

Is preview benefit from word $n + 2$ a common effect in reading Chinese? Evidence from eye movements

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Abstract Although most studies of reading English (and other alphabetic languages) have indicated that readers do not obtain preview benefit from word $n + 2$, Yang, Wang, Xu, and Rayner (2009) reported evidence that Chinese readers obtain preview benefit from word $n + 2$. However, this effect may not be common in Chinese because the character prior to the target word in Yang et al.'s experiment was always a very high frequency function word. In the current experiment, we utilized a relatively low frequency word $n + 1$ to examine whether an $n + 2$ preview benefit effect would still exist and failed to find any preview benefit from word $n + 2$. These results are consistent with a recent study which indicated that foveal load modulates the perceptual span during Chinese reading (Yan, Kliegl, Shu, Pan, & Zhou, 2010). Implications of these results for models of eye movement control are discussed.

Keywords Chinese reading · Eye movements · Preview benefit

Introduction

The extent to which readers obtain information from not-yet-fixated words has been the topic of considerable research. Most studies addressing this issue have utilized the gaze-contingent boundary paradigm (Rayner, 1975). In the boundary paradigm, readers either get a valid preview of a target word or the target word is masked or replaced by another word. When the reader's eyes cross an invisible boundary

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location, the preview word is replaced by the target word. Since this display change occurs during a saccade, when vision is suppressed, readers do not notice the display change. There is now considerable agreement (see Rayner, 1998, 2009) that, while looking at word n (the fixated word), readers obtain useful information (preview benefit) from word $n + 1$ (the word to the right of fixation). Preview benefit is defined as the amount of time that readers look at a word when given a full preview of it subtracted from the amount of time that readers look at the word when they didn't have a valid preview.

There is also considerable agreement that Chinese readers, like readers of alphabetic writing systems obtain useful preview information from the word to the right of fixation (Inhoff & Liu, 1997, 1998; Liu, Inhoff, Ye, & Wu, 2002; Tsai, Lee, Tzeng, Hung, & Yen, 2004; Yan, Kliegl, Shu, Pan, & Zhou, 2010; Yan, Richter, Shu, & Kliegl, 2009; Yang, Wang, Xu, & Rayner, 2009; Yen, Radach, Tzeng, Hung, & Tsai, 2009; Yen, Tsai, Tzeng, & Hung, 2008). Furthermore, for readers of alphabetic writing systems, there is evidence that readers generally do not obtain preview benefit from word $n + 2$ (Rayner, Juhasz, & Brown, 2007; McDonald, 2006; Kliegl, Risse, & Laubrock, 2007; Angele & Rayner, 2010; Angele, Slattery, Yang, Kliegl, & Rayner, 2008). Rayner, Juhasz, et al. (2007) used the boundary paradigm and placed the boundary location either after word $n - 2$ (relative to the target word¹) or after word $n - 1$. Thus, for example, when the reader fixated on word $n - 2$ and the boundary was located at the end of word $n - 2$, there was either a valid preview or an invalid preview of the target word (word n). When the reader's eyes crossed the boundary location, the display change occurred and the target word replaced the preview. When the boundary was located after word $n - 2$, this typically meant that after crossing the boundary the reader fixated first on word $n - 1$ and then on word n . In contrast, when the boundary was located after word $n - 1$, crossing the boundary location triggered the display change, but the reader's eye was typically on word n following the eye movement. Rayner et al. found the typical preview benefit effect in this latter case, but they found no evidence of preview benefit for the target word (word n) when the boundary was after word $n - 2$. Although Kliegl et al. (2007) found no preview benefit for word $n + 2$, a preview effect was observed when readers fixated on word $n + 1$, which was referred to as a delayed effect from word $n + 2$. Furthermore, Glover, Vorstius, and Radach (2010) reported preview benefit for word $n + 2$ when word $n + 1$ was a short high frequency three-character word. Of course, such short words would typically be skipped. Interestingly, Rayner, Li, et al. (2007) did not find preview benefit for word $n + 2$ when word $n + 1$ was a short four-character word.

The motivation for research on preview benefit of word $n + 2$ has been to discriminate between two kinds of computational models of eye movement control in reading. Specifically, serial attention shift (SAS) models like the E-Z Reader model (Pollatsek, Reichle, & Rayner, 2006; Rayner, Reichle, & Pollatsek, 1998, 2005; Reichle, Rayner, & Pollatsek, 2003; Reichle, Pollatsek, Fisher, & Rayner,

¹ For consistency with prior research, the boundary locations are referred to as character $n - 2$ and $n - 1$. Both designations are with respect to the target word which would be word n according to the scheme for the boundary location. However, the target word is also referred to as word $n + 2$, with two single character words (word n and word $n + 1$) preceding it.

1998) assume that lexical processing is guided by a spatial attentional system that processes one word at a time such that word $n + 1$ is processed only after the lexical processing of word n is completed. On the other hand, in guidance by attentional gradient (GAG) models such as SWIFT (Engbert, Nuthmann, Richter, & Kliegl, 2005; Engbert, Longtin, & Kliegl, 2002; Kliegl & Engbert, 2003) and Glenmore (Reilly & Radach, 2003, 2006), lexical processing is distributed over a number of words via a gradient of attention. A prediction that emerges from the differences between the two models is that readers should be able to obtain some type of preview benefit from word $n + 1$ and word $n + 2$ in GAG models. However, it will only be obtained from word $n + 1$ according to SAS models, although there are circumstances in which word $n + 2$ might yield preview benefit, such as when readers skip over word $n + 1$ (in such cases, they would have processed word $n + 1$ while still fixating on word n and their attention would have been directed to word $n + 2$). While Rayner, Juhasz, et al. (2007) concluded that readers generally do not obtain preview benefit from word $n + 2$, and that the results were consistent with SAS models (see also Angele et al., 2008; McDonald, 2006), Kliegl et al. (2007) and Glover et al. (2010) found evidence for preview benefit from word $n + 2$ under some circumstances (short high frequency $n + 1$ words) and argued that the results were consistent with GAG models.

In Chinese, Yang et al. (2009) recently found some evidence to indicate that Chinese readers obtain preview benefit from a two-character $n + 2$ word. Similar to Rayner, Juhasz, et al. (2007), there were two boundary locations in Yang et al.'s study: (1) boundary location $n - 1$, which was at the end of character $n - 1$ (the character to the left of the target), and (2) boundary location $n - 2$, which was at the end of character $n - 2$. In Experiment 1, characters, which are often regarded as the basic visual unit in written Chinese, were used as targets to examine whether readers obtain preview information from character $n + 1$ and character $n + 2$. The results suggested they do. However, given that character $n - 1$ could be a word on its own or a component character of a multiple character word, it may not have been clear that the target character was always the second word after boundary $n - 2$ in Experiment 1. This ambiguity was controlled in Experiment 2, which used two-character words as targets. Half of the time, character $n - 1$ was a single-character word, while the other half of the time it was a component character of a word consisting of character $n - 1$ and character $n - 2$. Therefore, the target word could be word $n + 1$ or word $n + 2$ in relation to the boundary $n - 2$ (the target word was always word $n + 1$ relative to the boundary $n - 1$). Robust preview effects were obtained for word $n + 1$. There was also evidence from gaze duration (the sum of all fixations on a word prior to moving to another word), suggesting preview benefit for word $n + 2$. That is, when the boundary was at the end of word $n - 2$, the identical preview word led to a shorter gaze duration on the target word than the different preview word, when character $n - 1$ was a single-character word. However, Yang et al. suggested that the preview benefit from word $n + 2$ in their study may not be a common effect in reading Chinese because the frequency of character $n - 1$ was extremely high (3,760 per million) when it was a word itself, as most of them were function words. Consequently, they suggested that if there was not a highly frequent function word $n + 1$, preview benefit would not be observed from word $n + 2$.

In the present experiment, we examined the generality of preview benefit from word $n + 2$ with a low frequent $n + 1$ word (the word prior to the target word, which we will refer to as character $n - 1$ relative to the position of the target word). However, before moving to the details of the experiment, it is necessary to discuss (1) some of the properties of written Chinese and (2) eye movements during the reading of Chinese.² Unlike English (and other alphabetic writing systems), Chinese is a logographic script in which written text is formed by strings of equally spaced box-like symbols called characters. Whereas most European languages adopt the letter as the elementary unit (phonemes in speech), in Chinese individual characters are used to represent the basic units of meaning (morphemes). Basically, there are many visual details packed into characters, since they can differ in the number of strokes and the manner of construction. Given that information is more densely packed in Chinese than English, more information may be available to the right of fixation in Chinese compared to alphabetic writing systems. This hypothesis is supported by the finding that in Chinese the size of the perceptual span to the right of fixation (2–3 characters) is only slightly larger than the average size of forward saccades (2.6 characters), indicating that there is only slight overlap in the perceptual span in reading Chinese (Inhoff & Liu, 1998). On the other hand, there is considerable overlap (up to 50%) between the right-side area of successive spans in reading English (Rayner, 1998); the perceptual span to the right of a fixation (about 14–15 letter spaces) is about twice the size of the average forward saccade (7–8 letter spaces). This implies that Chinese readers are able to obtain the maximum amount of new information from the right of fixation on each fixation (Chen, Song, Lau, Wong, & Tang, 2003).

Although a character in Chinese can be a single-character word, most characters can join with other characters to form a multiple-character word. In addition, there is no physical separation between words (the width of the space between words is identical to that between characters within a word). Thus, readers have to rely on context to determine whether a character is a word by itself or if it is a morpheme of a multiple-character word, which means that Chinese readers may need to obtain information from the right of fixation to segment words on-line.

Consistent with this view, Yang, Staub, Li, Wang, and Rayner (2010) found that Chinese readers might be able to locate likely word boundaries before they fixate on a word. In this study, Chinese readers' eye movements were monitored as they read sentences containing a critical character that was either a one-character word or the initial character of a two-character word. By manipulating the verb prior to the target word, the one-character target word (or the first character of the two-character target word) was either plausible or implausible as an independent word at the point at which it appeared, whereas the two-character word was always plausible. The eye movement data revealed that the plausibility manipulation did not exert an influence on the reading of the two-character word or its component characters. However, plausibility significantly influenced the reading of the one-character target word:

² For more general information about reading Chinese and how different it is from alphabetical languages, see Yang et al. (2009), Yan, Tian, Bai, and Rayner (2006), and Yen et al. (2008).

Gaze durations³ were significantly inflated on the region including the implausible one-character word and the preceding character. These results suggest that processes of semantic integration in reading Chinese are performed at a word level, instead of a character level, and that word segmentation must take place very early in the course of processing (see also Li, Rayner, & Cave, 2009).

Given the aforementioned characteristics of written Chinese, it seems that a distinct reading strategy may be adopted in reading Chinese, which enables Chinese readers to obtain important information from the right of fixation and identify word boundaries before fixating on the word. Consequently, there is the possibility that preview benefit from word $n + 2$ is a robust effect in Chinese, even if word $n + 1$ is not an extremely high frequency function word (as in Yang et al.'s study). Therefore, we used relatively low frequency words, which had an average frequency of about 200 per million, in the $n + 1$ location to test this hypothesis. Although words of 200 per million may not appear to be that infrequent, one-character words in Chinese tend to be fairly frequent (see footnote 5) and they are certainly much less frequent than words occurring at the rate of 3,760 per million (as per the $n + 1$ words in Yang et al., 2009). The reason we did not use lower frequency $n + 1$ words was to maximize the chance of observing a positive effect. However, if we failed to find evidence for preview benefit for word $n + 2$ in the current study, it would suggest that this effect is not a general phenomenon in reading across different languages, since it is not robust in a language which should favor such an effect.

Recently, Yan et al. (2010) examined preview benefit from word $n + 2$ with either low frequency or high-frequency $n + 1$ words. They found that preview benefit from word $n + 2$ was only obtained when word $n + 1$ was high frequency, but not when it was low frequency. However, all of the targets in Yan et al.'s study were integrated characters (which they referred to as pictographical and indicative characters), and each of them was embedded as the first character of a two-character word in the sentence. There are two groups of Chinese characters: integrated characters and compound characters. The integrated characters consist of crossed strokes that are inseparable, whereas compound characters usually consist of two separable subcomponents that denote semantic or phonological information (called radicals). Given that only 18% of Chinese characters are integrated characters (Xu, Pollatsek, & Potter, 1999), it is not clear if the results based on integrated characters are representative of reading Chinese, as noted by Yan et al. (2010). Indeed, in another paper by Yan et al. (2009), they suggested that the lexical processing of integrated and compound characters is different: while integrated characters are mapped more closely to meaning than to phonology, compound characters may be mapped more closely to phonology than to meaning as there is phonological input from their phonological radicals. Furthermore, the preview manipulation in Yan et al. (2010) was on the first character of a two-character target word, while the preview manipulation in Yang et al. study (2009) involved two characters within a word. Given the stimulus differences between these two studies, Yan et al. did not

³ When regions larger than a single word are examined, the measure is usually referred to as *first pass reading time* (the sum of all fixations in a region before leaving the region, see Rayner, 1998, 2009). However, for simplicity we will use the term gaze duration to refer to the sum of all fixations in the region before moving to another region in the present experiment.

make a direct comparison to Yang et al.'s study, and whether or not the preview benefit from word $n + 2$ in the latter study is due to the extremely high frequency of word $n + 1$ is still an open question. In contrast, using most of the target words from Yang et al. (2009) and relatively low frequency words in the $n + 1$ location, the present study allowed us to make a direct comparison with Yang et al.'s study.

Method

Participants

Thirty-six⁴ undergraduate students from South China Normal University, who were naïve concerning the purpose of the experiment, participated for course credit. They all had normal or corrected to normal vision and were native readers of Chinese.

Materials

Forty-eight experimental sentences, with a two-character target word (most of which were from Yang et al. 2009's Experiment 2) were developed for this experiment. An example sentence (with the target character in bold) and its English translation is:

1. 士兵们学拆**炸**弹花了不少时间。

(Learning to defuse a bomb takes the soldiers a lot of time)

Using the eye movement contingent boundary technique (Rayner, 1975), we presented either an identical (炸弹-*bomb*) or dissimilar preview (翅膀-*wing*) that changed to the target word when the reader moved his or her eyes across an invisible boundary. Two material sets were created for the experiment, each containing 48 experimental sentences and 64 filler sentences (which did not involve a boundary display change). In the experimental sentences, the boundary was either after character $n - 1$ (the character immediately to the left of the target word) or after character $n - 2$. Thus, the study utilized a 2 (preview type) \times 2 (boundary location) design, with appropriate counterbalancing across participants.

Mean word frequency⁵ was 26.8 (SD = 15.7) for the target words, and the matched frequency for the dissimilar previews was 26.6 (SD = 15.5). Each target word had two characters; the average character frequency⁶ of the two component characters was 216 (SD = 252) and 214 (SD = 245) and the average number of strokes was 9.3 (SD = 3.0) and 9.1 (SD = 3.3), for the target words and the dissimilar previews, respectively. Regarding the single-character word immediately to the left of the target word (character $n - 1$), its averaged word frequency was 277

⁴ Four additional participants were discarded because for them more than 30% of the display changes occurred during a fixation.

⁵ The word frequency counts are based on Liu (1990), and include 31,320 two-character words with an average word frequency of 32 per million, and 5,421 one-character words with an average word frequency of 329 per million. Although the majority of Chinese words are two-character words, one-character words are usually much more frequent than two-character words.

⁶ The character frequency counts are based on the National Languages Committee (1992).

(SD = 444), and the number of strokes averaged 9.3 (SD = 3.4). No character $n - 1$ overlapped with those in Yang et al. (2009) as the critical manipulation in the current experiment was to use a less frequent character $n - 1$ than those used in Yang et al. In Yang et al., word frequency of character $n - 1$ ranged from 1,395 to 4,540 per million (mean = 3,760 per million), except that two characters were less than 1,000 per million and two were higher than 40,000 per million. In the current experiment, the word frequency range of character $n - 1$ was from 2 to 748 per million, except one character was 2,948 per million.

To ensure that character $n - 1$ was a word by itself, namely, that the target word was the second word after boundary location $n - 2$, a word segmentation norming procedure was used. Eleven undergraduate students from the South China Normal University, who did not participate in the main experiment, were asked to segment the words of the sentences. Participants had 96% agreement that all of the target words (48 items) were two-character words. Regarding the two characters to the left of the target ($n - 2$ and $n - 1$), they agreed 90 and 92% of the time they were single-character words.

Apparatus

An SR Eyelink 1000 eye-tracking system was used to track eye movements at a rate of 1,000 HZ. The eye-tracker monitored movements of the right eye, although viewing was binocular. A Dell 19-inch SVGA monitor was used to display the stimuli. The monitor was set to a refresh rate of 150 Hz. The delay in detecting an eye movement crossing the boundary and changing the display was 10 ms. Since the display change occurred during a saccade, readers were not aware of the change.

All stimuli were presented in white on a black background on the computer monitor. All characters were printed in simple Kai-Ti font. Each character was about 1×1 cm in size and subtended approximately 0.9° of visual angle (with the participants' eyes being 64 cm away from the monitor).

Procedure

Participants were randomly assigned to one of four stimulus sets and were tested individually. The experiment consisted of a calibration phase and an experimental phase. In the calibration phase, each participant performed a 3-point calibration procedure to make sure that the eye-tracker recordings were accurate. The experimental phase then followed. At the beginning of the experimental phase, before reading each sentence, readers were first asked to fixate on a dot at the left corner of the computer screen that indicated the position of the first character of the sentence. Once they fixated on the dot, the sentence was displayed. Participants read each sentence at their own pace and then pressed a button to terminate the end of the trial. One-third of the sentences were followed by a true–false comprehension question. Participants answered the question based on the information from the previous sentence by pressing an appropriate button.

Each participant read the 48 experimental and 64 filler sentences in a random order; the whole experiment lasted about 40 min. Six practice sentences were presented at the beginning of the experiment to familiarize participants with the procedure; they were informed that they could take a break whenever they needed one.

Results

Participants scored 82% or better in response to the questions, averaging 96%. Trials were excluded from the analysis due to track losses or if the duration of a fixation on or adjacent to the target word was greater than 600 ms or less than 60 ms, which led to less than 1% of data lost. In addition, trials in which the display change occurred during a fixation were excluded. In self-report about whether they noticed something weird during reading, only 5 participants of 36 noticed something flickered in one or two sentences. On average, 16% of the data were lost, but none of the participants had more than 30% of the data missing, and there were no differences across conditions.

The data were analyzed on four standard measures typically used in eye movement research (Rayner, 1998): first fixation duration (the duration of the first fixation on a character/word), gaze duration (the sum of all fixations on a character/word prior to moving to another character/word), single fixation duration (the duration when there was exactly one fixation in the first reading) and the probability of skipping the character.

Statistical analyses on the various eye movement measures were performed using Linear mixed models (LMM) for durations and generalized linear mixed models (GLMM) for binary dependent variables (skipping), specifying participants and items as crossed random effects. These analyses were carried out using the *lmer* program of the *lme4* package (Bates & Maechler, 2009) in R, an open-source programming language and environment for statistical computation (R Development Core Team, 2009). We report regression coefficients (*bs*, effects relative to the intercept, which indicate effect size in milliseconds for durations, and change in log odds for binary dependent variables), standard errors (SEs), *t* values (for durations), *z* values (for binary dependent variables), and *p* values. The *p* values corresponding to the *t* values were estimated using posterior distributions for model parameters obtained by Markov Chain Monte Carlo sampling (Baayen, 2008; Baayen, Davidson, & Bates, 2008).

The major issue is whether or not readers obtain preview benefit from the target word when the boundary was at the end of character $n - 2$ as well as at the end of character $n - 1$. To address this issue, two contrasts were set up: (1) identical vs dissimilar conditions at boundary $n - 1$, and (2) identical vs dissimilar conditions at boundary $n - 2$. We computed the different eye movement measures associated with characters $n - 2$ through character $n + 1$. The reason we were interested in the effect of the preview manipulation on character $n - 2$ and $n - 1$ is because the processing of the word to the right of fixation can sometimes exert an influence on the currently fixated word (a parafoveal-on-foveal effect) for readers of Chinese. For example, Yang et al. (2009) found that reading time on character $n - 1$ was shorter when the

target word was in the identical preview condition than when it was in the different preview condition.

Character $n - 2$

When the eyes landed on character $n - 2$ (for both boundary locations, this would be prior to the display change), there was no effect of the preview manipulation for either boundary location in all analyzed measures, $ps > .1$. The skipping rate averaged .44 across conditions, and the reading time averaged 245, 244 and 256 ms across conditions for first fixation duration, single fixation duration and gaze duration, respectively.

Character $n - 1$

When the eyes landed on character $n - 1$, it could have been either before the display change (when the boundary was after character $n - 1$) or after the boundary change (when the boundary was after character $n - 2$). In the former case, any effect would presumably reflect some type of parafoveal-on-foveal effect, while in the latter case it would reflect some type of preview effect. When the boundary was after character $n - 2$, no reliable effect was observed, $ps > .2$ (see Table 1 for means in the different conditions). When the boundary was after $n - 1$, gaze duration was longer in the dissimilar condition, than in the identical condition, but the effect was only marginally significant, $b = 20$, $SE = 10.8$, $p = .068$; although the same pattern was observed for first fixation duration and single fixation, this effect was not significant, $ps > .2$. Thus, there was some weak evidence for a parafoveal-on-foveal effect.

Table 1 Eye movement measures in the target word and two characters on its either side as a function of preview and boundary location

Boundary	$n - 1$			$n - 2$		
	Identical	Dissimilar	p value	Identical	Dissimilar	p value
Character $n - 1$						
FFD	254 (44)	267 (39)	.22	260 (46)	266 (46)	> .34
Single	258 (44)	269 (42)	.25	262 (50)	268 (48)	> .32
Gaze	269 (48)	291 (54)	.068	286 (62)	278 (55)	> .39
Skipping	40 (20)	36 (22)	.47	36 (21)	40 (19)	.26
Target word (2 characters)						
FFD	256 (41)	270 (39)	< .05	254 (41)	258 (41)	> .4
Single	261 (58)	280 (56)	< .05	255 (48)	266 (49)	> .6
Gaze	307 (78)	382 (113)	< .001	323 (69)	323 (87)	> .9
Skipping	16 (16)	10 (14)	< .01	14 (16)	11 (13)	.17
Last	250 (41)	252 (32)	> .6	239 (36)	247 (31)	> .2

Target word

The target word was examined to determine if there was evidence that readers acquire preview benefit from word $n + 1$ or word $n + 2$. When the boundary was at the end of character $n - 1$, we found a standard preview effect in all analyzed measures as readers fixated longer in the dissimilar condition than the identical condition: first fixation duration, $b = 14$, $SE = 6.5$, $p < .05$, single fixation duration, $b = 17$, $SE = 8.4$, $p < .05$, and gaze duration, $b = 75$, $SE = 11.9$, $p < .001$. Moreover, readers were more likely to skip the target word in the identical condition than the dissimilar condition, $b = .67$, $SE = .25$, $p < .01$. However, no preview effect was found when the boundary was at the end of character $n - 2$, all $ps > .1$.

The results for the target word show that when the boundary was at the end of character $n - 1$, there was preview benefit for the target word,⁷ whereas there was no preview benefit when the boundary was at the end of character $n - 2$. Therefore, a preview effect from word $n + 2$ was not found when word $n + 1$ was not an extremely high frequency word. The prior results reported by Yang et al. (2009) wherein they observed a preview effect for word $n + 2$ apparently was due to the presence of a high frequency word in the $n + 1$ location. Furthermore, there was strong evidence for the preview effect for word $n + 1$ independent of whether there was a high frequency word or a low frequency word prior to the target word.

Character $n + 1$

The effect of preview manipulation on the target word did not spill-over to character $n + 1$ since no contrasts were significant on this character, $ps > .2$. The skipping rate averaged .55 across conditions, and the reading time averaged 227, 229, and 232 ms across conditions for first fixation duration, single fixation duration and gaze duration, respectively.

General Discussion

In the experiment reported here, we utilized relatively low frequency $n + 1$ words (about 200 per million) in comparison to the more frequent $n + 1$ words (3,760 per

⁷ Two supplementary analyses were conducted to determine if the duration of the fixation prior to the boundary had an effect on the amount of preview benefit. In the first analysis, the duration of the last fixation prior to the boundary was included as a continuous predictor. It did not show an interaction with preview benefit from word $n + 1$ and word $n + 2$ in first fixation duration or single fixation duration. However, in gaze duration, there was an interaction between the duration of the fixation prior to the boundary and the preview benefit from word $n + 1$: the longer the prior duration, the stronger the preview benefit from word $n + 1$. But preview benefit from word $n + 2$ was not affected. In the second analysis, the fixations prior to the boundary were divided into long and short durations (with 230 ms the cutoff). Again, the analysis revealed a stronger preview benefit for word $n + 1$ when the prior duration was long than when it was short. But, the duration of the fixation prior to the boundary had no effect on preview benefit for word $n + 2$. In sum, these analyses indicated that preview benefit from word $n + 2$ was not affected by the duration of the prior fixation.

million) used in the Yang et al. study (2009), to test the generality of preview benefit from word $n + 2$ during the reading of Chinese sentences. We found that for all analyzed eye movement measures (first fixation duration, single fixation duration, gaze duration, and skipping), there was no evidence for preview benefit from word $n + 2$, although the preview benefit effect from word $n + 1$ was robust in all measures. This result differs from Yang et al. (2009), in that in the prior study we found evidence (via gaze duration) for preview benefit from word $n + 2$. Since the target words used in these two studies were almost the same, the inconsistent results across the two studies must be due to the differences in word frequency of word $n + 1$: the $n + 1$ words used in the current study were of much lower frequency than the $n + 1$ words (which were of extremely high frequency) in Yang et al. (2009).

When the results of the current study and Yang et al. (2009) are taken together, they are consistent with the view that the parafoveal load of word $n + 1$ modulates the preprocessing effectiveness of word $n + 2$, as also suggested by Yan et al. (2010). As we noted in the Introduction, they found that preview benefit from word $n + 2$ was only obtained when word $n + 1$ was high frequency, but not when it was low frequency. Although the preview manipulation and target words were different across these studies, they serve as complements to each other and demonstrate that preview benefit for word $n + 2$ is a conditional effect.

In terms of the two main models that have been proposed to account for the control of eye movements in reading, namely E-Z Reader (Reichle et al., 1998) and SWIFT (Engbert et al., 2005), our view is that the overall pattern of results is more consistent with E-Z Reader than with SWIFT. Presumably in SWIFT, given its provision of parallel lexical processing, preview benefit from word $n + 2$ should be quite pervasive. However, this seems to not be the case when word $n + 1$ is relatively low frequent. On the other hand, E-Z Reader, which has been extended to Chinese (Rayner, Li, et al., 2007), would predict that there could be preview benefit for word $n + 2$ when word $n + 1$ is very high frequency, and hence the probability of identifying that word while still fixated on word n would be rather high. However, when word $n + 1$ is relatively low frequency, the odds that word $n + 1$ would be identified on word n is much lower, leading to no preview benefit for word $n + 2$.

To summarize, with respect to the question that we raised at the outset, the results of the present study indicate that Chinese readers do not routinely obtain preview benefit for word $n + 2$, even though the characteristics of written Chinese would seem to be in favor of observing this effect. More specifically, when considering the three studies that have examined preview benefit for word $n + 2$ in Chinese, the general picture that emerges is that preview benefit for word $n + 2$ seems to emerge when word $n + 1$ is extremely high frequency, but not when it is relatively low frequency.

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