and the predictability of the word to influence the decision of both *when* to execute a saccade and *where* to execute a saccade (i.e., to refixate a word or saccade to the next word). There is already evidence in Chinese (Yan et al., 2006) that the decision of when to execute a saccade is influenced by variables such as word and character frequency and the data of Experiment 2 confirm this. Our data further indicate that there is an analogous mechanism operating in Chinese for determining *where* to execute a saccade. However, the exact mechanism of how this is done still needs further study.

In summary, the results of our experiments support a processing-based strategy used for saccade target selection in Chinese reading. Chinese readers might estimate how many characters they can process efficiently on that fixation and move their fixation beyond. As a consequence, the properties of the fixated region affect the outgoing saccade length. The easier the processing of the fixated region, the longer the outgoing saccade length is. Such a strategy would clearly be productive as it would be more likely to place the reader in regions of text that are "new" and need to be processed as opposed to regions of text that have already been processed by the end of the prior fixation. Such a processing model is blind to the physical word boundaries. Thus, when modeling data that only are looking at actual word boundaries (such as those we discussed in the introduction), it will be quite hard to tell from a constant distance model.

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