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Word Recognition In The Parafovea: An Eye Movement Investigation Of Chinese Reading

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WORD RECOGNITION IN THE PARAFOVEA: AN EYE MOVEMENT INVESTIGATION OF CHINESE READING

A Dissertation Presented

by

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DEDICATION

To my parents and husband

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ABSTRACT

WORD RECOGNITION IN THE PARAFOVEA:

AN EYE MOVEMENT INVESTIGATION OF CHINESE READING

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Chinese is a logographic writing system that drastically differs from alphabetic scripts in many important aspects. Thus, the nature of parafoveal processing in reading Chinese may be different from that in reading alphabetic languages. Here, four eye-tracking experiments using the boundary display change paradigm (Rayner, 1975) were conducted to explore the role of high level information, like semantic and plausibility information, in the parafovea for Chinese readers.

Experiments 1 and 2 used two-character words that can have the order of their component characters reversed, and still be lexical units as target words. Readers received a parafoveal preview of a target word that was either (1) identical to the target word, (2) a reversed word that was the target word with the order of its characters reversed, or (3) a control word. The results indicated that fixation durations on the target words were comparable in the identical and the reverse preview condition when the reversed preview word was plausible; however, fixation durations were longer in the reverse than the identical preview condition when the reverse preview word was

implausible. This plausibility preview effect was independent of whether the reverse preview word shared the meaning with the target word or not. Moreover, a plausible reverse preview word provided more facilitation to the processing of the target word than a plausible control preview word, since the former one had orthographic overlap with the target word.

Experiment 3 tested whether plausible preview words would yield a semantic preview benefit. That is, the question was whether a semantically related & plausible preview word would provide more benefit than a semantically unrelated & plausible preview word to the processing of the target word. However, such semantic preview effect was only marginally significant by participants. In addition, a plausibility preview effect was revealed in Experiment 3. Furthermore, Experiment 4 found that contextual information could affect word recognition in the parafovea: Chinese readers were more likely to encode a plausible preview word than an implausible preview word. Collectively, these experiments indicated that the plausibility of a preview word has an important role in reading Chinese.

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CHAPTER 1

BACKGROUND

Introduction

It has been confirmed by a large number of studies that the processing of a word starts when it is to the right of fixation, which is usually located in the parafoveal region of the visual field[1] (Rayner, 1998). This is apparent from the fact that fixation times on word n+1 are shorter when it was visible when the eyes are fixating on word n than when it was masked (e.g., McConkie & Rayner,1975; Rayner, 1975, Rayner & Bertera, 1979; also see Rayner 1998, 2009 for reviews). This effect has been referred to as parafoveal preview benefit, and it has typically been assessed via the use of a gaze-contingent boundary paradigm (Rayner, 1975). In experiments of this sort, an invisible, predetermined boundary is placed just to the left of a target word location, which is initially occupied by a preview word. When the reader's eyes cross the boundary location, the preview word is replaced by the target word. Since this display change occurs during a saccade, when vision is suppressed, readers generally do not notice it. With this paradigm, the kind of information conveyed by the preview word can be controlled and varied. For example, to explore whether phonological information can be obtained from the parafovea, there could be two kinds of previews for the target word "beach": a homophone preview "beech", and an orthographic control preview "bench". If reading times on the target word (beach) is shorter with a homophone preview (beech) than with an orthographic control preview (bench), it can be inferred that phonological information of the preview word "beech" has been activated in the parafovea, and then facilitate the lexical access of word "beach" (example from Pollatsek, Lesch, Morris, & Rayner, 1992).

Hence, parafoveal preview benefit is defined as the amount of time that readers look at the target word when given a valid preview subtracted from the amount of time that they look at it when they didn't have a valid preview. Nevertheless, it is also appropriate to talk about 'preview disruption' rather than 'preview benefit' as the invalid preview slows down participants as compared to a valid preview. In the current experiments, in general, I will refer it as a 'preview effect'.

The Availability of Parafoveal Information in Reading Alphabetic Languages

There have generally been convergent findings regarding the nature of parafoveal preview benefit during the reading of alphabetic languages. That is, readers obtain sub-lexical information from the parafovea, such as orthographic or partial word information, word length information and phonological information, and use it to identify the word when it is later fixated.

(1) *Partial word information*. When the previews and targets shared letters, especially the first two or three letters, fixation durations on the target word was shorter than when the previews was entirely different from the target (Lima & Inhoff, 1985; Lima, 1987; Inhoff, 1989a, 1990; Rayner, Well, Pollatsek, & Bertera, 1982; Briihl & Inhoff, 1995).

(2) *Word length/word boundary information*. Readers rely on parafoveal word length information to decide where to move the eyes from the current fixation (McConkie & Rayner, 1975; Pollatsek & Rayner, 1982; Rayner & Bertera, 1979). That is why, although the word length changes from word to word in English, readers usually land halfway between the beginning and the middle of a word, a position known as the

preferred viewing location (Rayner, 1979). If word length information is denied in the parafovea, readers are unable to plan a saccade to the preferred viewing location and tend to undershoot (make a shorter saccade length, see Pollatsek & Rayner, 1982; Morris, Rayner & Pollatsek, 1990; Inhoff, Radach, Eiter & Juhasz, 2003; Juhasz, White, Liversedge, & Rayner, 2008).

(3) *Phonological information.* It has been replicated across many studies that phonological information is a source of parafoveal preview benefit (e.g., Ashby & Rayner, 2004; Ashby, Treiman, Kessler, & Rayner, 2006; Henderson, Dixon, Petersen, Twilley, & Ferreira, 1995; Pollatsek et al., 1992; Miellet & Sparrow, 2004; Chace, Rayner, & Well, 2005). Pollatsek and colleagues (1992) first reported that a homophone provided greater preview benefit than did a visually matched control (e.g., cite was a better preview for site than sake was for cake) in naming task and reading. Moreover, Henderson et al. (1995) found that a phonological code could be derived from the initial part of a 6-letter word in the parafovea. Subsequent studies further pinpointed that the representation of phonological coding in the parafovea involves sublexical syllable (Ashby & Rayner, 2004) and vowel information (Ashby et al., 2006).

However, parafoveal preview benefits do not extend to higher linguistic levels, such as orthographic body, morphological codes, and semantic codes (see below for reference).

(1) *Orthographic body*. In polysyllabic words, the orthographic body was defined as the word's first vowel plus all consonants up to the next vowel, for example, the orthographic body of the word “thunder” is “und”. In two experiments, Briihl and Inhoff (1995) found that an orthographic body preview was less effective than the preview of a

matched number of initial letters for the target word. They also found that there was no significant difference between invalid preview and orthographic body preview conditions.

(2) *Morphological codes.* Lima (1987) found that preview benefit from prefixes was equal for words with true prefixes (e.g., revive) and for words with "pseudo-prefixes" (e.g., rescue). Similarly, Inhoff (1989b) found that preview benefit from the first morpheme was equal for a compound word (e.g., cowxxx as a preview for cowboy) and for a pseudo-compound word (e.g., carxxx for carpet). As an extension of Lima's study, Kambe (2004) sorted prefixed words into two kinds: free-stem (e.g., review, the stem "view" is a word itself) and bound-stem (e.g., reduce, the stem "duce" is not a word). Consistent with the results from previous studies, a prefix provided no more facilitation for either kind of prefix word than a pseudoprefixed word (e.g., region) in the parafovea. Moreover, in Finnish, a language that has very similar linguistic properties to English, morphological preview benefit was not observed (Bertram & Hyona, 2007)[2].

(3) *Semantic information.* Several studies have indicated that semantic preview benefit is not observed during the reading of English (Altarriba, Kambe, Pollatsek, & Rayner, 2001; Balota, Pollatsek, & Rayner, 1985; Rayner, Balota, & Pollatsek, 1986; Rayner & Morris, 1992). For example, Rayner et al., (1986) presented readers with four types of parafoveal previews with respect to a target word (in the example used here, tune): identical (tune), orthographically similar (turc), semantically related (song), or semantically unrelated (door). They found parafoveal preview benefit in the identical and orthographically similar conditions, but there was no difference between the semantically related and unrelated previews. More recently, Altarriba et al. (2001) used fluent Spanish-English bilinguals to study parafoveal semantic processing in reading. Target

words could be English or Spanish words and their previews were translations of the other language. There were 5 kinds of previews: identical (cream as a preview for cream), cognate translations (crema was a preview for cream), non-cognate translations (fuerte, which means strong, was a preview for strong), pseudo-cognates (words that are unrelated except that they are orthographically similar such as grasa as a preview for grass), or unrelated words (grito as a preview for sweet). There was no preview benefit from non-cognate translations, and preview benefit from cognates did not differ from that of pseudo-cognates. These findings again indicate that preview benefit is due to orthographic overlap of previews and targets, but not to semantic relatedness[3].

In addition, preview benefit observed in reading alphabetic languages is apparent from the first word (word n+1) to the right of fixation, but not the second one (word n+2). Rayner, Juhasz, and Brown (2007) first reported this finding. In their experiments, the boundary location was either placed at the end of the word prior to the target word (which was named word n-1 in relation to the location of the target word), or at the end of word n-2. There was either a valid preview or an invalid preview of the target word. The results indicated that the preview benefit (reading times on the target word were shorter in the valid preview condition than the invalid condition) was only significant when the boundary was at the end of word n-1, suggesting that readers did not obtain useful information from the second word in the parafovea (the target word was counted as the second word in the parafovea when the boundary was at the end of word n-2). These findings were further confirmed by Kliegl, Risse, and Laubrock (2007) in reading German, and Angele, Slattery, Yang, Kliegl, and Rayner (2008) and Angele and Rayner (2010) in reading English.

In sum, readers of alphabetic languages are able to extract low level information, including partial word, word length, and phonological information from the parafovea and integrate it with further information acquired when fixating the target word. Specifically, such preprocessing is largely observed from the first word to the right of fixation. However, high level linguistic information, such as orthographic body, morphology, and semantic information, doesn’t yield parafoveal preview benefit, at least during the reading of English.

Parafoveal Processing in Reading Chinese

Compared to alphabetic languages, less is known about the nature of parafoveal processing with respect to Chinese, a logographic writing system that is drastically different from alphabetic scripts in how meaning and speech are represented (see Yang, Wang, Chen, & Rayner, 2009, Wang, Chen, Yang, & Mo, 2008). It is not obvious that the results obtained from English can be applied to Chinese given its particular properties. Before moving to what has been known about preview processing during the reading of Chinese, it is important to have some background information about the characteristics of written Chinese and the basic pattern of eye movements during reading.

Characteristics of Written Chinese

First, unlike alphabetic writing systems, written Chinese is formed by strings of equally spaced box-like symbols called characters. Whereas most European languages adopt the letter to represent elementary units (phonemes in speech), Chinese uses individual characters to represent the basic units of meaning (morphemes); characters also represent a syllable with tonal characteristics. Basically, there are many visual details packed into characters, since they can differ in (1) the number of strokes, and (2) the manner of construction (that is, strokes can be combined in different ways to form a character). According to the manner of construction, Chinese characters can be sorted into two main groups: integrated characters (18%) and compound characters (82%, Xu, Pollatsek, & Potter, 1999). 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). The semantic radical provides a categorical cue to the meaning of the whole character, while the phonetic radical provides a cue to the pronunciation of the whole character. It was suggested that about 40% of the compound characters have a phonetic radical that correctly predicts the sound of the character (Chen, Flores, & Cheung, 1995); however, it is hard to compute the ratio of compound characters that have a valid semantic radical because the meaning of such radicals can be vague and a single character could have multiple meanings that are dramatically different from each other.

Second, given that Chinese words are often composed of more than a single character and the majority of characters can join with others to form multiple-character words with distinctively different meanings (Chen, Song, Lau, Wong, & Tang, 2003), the semantic and syntactic attributes of a character may not be transparent by themselves and can be context-dependent. For example, the character "花" could be a verb or a noun when it is presented individually, which means "spend" or "flower". Furthermore, it can join with the character "生" to form a two-character word "花生 (peanut)", or join with other characters to form a three-character word "花崗岩(granite)", or a four-character word “花言巧语 (blandishments)”. According to the *Lexicon of common words in contemporary Chinese* (2009), which includes 56,008 words, 6% are one-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. However, one-character words are much more frequent than multiple-character words. In a corpus (Text book for information processing in Chinese, 2005) with 1,068,000 characters that are segmented into 704,841 words, about 53 % of these words are one-character words, while 44% of them are two-character words.

Third, there is no explicit marker between words in written Chinese. That is, the width of the space between words is identical to that between characters within a word. Therefore, Chinese readers can sometimes disagree concerning where word boundaries are located. For example, a three-character string “美国人 (American)” could be considered a three-character word, or a two-character word “美国 (America)” and a one-character word “人 (person/ people)”. In addition, there are no inflectional markers, or markers of tense or case, that help to specify the grammatical category of Chinese words, as is the case in English and other European languages (Chen, 1992, 1996; Chen et al., 2003). Hence, words in Chinese may not be as salient (or distinctive) compared to those in alphabetic writing systems (nor as distinctive as Chinese characters).

Eye Movements during Reading Chinese

It is not surprising that the characteristics of eye movements of Chinese readers are somewhat different from those of English readers in a number of ways. First, the perceptual span (or region of effective vision) for Chinese extends one character to the left of fixation to two to three characters to the right when reading from left to right (Chen & Tang, 1998; Inhoff & Liu, 1997, 1998); in contrast, in English the span extends 3-4 letters to the left of fixation to about 14-15 letters to the right of fixation (Rayner, 1998). Second, saccades are much shorter in Chinese (averaging about 2.6 characters) than in English (about 7-8 letters) because the information is more densely packed in Chinese (Chen et al., 2003). Clearly, the size of the right-side perceptual span (two to three characters) is comparable to the average size of forward saccades (2.6 character spaces), indicating that there is only slight overlap in the perceptual span in reading Chinese (Inhoff & Liu, 1998). However, there is considerable overlap (up to 50%) between the right-side area of successive spans in reading English; the perceptual span (about 14-15 letter spaces) to the right of a fixation is about twice the size of the average forward saccade (7-8 letter spaces). This implies that Chinese readers are able to bring in the maximum amount of new information from the right of fixation on each fixation. Third, regression rate appears to be slightly higher in Chinese (about 15%) than in English (about 10%) skilled readers (Chen et al., 2003; Rayner, 1998).

Despite the differences between Chinese and English, there are also a number of similarities in eye movement data (and many of these similarities are related to word properties). First, average fixation durations tend to be very similar (about 225-250 ms) for readers of Chinese and English (Chen et al., 2003; Sun & Feng, 1999). Second, like English readers, Chinese readers fixate for less time on high-frequency words than on low-frequency words (Yan, Tian, Bai, & Rayner, 2006) and on high-predictable words than on low-predictable words (Rayner, Li, Juhasz, & Yan, 2005); character frequency affects fixation time on a word, but only when the overall word frequency is low (Yan et al., 2006). Third, like English readers, Chinese readers skip high-predictable words more than unpredictable words (Rayner et al., 2005). Finally, and most important for the present purposes, experiments using the boundary paradigm have clearly indicated that Chinese readers obtain preview benefit from characters to the right of the fixated character (e.g., Yang Wang, Xu, & Rayner, 2009). I will refer the character/word to the right of fixation as the parafoveal character/word to be consistent with prior research, although it may not technically be in the parafovea.

What Has Been Learned about Preview Processing in Reading Chinese?

Although the nature of parafoveal processing with respect to Chinese is not as widely investigated as alphabetic languages, it has been receiving more and more attention in the last ten years and some important findings have been reported.

(1) *Orthographical and phonological preview benefit*. In a character naming task, Pollatsek, Tan and Rayner (2000) found that target naming latencies were equally shorter in the orthographically similar homophonic and orthographically dissimilar homophonic character preview conditions, as compared with the control preview condition. Moreover, sublexical phonological codes from the phonetic radical of Chinese characters could be activated in the preview processing. In two reading experiments (Liu, Inhoff, Ye, and Wu, 2002; Tsai, Lee, Tzeng, Hung, and Yen , 2004), similar phonological preview benefits were observed, as well as a preview benefit from a character that was orthographically similar and phonologically dissimilar to the target character (orthographic preview benefit). More interestingly, Tsai et al. (2004) examined the effect of the phonetic consistency between a character and its phonetic radical on phonological

preview benefit. As noted above, a compound Chinese character usually includes a phonological radical that denotes phonological information. They found that the phonological preview benefits were reliable only for target words where the pronunciation of their phonetic radical was identical to the pronunciation of the whole character. Taken together, the three experiments consistently indicated that phonological and orthographic codes in the parafovea can contribute to character processing jointly in reading Chinese, and this processing can be at the lexical and sublexical levels. These findings also suggest that phonological and orthographic preview benefits are common across alphabetic languages and Chinese.

(2) *Morphological preview benefit*. Yen, Tsai, Tzeng, and Hung (2008, Experiment 2) examined whether Chinese readers obtain morphological preview information from a component character of a two-character target word. There were three types of two-character string previews with the same first character as the target word: (1) same morpheme preview - its first character shared the meaning with the first character of the target word, (2) different morpheme preview - its first character had a different meaning from the first character of the target word, and (3) pseudoword preview. For example, given a target word “戒烟 (to quit smoking)”, its three types of previews were: “戒除 (to give up a habit)”, “戒备 (to guard against)” and “戒料” in the same morpheme, different morpheme, and pseudoword preview conditions, respectively. The results indicated that target words with the pseudoword preview had the longest duration, with the different morpheme preview being intermediate, and the same morpheme shortest. However, significant differences were only found between the same morpheme and the pseudoword previews, suggesting that the first character of the preview stimuli was processed within

the context of the two-character string. This pattern of results may reveal the complexity underlying parafoveal processing of Chinese characters with multiple meanings. Yen et al (2008) suggested that all morpheme meanings associated with a character could be activated initially, however, only the appropriate meanings would remain activated later on. Thus, there could be facilitation from a different-morpheme preview word at the early stage of preview processing, which would become an inhibition effect later. In sum, the results from Yen et al's study implied that morphological processing is involved in extracting information from parafoveal words in Chinese reading.

(3) *Semantic preview benefit*. Despite the finding that there was little evidence for a semantic parafoveal preview effect during the reading of alphabetic languages, Yan, Richter, Shu and Kliegl (2009) recently reported semantic preview benefit for integrated characters (which they referred as pictographical or indicative characters) during the reading of Chinese sentences. In their experiment, there were five kinds of preview characters for the target characters: (1) identical, (2) orthographically related, (3) phonologically related, (4) semantically related, and (5) unrelated. A reliable benefit was found from orthographically and semantically related previews.

However, with a similar design, Yang, Wang, Tong and Rayner (2010) failed to find this effect as reading times on the target word in the semantic relatedness condition were comparable to those in the semantically unrelated condition. The inconsistent results across Yan et al. (2009)'s and Yang et al.'s studies could be due to stimulus differences. While targets in Yan et al.'s study were integrated characters, targets in Yang et al's study were single-character nouns and most of them were compound characters. As noted by Yan et al., the integrated target characters in their experiment were mapped more closely to meaning than to phonology, and thus maximized chances of observing a semantic preview benefit effect.

Furthermore, using similar target characters to those in Yang, Wang, et al (2010)'s study, Wang, Tong, Yang and Leng (2009) found that when the plausibility of the preview word was manipulated (they called it consistency with the context), reading times on the target words were shorter with a plausible preview word than with an implausible preview word (the semantic relatedness between the preview words and the target word were matched). Hence, Wang et al. suggested that Chinese readers are not only able to obtain semantic information from a preview word, they are also able to integrate such information with the context (although it was not clear why the typical semantic preview benefit was not observed on these characters).

(4) *Preview benefits from word n+2.* Similar to Rayner et al's study (2007), Yang Wang, Xu, and Rayner (2009) examined to what extend Chinese readers obtain preview benefit from characters/words in the parafovea. The results of their Experiment 1 indicated that Chinese readers are able to obtain information from both character n+1 and n+2 to the right of fixation. Furthermore, when two-character words were used in Experiment 2, the results demonstrated that readers obtain robust preview effects for word n+1; there was also evidence suggesting preview benefit from word n+2, which could be due to the fact that the single-character character preceding the target word was extremely high frequency. Yang et al. suggested that when the character frequency of this character is low, preview benefit from a two-character word n+2 may not be observed. This hypothesis was supported by a recent study by Yan, Kliegl, Shu, Pan, and Zhou (in press) which demonstrated that parafoveal load of character n+1 modulated the

preprocessing effectiveness of word n+2 in Chinese reading. On the basis of these two studies, it appears that Chinese readers obtain information from two characters to the right of fixation, independent of whether these characters are words on their own or they form a two-character word. Moreover, they are also able to obtain preview benefit from a two-character word n+2 when word n+1 is a high frequency one-character word (also see Yang, Rayner, Li, & Wang, 2010, manuscript submitted for publication).

In conclusion, although phonological preview benefit is common between alphabetic languages and Chinese, preview processing in reading Chinese is different from alphabetic languages in that preview benefit can extend to high level information, such as morphological and semantic information. Moreover, preview processing can be performed on two parafoveal characters or even on a two-character word n+2 when word n+1 is a high frequency one-character word. This is in contrast to the fact that preview benefit is mostly observed from word n+1 in alphabetic languages.

Outline of Experiments

The current four experiments aim to further investigate the role of semantic and plausibility information in the parafovea for Chinese readers, and whether these two kinds of high-level information interact with each other. Furthermore, the goal was to determine to what extent orthographic properties of a preview word would affect the semantic or plausibility preview effects, if there are such effects.

Experiment 1 and Experiment 2 explored whether there is a difference between the two situations when an orthographically similar preview word is a synonym of the target word or not. This was accomplished with the use of **transposed words** (a concept borrowed from English, see Johnson, 2007). Transposed words can have the order of their component characters reversed, and still be lexical units (words). There are two kinds of transposed words: (1) synonymous-transposed (ST), the meaning of which remains when the order of its component characters are reversed, such as 合适(suitable) and 适合 (suitable); and (2) different-transposed (DT), the meaning of which changes when the order of its component characters are reversed, such as 人情(favor) and 情人 (lover). In short, the meaning of a transposed word could be changed or not, and thus be plausible or implausible in a sentence, after the order of its component characters is reversed.

Experiment 1 used both ST and DT words to explore semantic and plausibility effects with three kinds of previews: (1) identical preview (the preview and the target word were identical), (2) reverse word preview (the preview was the target word with the order of its component characters reversed, like a preview word BA for a target word AB), and (3) control word preview (a two-character word different from the target word in orthography and phonology). The ST words, and their reverse preview words, are plausible in the sentence. For the DT words, their reverse preview words are implausible in the sentence. Different inferences could be made from the pattern of the eye movement data. For example, comparing the difference between the reverse and the identical preview condition across two kinds of target words would allow us to infer whether there is a semantic and/or a plausibility effect. To be specific, if a reverse preview word slows down (compared to the identical preview word) readers more for a DT word than a ST word, it could be due to semantic information as the reverse word of a ST word has the same meaning as the target word, while the reverse word of a DT word has a different meaning from the target word. However, this effect could be due to plausibility information as the reverse word of a ST word is plausible while the reverse word of a DT word is implausible in the sentence. In other words, Experiment 1 could not discriminate whether the different pattern between the ST and DT words is due to semantic or plausibility effects. Experiment 2 was therefore designed to address this question.

Experiment 2 only used the DT words, which were embedded into a different sentence from Experiment 1 so that both the DT words and their reverse preview words fit equally well into the sentences. As a result, although the meaning of a reverse preview word differed from the target word, its plausibility was kept constant. If plausibility information plays a more important role than semantic information, the reverse word would not induce as much disruption (as compared to the identical preview word) in Experiment 2 as that in Experiment 1. But, if what matters is semantic information, the pattern would not differ between these two experiments.

As a preview, Experiment 1 and 2 showed a strong effect of plausibility. It is intuitive to think that the plausibility effect is based on semantic information. However, as mentioned above, Yang, Wang, et al (2010) did not find a semantic preview benefit on characters the majority of which were compound characters, when the semantically related and unrelated preview characters were implausible in the context. Given that the plausibility of a preview word plays an important role in parafoveal processing, would there be a semantic preview benefit when the semantically related and unrelated preview words were plausible in the context? Using single character target words, Experiment 3 was designed to address this question, as well as to replicate the plausible preview effect with non-transposed words.

Furthermore, Experiment 4 tested the possibility that readers process the plausible preview word and go merrily along their way because it fits in the sentence. If this occurs, readers would not actually read the target word even when the eyes land on it. This is because attention can shift without eye movements, the plausible preview word could be identified in the parafovea, and then attention could shift to the next word when the eyes landed on the target word and started the processing of the next word (preview processing). For simplicity, I will refer to the situation in which readers actually read the plausible preview word, instead of the target word, as a misreading effect, although it is different from the typical "misreading effect" which means that readers thought a word like "branch" was "brunch" because they look alike in orthographic similarity (e.g., Ehrlich & Rayner, 1981; Slattery, 2009). The design of Experiment 4 will be discussed in detail in Chapter 5.

Thus, the four current experiments address a variety of research questions surrounding the nature of preview processing during the reading of Chinese sentences. First of all, they explored whether readers obtain semantic and plausibility information from a target word prior to fixating on it. With the use of the boundary display change technique (Rayner, 1975), Experiments 1 and 2 presented readers with different kinds of parafoveal previews that resulted in the meaning being changed or not in relation to a transposed target word. In addition, the preview words could be plausible or implausible in the sentence context. If semantic and/or plausibility information is accessed prior to fixation, these effects would be reflected by eye movement measures, for example, reading times on the target word would be shorter when it has a synonym and/or plausible preview word. Moreover, Experiment 2 further tested whether plausibility or semantic information plays a more important role in the parafovea. Furthermore, Experiment 3 tested whether plausible preview words would yield a semantic preview benefit. And Experiment 4 aimed to test whether a plausible preview word would yield misreading effects.

Experiment 1 and 2 will help to inform our knowledge about how characters are encoded within a given word by comparing the identical and the reverse preview conditions. In the reading of English, it has been demonstrated that the coding of letter position in the parafovea is approximate rather than absolute. Johnson (2009) found that readers' fixation durations on target words were significantly shorter when the parafoveal previews were transposed letter neighbors (e.g., *clam* as the preview of a target word *calm*) than when they were substituted-letter nonwords (e.g., *chem* as the preview of a target word *calm*). The substituted-letter condition and the transposed-letter condition were matched on word shape so that ascending letters were substituted with ascending letters, and descending letters were substituted with descending letters. This result suggested that transposed letter neighbors (when presented in the parafovea) facilitate word recognition. If this finding holds in reading Chinese, facilitation from the reverse preview word will be observed, and this could enhance the semantic/plausibility effect too. Collectively, these four experiments help us better understand how high-level information, as well orthographic information, is processed in the parafovea.

One benefit of using the eye-tracking paradigm is to manipulate the kind of information presented in the parafovea. More importantly, the richness of the eye movement data set allows us to see how information in the parafovea affects the processing of the target word, and at what time windows. For example, the preview effect could occur in the early processing of the target word, which could be reflected by the probability of skipping, first fixation duration, single fixation duration, and gaze duration. The preview effect could also influence a relatively late process, which would be reflected by the probability of regressions back to the target word from a later part of the sentence, second pass reading time, and so on (more details about eye movement measures will be discussed in the Results Section of Experiment 1).

CHAPTER 2

EXPERIMENT 1:

IS THERE A SEMANTIC/PLAUSIBILITY PREVIEW EFFECT FROM A TWO-CHARACTER TRANSPOSED WORD?

Motivation

As outlined above, with the use of ST and DT transposed target words, the goal of Experiment 1 was mainly to explore whether or not a semantic/plausibility preview benefit was evident on a two-character word during the reading of Chinese sentences. This experiment also allowed me to examine the effect of orthographic coding in the parafovea, and how this information would affect the processing of higher level information.

Each target word was paired with three types of previews: (1) identical (the preview and the target word were identical), (2) reverse (the preview was the target word with the order of its two component characters reversed, like a preview word BA for a target word AB), and (3) control (the preview was a two-character word different from the target word in orthography and phonology). Since the meaning of ST words do not change after reversing the order of their component characters, their reverse preview words fit as well as the target words in the context. However, for DT words, given that the meaning changes when the order of their component characters is reversed, their reverse preview words are implausible in the sentence. The control word was matched with the reverse word in relation to their plausibility in the sentence. That is, the control word of a ST target word fit in the sentence while the control word of DT target word did not fit in the sentence.

If semantic/plausibility information was obtained from the preview word, a different pattern of preview effects would be observed between the ST and DT target words. For example, readers might be less slowed down by the reverse preview word in reading the ST words than the DT words, given that the reverse preview word of a ST word shares the meaning with the target word and was plausible in the context, while the reverse preview word of a DT has a different meaning from the target word and was implausible in the context. Similarly, readers might be less slowed down by the ST words' control preview word than the DT words' control preview word because the former was plausible but the latter was not. Furthermore, if reading times on the target words were faster in the reverse preview condition than in the control preview condition, it would suggest an orthographic preview benefit as reverse words keep the same amount of visual properties as the target words except that the order of the two characters changes.

Method

Participants.

Forty-eight undergraduate students from the South China Normal University, who were all naïve concerning the purpose of the experiment, participated in the eye-tracking portion of this experiment. All participants were native speakers of Chinese, had normal or corrected to normal vision, and received either cash or course credit as compensation for their time.

Design & Stimuli.

18 pairs of ST and DT target words were selected for this experiment. For each pair of target words, like AB and BA, two different sentence frames were developed, so that there were 36 sentences for each type of target word, and totally 72 experimental sentences. Each target word was paired with three previews: the target word itself (identical preview), its reverse word, and a control word, which was different from the target word in orthography and phonology. For example, given a pair of ST words, 适合 and 合适, which mean “suitable”, there were two sets of sentences (1a and 1b with the target word and preview words being underlined) and their English translation (the boundaries for meaning units corresponding to English words were marked by *):

1a 我*想到*一个*适合/合适/改良*的*方案*来*处理*这个*问题*。

(I* came up* one* *suitable/ suitable/ improved** of* project* for * solve* this* problem*.)

I came up with a (an) suitable/ suitable/ improved project to solve this problem.

1b 老李的*方案*听上去*很*合适/适合/绝对*但*事实*未必*如此*。

(Mr Li’s* proposal* sounds* very* *suitable/ suitable/ extreme** but* the fact* not necessarily * so*.)

Mr Li’s proposal sounds rather suitable/ suitable/ extreme but it is not necessarily true.

In sentence 1a, the target was word 适合 (AB, suitable), which was a reverse word for the target word 合适 (BA, suitable) in sentence 1b; conversely, the target word in sentence 1b was the reverse word in sentence 1a. Both the target word and its reverse word fit in the sentence as their meaning are the same. In addition, the control word was matched with the reverse word in lexical properties and plausibility. Therefore, the control words, such as 改良 (improved) in sentence 1a and 绝对 (extreme) in sentence 1b, were plausible in the sentence.

Similarly, given a pair of DT words, 画笔 (paintbrush) and 笔画 (strokes of a Chinese character) , the two sets of sentences (2a and 2b with the target word and preview words being underlined) and their English translation were (the boundaries for meaning units corresponding to English words were marked by *):

2a 叔叔*书房*里*挂*的*<u>画笔/笔画/船票</u>*是*一件*珍贵的*文物。

(Uncle* study* inside* hang* of* <u>*paintbrush/ stroke/ boat ticket**</u> is* a* precious* relic*.)

The <u>paintbrush/ stroke/ boat ticket</u> hanging in my uncle's study is a precious relic.

2b 这*几个*字*对*幼儿园*小朋友*来*说*<u>笔画/画笔/配角*</u>太*多*太*复杂*了*。

(These* several* character* for* kindergarten* kids* NA*NA *<u>*stokes/ paintbrush/ supporting role*</u>* too* many* too* complicated* already*.)

These characters have too many <u>stokes/ paintbrush/supporting role</u> and too complicated for kids in the kindergarten.

In sentence 2a, the target was 画笔 (AB, paintbrush), which was a reverse word for the target word 笔画 (BA, strokes of a Chinese character) in sentence 2b; conversely, the target word in sentence 2b was the reverse word in sentence 2a. However, the reverse word has a different meaning from the target word and did not fit into the context. As with the ST words, the control word was matched with the reverse word in lexical properties and plausibility, hence, the control words, such as 船票 (boat ticket) in sentence 2a and 配角 (supporting role) in sentence 2b, were not plausible in the sentences.

In total, there were six conditions corresponding to two types of target words (ST and DT words) and three types of previews (identical, reverse, and control). These factors were manipulated within participants, as all participants saw all items. However, the type of target word was manipulated between items while the type of preview was manipulated within items.

As just mentioned, lexical properties, including word frequency, character frequency, and number of strokes of the component characters were matched as closely as possible between the reverse words and the control words. Moreover, to avoid any orthographic and homophonic benefit from the control words, such similarities between the control words and the target words were controlled. In other words, the control words did not share any radicals (component of Chinese characters) and syllables with the target words. Although it is impossible to match the lexical properties of the reverse preview words with the target words individually, the means of these properties are identical between these two kinds of words. This is because there was the same list of words in these two conditions across all sentences. In short, there were no significant differences with respect to the lexical properties across the three kinds of preview words. Table 1 presents the stimulus characteristics.

By counterbalancing the sentences in the experiment, three material sets were created, each containing 36 experimental sentences with a ST word, 36 experimental sentences with a DT word, and 72 filler sentences. For each type of target word, one-third of them were presented with the identical preview, one-third with the reverse preview, and one-third with control preview. Each version of the experimental sentences appeared once across the three sets.

Furthermore, each material set was divided into two blocks to avoid having readers read a target word AB shortly after they read its reverse word BA in the fovea. As noted above, each pair of ST and DT words were embedded into two sentences as the target word. Therefore, words within each pair of the transposed word were presented in different blocks; thus, sentence 1a and 1b were presented in different blocks. Target words were always in the middle of the sentence, with at least 4 characters from the beginning and 3 characters from the end of the sentence.

Apparatus.

An SR Eyelink 1000 eye-tracking system was used to track eye movements at the rate of 1000HZ. 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. All stimuli were presented in white on a black background on the computer monitor. All characters were printed in Kai-Ti font. The size of each character was $0.95 \times 0.95 cm^2$, with 0.25cm between individual characters. Each character subtended approximately 1 degree of visual angle with the participant's eyes being 64 cm away from the monitor. For each experimental trial, the sentence always appeared in the center of the screen and the crucial word also appeared in the middle of the sentence.

Procedure.

Participants were tested individually and randomly assigned to one of three stimulus sets (which were divided into two blocks). The order of the two blocks was counterbalanced across subjects. 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.

Before reading each sentence, participants 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. The eye movement contingent boundary technique (Rayner, 1975) was used to vary parafoveal preview information (see Figure 1). Upon initiation of the sentence, the ST or DT target words were presented in one of the identical, reversed, and control preview conditions. When the readers' eyes crossed the invisible boundary, which was located at the end of the character preceding the target word, the preview was changed to the target word . 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 immediately followed by a true-false comprehension question to ensure that participants were not merely skimming the sentences. Participants answered the question based on the information from the previous sentence by pressing an appropriate button. The answer to a question of an experimental sentence was identical in the three preview conditions. Each participant read the 36 experimental and 36 filler sentences (which did not have a boundary display change) in a random order in each block; 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.

Normative Data.

Prior to collecting the eye-tracking data, a meaning rating study was conducted on transposed words for selecting DT and ST words. Twelve Chinese undergraduate students were given 82 pairs of transposed words and asked to rate on a 5-point scale (where 1 means "totally different" and 5 means "identical") how similar the meaning of the two words in each pair was. Given that a Chinese word may have several meanings, participants were required to make the judgment on the basis of the meaning they first came up with. Then 18 word pairs, which had a mean rating value equal to or larger than 4 (M = 4.6, SD = .37), were defined as ST words, and another 18 word pairs, which had a mean rating value equal to or less than 2 (M = 1.5, SD = .26), were defined as DT words.

Moreover, a familiarity norming study was conducted for the 18 pairs of DT and ST target words and their preview words. Twenty-two Chinese students participated in this rating study and were asked to rate the familiarity of these words on a 5-point scale (where 1 means "extremely unfamiliar" and 5 means "extremely familiar"). All of these words were highly familiar to readers (overall mean = 4.3) and no significant difference across conditions (Fs < 1).

In addition, all the experimental sentences were normed for predictability and plausibility. Previous research has indicated that highly predictable words are skipped more often or fixated for less time than unpredictable words in reading English (Rayner & Well, 1996; Rayner, Ashby, Pollatsek, & Reichle, 2004) and Chinese (Rayner et al, 2005). Readers also obtain larger preview benefit from high-predictable target words than low-predictable target words (Balota, et al., 1985). Therefore, the predictability of target words and their preview words were controlled in the current experiment. Eight undergraduate students were given the first part of the experimental sentence up to (and including) the character to the left of the target word and asked to provide the next word in the sentence (i.e., predict the target word). Since a Chinese word could consist of one to several characters, what participants provided included one to seven characters. Some of these character strings were actually a phrase. This is because Chinese readers do not always agree where a word boundary is. To be conservative, the data were analyzed in two ways: (1) whether the first two characters and (2) the first character provided by the participants overlapped with the target word or the preview words. Average predictability was very low in the two ways of analysis. The predictability of the DT and ST target words was 6% and 1% respectively, with 0% for their reverse and control preview words. Regarding the first character of the target words or the preview words, predictability averaged 3% in the three conditions for each type of target words, with no significant differences across conditions.

Furthermore, each sentence was normed for plausibility to ensure that the ST and DT target words, and the reverse and control preview words for the ST words fit well within the sentence context. Thirty-three participants read the 72 experimental sentences in one of the three preview conditions offline and rated on a scale of 1 to 5 how well each target word or its preview word fits within its sentence frame (1 = highly implausible; 5 = highly plausible). Sentences were counterbalanced so that every participant saw each sentence frame only once. For the ST target words, the plausibility of the sentences with the target word, reverse preview, and control preview words averaged 3.35 (SD = .34), 3.38 (SD = .43), and 3.35 (SD = .41), respectively, with no significant differences across the three conditions (Fs < 1). For the DT target words, the plausibility of the sentences with the target word, reverse preview, and control preview words averaged 3.60 (SD = .34), 2.69 (SD = .50), and 2.42 (SD = .47), respectively. The main effect of plausibility was significant, $F(2,66) = 76.84$, $p < .001$. Pair-wise t-tests indicated the plausibility of sentences with the DT target word was significantly higher than the other two conditions, *ts* > 9.0, *p*s < .001. Although the average rating value for the sentences with a reverse preview word was higher than those with a control preview word, $t(35) = 2.61$, $p < .05$, their norming values were smaller than 3. This difference is probably due to the natured confound that reverse words are more connected with target words than the control words.

All participants in the four rating studies were undergraduate students from the South China Normal University. They did not participate in the main experiment and they only participated in one of these rating studies. Together, the rating studies ensured that the all target words and their preview words were highly familiar to readers, and they are unpredictable from the pretarget context. More importantly, the plausibility manipulation of the target words and their preview words was effective: while reverse and control preview words of the ST target words were plausible in the sentence context, these two types of preview words of the DT target words were implausible.

Results

All participants scored 75% or better in response to the questions, averaging 91%. Trials in which readers blinked or fixated longer than 600 ms in a single fixation on the target word or two characters on its either side were discarded from analyses. In addition, extremely short (less than 60 ms) fixations were pooled with the fixation adjacent to them (on the same character), and any isolated extremely short fixations, and extremely long fixations (longer than 600 ms) were removed from the data. Moreover, trials in which the display change occurred during a fixation were excluded. No subjects lost more than 30% of the trials and in total, 12.8% of the data were lost, including track losses.

Several standard eye-movement measures reflecting early processing, which have been generally used in eye movement research (Rayner, 1998), were computed to access the influence of orthographic, semantic and/or plausibility information from the preview words on the target region (the two-character target word). These measures include (1) *skipping rate* (the percentage of skipping the region on the first pass reading), (2) *first fixation duration* (the amount of time a reader spends on the initial fixation on the region regardless of the total number of fixations made on it), (3) *single fixation duration* (the time spent on the initial fixation on the region given that the reader made only one fixation on the target word on the first pass reading of the word), and (4) *gaze duration* (the sum of all fixations on the region prior to leaving it)[4,5.]

In addition, two measures that represent later processing which occurs after the reader has left the target word on their first pass reading of the text were computed in order to access whether the preview effects last to later processing. They were: (1) *second pass time* (the time spent on the target region after going past it or during the second reading of the region), and *regressions-in* (the percentage of regressions made back into the target region after leaving it).

For all of these dependent measures, 2 x 3 analyses of variance (ANOVAs) were carried out on the data via both participants (F1) and items (F2), and with word type (ST and DT target words) and preview condition (identical, reverse, and different) as independent variables. Paired-t tests were conducted when they were appropriate to address the questions mentioned above. Participant means as a function of preview on each type of target word were presented in Table 2.

Early Eye Movement Measures

Skipping. The main effect of word type and preview, and the interaction between these two factors, were not significant (all Fs < 2.5, ps $> .1$). However, there was a tendency for the DT target word to be skipped more in the identical preview condition (16%) than in the reverse (13%) and control (8.0%) preview conditions, while for the ST target words, the skipping rate did not differ across three conditions (average 12%).

Fixation times. The main effect of word type wasn't significant in any measure (all Fs < 1, $ps > .3$). This effect won't be discussed further since it is of no direct interest in the current experiment. Importantly, every measure showed a main effect of preview condition: first fixation duration, $F1(2, 94) = 14.41$, $p < .01$, $F2(2,140) = 11.31$, $p < .001$; single fixation duration, $F1(2, 94) = 7.84$, $p < .01$, $F2(2,140) = 10.28$, $p < .001$; and gaze duration, $F1(2, 94) = 16.28$, $p < .001$, $F2(2,140) = 17.05$, $p < .001$. The interaction between word type and preview condition, as well as paired-t tests between different conditions, for each type of target word associated with those measures are discussed below.

For first fixation duration, the word type by preview interaction was significant, $F1(2, 94) = 5.13$, $p < .01$, $F2(2,140) = 4.06$, $p < .05$, and was driven by the fact that participants were less slowed down by the reverse and the control previews in reading the ST target word, as compared with reading the DT target words. This pattern of effects was further revealed by the comparison between (1) identical vs. reverse, for ST words (248 ms vs. 253 ms), *ts* <1, *ps* > .2, for DT words (241 ms vs 250), $t1(47) = 2.33$, $p < .05$, $t2(35) = 2.26$, $p < .05$; .and (2) identical vs. control, for ST words (248 ms vs. 257 ms), the 9 ms difference was not significant by items, $t1(47) = 2.06$, $p < .05$, $t2(35) = 1.25$, $p > .2$, for DT words (241 ms vs 268 ms), the 27 ms difference was highly significant, $t1(47) = 5.45$, $p < .001$, $t2(35) = 5.76$, $p < .001$. This pattern of effects clearly showed that a plausible preview word (the meaning of which could be the same or different from the target word) can facilitate the processing of the target word, as compared to an implausible preview word.

Furthermore, regarding the comparison between the reverse and the control preview word, there was a different pattern between the ST and DT words, as well. The 3 ms difference was not significant for the ST words, *ts* <1, *ps* > .3, while the 18 ms difference was significant for the DT words, $t1(47) = 3.76$, $p < .01$, $t2(35) = 3.33$, $p < .01$. Note that the relative change of orthographic characteristics was the same for the ST and DT words when the order of the characters reversed. So, this pattern of effects could not be purely explained by the orthographic information itself (the reverse preview word shared the same two characters with the target word, but the control word was totally different from the target word in orthographic characteristics). The different pattern of preview effects between the ST and DT words must be due to the fact that the orthographic effect was more pronounced when the preview words were implausible (for the DT words) than when they were plausible (for the ST words) .

A similar pattern was observed in single fixation duration with some effects being weaker, and I will not discuss these effects in detail. The word type by preview interaction was significant by items, $F1(2, 94) = 2.06$, $p = .13$, $F2(2,140) = 3.21$, $p < .05$. For the ST target words, the single fixation averaged 249 ms, 256 ms, and 259 ms in the identical, reverse and different conditions, respectively, with a marginally significant difference between the identical and the control preview conditions via the subject analysis, $t1(47) = 1.93$, $p = .06$, $t2(35) = 1.54$, $p > .1$. Single fixation duration on the DT target words was longer in the control preview condition (270 ms) than the identical condition (246 ms), $t1(47) = 3.09$, $p < .01$, $t2(35) = 4.41$, $p < .001$, and the reverse condition (251 ms), $t1(47) = 3.33$, $p < .01$, $t2(35) = 3.22$, $p < .01$. The difference between the reverse and identical preview condition was significant by items, $t1(47) < 1$, $p > .4$, $t2(35) = 2.03$, $p = .05$.

For gaze duration, however, the interaction between word type and preview was not significant, *F*s < 1.3, *ps* > .2. A similar pattern was shown on the two kinds of target words such that the gaze duration was longer in the control preview than the other two conditions. For ST target words, gaze duration averaged 286 ms, 293 ms, and 317 ms in the identical, reverse and control preview conditions, respectively: identical vs. control, $t1(47) = 4.0$, $p <.001$, $t2(35) = 2.97$, $p < .01$; reverse vs. control, $t1(47) = 2.37$, $p <.05$, $t2(35) = 1.68$, $p = .1$. For the DT target words, gaze duration averaged 280 ms, 298 ms, and 328 ms in these three conditions: identical vs. control, $t1(47) = 5.04$, $p <.001$, $t2(35) = 4.96$, $p < .001$; reverse vs. control, $t1(47) = 3.0$, $p <.01$, $t2(35) = 3.47$, $p < .01$. Although the interaction was not significant, the difference between the identical and the reverse preview condition showed different patterns (as in first fixation duration): the 18 ms difference was significant for the DT words, $t1(47) = 2.11$, $p < .05$, $t2(35) = 2.30$, $p < .05$; and the 7 ms difference was far from significant for the ST words, *ts* < 1.2, *ps* >.2. This effect again was due to the semantic/plausibility information of the reverse word.

Late Eye Movement Measures

For second pass reading time, the main effects of word type and preview were not significant, *F*s < 1.15, *ps* > .3. The interaction between these two factors was significant by participants, $F1(2,94) = 3.66$, $p < .05$, $F2(2,140) < 1$, $p > .4$. For the DT words, paired t tests indicated that readers had longer second pass reading time in the reverse preview condition than in the identical preview condition by participants, 73 ms vs. 49 ms, $t1(47) = 2.63$, $p < .05$, $t2(35) = 1.42$, $p > .1$. Second pass time in the control preview condition was intermediate between the other two conditions (58 ms), but it did not differ from them. For the ST target words, second pass time averaged 67 ms, 60 ms, and 71 ms in the three preview conditions, and the means did not differ from each other, *ts* < 1.1, *ps* > .2. The longer second pass reading time on the DT target word in the reverse preview condition suggested that readers may have difficulties accessing the target word (lexical processing), or integrating it with the context (post-lexical processing). I will return to this finding in the Discussion.

For regressions-in, the main effect of word type and preview, and the interaction between them were not significant, *F*s < 2.6, *ps* > .1. Readers averaged 17% for the ST words and 15% for the DT words across three preview conditions.

Pre-target and post-target region

Previous research on preview effects has been indicated that characteristic of the word to the right of fixation can influence the processing of the currently fixated word for readers of Chinese (e.g., Yang, Wang, Xu, et al., 2009). This is referred to as a parafoveal-on-foveal effect (see Rayner, 2009 for discussion). In order to examine this effect in the current study, early eye movement measures (e.g., first fixation duration, single duration and gaze duration) were analyzed on the pre-target region (the two characters prior to the target word) to see whether the preview manipulation of the target word would affect the processing of the pre-target region. No significant effects were found in this region (the initial skipping probability of which was less than 10%), Fs < 2.3, ps > .1. Across the three preview conditions, first fixation duration averaged 222 ms and 229 ms, the single fixation averaged 221 ms and 228 ms, and gaze duration averaged 253 ms and 260 ms for the ST and DT target words, respectively.

Similarly, these measures were computed on the post-target region (the two characters following the target word) to access the spillover effect from the processing difficulty on the target word. Although gaze duration on the post-target was longer following the DT target words and the ST words by subjects $F1(1,47) = 5.18$, $p < .05$, $F2(1,70) = 1.48$, $p > .2$, it is not of direct interest for this analysis because the post-target regions following the ST and DT words were different (the two types of target words were embedded into two different sentences frames). There were no significant effects related to preview manipulation, Fs < 1.4, ps > .2. Across the three preview conditions, first fixation duration averaged 235 ms and 235 ms, the single fixation averaged 234 ms and 235 ms, and gaze duration averaged 267 ms and 280 ms on the post-target region in sentences with a ST target words and DT target words, respectively.

Word Frequency Effects

Another question that can be addressed by this experiment is whether the relative frequency of the reverse word (in comparison to the target word itself) influences any preview effects. For example, a DT word “科学 (science)” has a higher written word frequency than its reverse word “学科 (subject)”, 508 per million vs. 59 per million. It is possible that preview effects from reverse preview words are stronger when they are of higher frequency than the target word. However, the chance to factorially manipulate word frequency in this experiment was very small. This is because there are less than 100 pairs of transposed words in Chinese, and attempts to control items across conditions would further limit this number. Therefore, in order to assess the role of word frequency in preview effects, separate post-hoc analyses were conducted.

First, for each item across each of the different dependent measures, the difference between the identical preview condition and the reverse preview condition was calculated. If word frequency of the reverse preview word modulates the size of this preview effect, we may see a different pattern of preview effects when the reverse word is the lower frequency member in relation to the target word versus when it is the higher frequency member in relation to the target word. Thus, each reverse word was coded to identify it as either the lower or higher frequency member in relation to the target word. A 2(word type) by 2(frequency) ANOVA was then run across all of the above mentioned dependent measures, to compare the reverse preview effect across the two word frequency conditions and two types of target words. The effects of word frequency and word type were not significant across any of these measures (all *F*s < 1, *ps* $>.4$), nor was their interaction (all *F*s < 2.3, *ps* $> .13$).

The role of word frequency was also explored using regression techniques. For each of the dependent measures, the difference between the identical preview condition and the reverse preview condition was regressed on the frequency difference between the target word and the reverse preview word. The unstandardized beta coefficient never differed significantly from zero (all *ps* $> .22$). Furthermore, for each of the dependent measures, the reverse preview effect was regressed on the frequency of the target word and the frequency of the reverse preview word. Again, the unstandardized beta coefficient again never reached significance (all *ps* $> .44$). These regression analyses also suggest that the reverse preview effect does not differ as a function of either the word frequency of the target word itself or of the word frequency of the reverse preview word.

Discussion

Experiment 1 examined the effect of semantic and plausibility information on preview processing with three kinds of previews: (1) identical, (2) reverse, and (3) control when readers were reading ST and DT words. The results showed a significant main effect of preview manipulation in all early eye movement measures, and an interaction between word type and preview in first fixation duration and single fixation duration. The most important finding in this experiment is that the reverse preview word did not slow down readers for ST target words: readers fixated on the target words for a comparable amount of time in the reverse preview word condition as in the identical preview word condition in all measures (e.g., 286 ms vs. 293 ms in gaze duration). This effect could not be solely due to orthographic information because there was a different effect for the DT words: readers fixated longer on the target words in the reverse preview word condition than in the identical preview word condition in all measures (e.g., 280 ms vs. 298 ms in gaze duration). The different patterns between the ST and DT words clearly indicated that semantic/plausibility information from a preview word exerted an important influence on the processing of the target word. However, it is hard to discriminate whether this preview effect was solely due to semantic or plausibility information because semantic and plausibility information were not manipulated independently: the reverse preview word was either a synonym to the target word and plausible, or had a different meaning from the target word and was implausible.

The comparison between the reverse and the control preview condition also showed a different pattern between the two kinds of target words. For the DT target words, readers fixated for less time in the reverse preview condition than in the control preview condition (e.g., 18 ms shorter in first fixation duration and 30 ms shorter in gaze duration). The nature of this effect was due to orthographic preview processing because the reverse preview word shared the same two component characters with the target word (although the order of these two characters reversed), while the control preview word had no orthographic similarity with the target word. This finding was consistent with previous studies showing a robust orthographic preview benefit (e.g., Tsai et al, 2004). The picture gets a little bit complicated for the ST words as the difference between the reverse and control preview condition was not significant in first fixation duration and single fixation duration, and it was only significant by participants in gaze duration. This is related to the fact that the reverse and the control preview words for the ST words were plausible, so that the plausibility benefit reduces the difference between these two conditions in orthographic information. Again, this was evidence that the plausibility of a preview word plays an important role in the processing of the target word.

It is important to emphasize that having the reverse preview word, readers almost read as fast as when they had the identical preview word for the ST words, in which the reverse word kept the semantic and plausibility and even orthographic information as the target word. An inference could be made that preview processing of a two-character word is not strictly character by character (in a serial way). Instead, the word was processed as a whole and the characters within this word are processed at the same time (in a parallel way). Interestingly, a parallel parafoveal morpheme processing view was suggested in reading English recently (Angele & Rayner, 2010). In this study, the availability of the two morphemes within a bimorphemic compound word was orthogonally manipulated. The results showed that readers were able to extract some morpheme information even from a reverse order preview. Nevertheless, readers obtained a greater preview benefit preview of a compound word when its morphemes were presented in the correct order than in the wrong order in the parafovea (cowboy vs. boycow), which is different from the current experiment where a reverse preview word provided a comparable preview benefit as the identical preview word when it is plausible. The cost for reversing the order of the two morphemes of an English compound word could be because it was no longer a lexical unit in this situation.

Furthermore, two post-hoc analyses failed to show that the relative word frequency of the reverse words in relation to the target words would affect the preview effects. That is, preview effects from the reverse preview word were similar regardless of whether its frequency was higher or lower than the target word. This does not mean that word frequency of the preview word does not matter in the parafovea. However, it may suggest that when there was orthographic and high-level information available from the preview word, the effect of word frequency is not that important.

One more effect that needs attention is the finding that second pass reading time on the DT words was statistically longer via the participant analysis in the reverse preview condition than in the identical preview condition (there were no other significant difference across conditions). At first glance, this effect is weird: if it was because of the implausibility of the preview word, a longer second pass reading time should be observed on the target word in the control preview condition, as well. However, it was not. A possible reason is that readers misperceived the reverse preview word as the DT target word given that the reverse preview words were orthographically similar to the target word. However, readers should encounter conflict when they get to the later part of the sentence as the reverse preview words of the DT target words did not make sense in context (see Slattery, 2009 for more discussion of misperceiving effects). But for the ST words, even if the readers misperceived the reverse word as the target word, they would not notice this as the reverse word also fit into the sentence.

In short, Experiment 1 indicated robust semantic or plausibility effects from a preview word, as well as orthographic effects. As mentioned above, it did not differentiate whether semantic or plausibility information is more important in the parafovea. Hence, Experiment 2 was conducted to address this question.

CHAPTER 3

EXPERIMENT 2:

WAS SEMANTIC OR PLAUSIBILITY INFORMATION RESPONSIBLE FOR THE DIFFERENCE BETWEEN DT WORDS AND ST WORDS IN EXPERIMENT 1?

Motivation

As just mentioned, Experiment 2 was designed to examine whether the different pattern of identical vs. reverse effects was due to semantic or plausibility information in Experiment 1. Only the DT words were used, and there were also three types of previews: (1) identical, (2) reverse, and (3) control. The difference from Experiment 1 was that the reverse preview words were plausible in the sentences, although their meanings were different from the target words. If the effects from the reverse preview word in Experiment 1 were largely due to semantic information, we should see a similar pattern of effects from the reverse word as in Experiment 1. In contrast, if plausibility information plays a more important role than semantic information, the reverse preview word may provide comparable preview benefit to the identical preview word, which would show a similar pattern of effects as the ST words in Experiment 1.

Method

Participants.

Fifty-four undergraduate students from the South China Normal University, who were all naïve concerning the purpose of the experiment, participated in the eye-tracking portion of this experiment either for course credit or cash. They all had normal or corrected to normal vision and were native readers of Chinese.

Design & Stimuli.

Twenty-four pairs of DT transposed words, which were normed in Experiment 1 to determine how similar the meaning of the words in the word pair is were selected for this experiment. Each pair of the DT words had a mean rating value equal to or less than 2 (M = 1.5, SD = .24) on a 5-point scale (where 1 means “totally different” and 5 means “identical”).

Each pair of target words was embedded into a sentence frame such that the two words in the word pair were plausible. Target words were always in the middle of the sentence, with at least 4 characters from the beginning and 3 characters from the end of the sentence. Ideally, two sentence frames should be created for each pair of the DT words, and subjects would read the two words (AB and BA) as target words in different sentences, just as I had done in Experiment 1. However, it was very hard to do this in Experiment 2 given the plausibility manipulation on the word pairs. In order to make each word in a word pair read as a target word, the two words within a word pair were randomly assigned into two groups (A and B). Half of the subjects read sentences embedded with target words in group A, and the other half of the subjects read sentences embedded with target words in group B. Since the target words in group A were reverse previews in group B, and vice versa, each word in a word pair was read as a target word and a preview word across participants. Give a pair of DT words, 画笔 (paintbrush) and 笔画 (strokes of a Chinese character), they were embedded into a sentence frame as below (with the target word being underlined).

3.上*幼儿园*的*小宝*总是*数*错*<u>画笔/笔画*</u>的*数量。

(In* kindergarten* of* kid* always* count* wrong* _paintbrushes/strokes*_ *of * number*)*

The kid, who is at kindergarten age, always makes mistakes in counting the number of *paintbrushes/strokes.*

Subjects assigned to group A read the sentence having 画笔(paintbrush) as the target word and subjects assigned to group B read the sentence having 笔画(strokes) as the target word. For each group, the target word was paired with three kinds of preview words: identical, reverse, and control word. To be specific, the three kinds of preview words were 画笔(paintbrush), 笔画(strokes), and 索引(index) for the target word in group A, and they were 笔画(strokes), 画笔(paintbrush), and 病危(serious illness) for the target word in group B.

As in Experiment 1, the control words were different from the target words in orthography and phonology, and their lexical properties (word frequency, frequency of component character, and number of strokes of the component character) were matched with the reverse preview word. However, as the plausibility of the control words was not of direct interest, in addition to the difficulties in making the control preview word plausible, the control words were developed to be implausible. On average, lexical properties did not differ across the identical, reverse, and control preview conditions for each group of target word. In addition, there were no significant difference between the two groups with respect to these lexical properties, nor interaction between the group and previews (*F*s <1). Hence, I averaged the lexical properties between the two groups for each preview condition. Table 3 presents the stimulus information.

A counterbalanced design was performed for each group of sentences so that each of the 24 sentence frames was read only once by each participant with 8 sentences in each preview condition. Twenty-seven participants were be assigned to group A and read 画笔 **(**paintbrush) as the target word while another 27 participants were assigned to group B and read 笔画(strokes) as the target word. In addition, 60 sentences from an unrelated experiment and 60 filler sentences with no display changes were added into the material set. Totally, each participant read 9 practice sentences followed by the 144 sentences in a random order.

<u>Apparatus and Procedure.</u>

These were identical to Experiment 1.

<u>Normative Data.</u>

As indicated by the familiarity norm in Experiment 1, all of the target words and preview words are highly familiar to readers (overall mean = 4.3), with no significant difference across conditions (Fs < 1).

Similar to that in Experiment 1, all the experimental sentences were normed for predictability. Twenty undergraduate students were given the first part of the experimental sentence up to (and including) the character to the left of the target word and asked to provide the next word in the sentence (i.e., predict the target word). Less than 1% of the time the target words or preview words were predicted by participants, and less than 5% of the time the first character of the target words or preview words was predicted.

More important, each sentence was normed for plausibility to ensure that the reverse preview words fit equally well as the target words in the sentence. Twelve participants were assigned to read the 24 sentences in group A, while another twelve participants were assigned to read the 24 sentences in group B and rate them on a scale of 1 to 5 (1 = not plausible; 5 = very plausible) regarding how well the target word fit within its sentence frame. Sentences were counterbalanced so that every participant saw each sentence frame only once, one third of them with a target word, one third with a reverse word, and one third with a control word. Again there was no group effect and no interactions between group and preview types; hence, I averaged the data for each preview condition between the two groups. The plausibility of the sentences with the target word, reverse preview, and control preview words averaged, 3.62 (SD = .48), 3.69 (SD = .46) and 2.58 (SD = .66), respectively. The main effect of plausibility was significant, $F(2,94) = 67.9$, $p < .001$, and there was no significant difference between the target word and reverse word, *t*s < 1, while both of them were higher than the control word condition, *t*s > 8.0, *p*s < .001.

All participants enrolled in the rating studies were graduate or undergraduate students from South China Normal University. They did not participate in the main experiment and they only participated in one of these rating studies.

Results

All participants scored 75% or better in response to the questions, averaging 93%. The eye-movement data were again trimmed using the same procedures and cutoffs outlined in Experiment 1, leading to the removal of 14.9% of the data.

Just as in Experiment 1, several eye-movement measures were analyzed on the target region to examine the plausibility preview effect, as well as on the pretarget region for parafoveal-on-foveal effects, and on the post target region for spillover effects. For all of these dependent measures, analyses of variance (ANOVAs) were carried out on the data via both participants (F1) and items (F2), with preview condition (identical, reverse, and control) as independent variables[6]. Paired-t tests were conducted comparing the differences between two conditions when it was appropriate. Readers should spend more time fixating the target words in the control preview condition than in the identical preview condition, which is the typical preview effect. Of particular interest, however, is the comparison between the identical and the reverse preview condition. If plausibility plays an important role in preprocessing, we should see the reverse preview word did not slow down readers as much as it in Experiment 1. Participant means as a function of preview on the target region are shown in Table 4.

Early Eye Movement Measures

Skipping. The main effect of preview was not significant, Fs < 1, ps > .4, as the skipping rate did not differ across three conditions (average 10%).

Fixation times. The main effect of preview was highly significant in all reported measures: first fixation duration, $F1(2, 106) = 16.13$, $p < .001$, $F2(2,94) = 10.62$, $p < .001$; single fixation, $F1(2, 106) = 16.38$, $p < .001$, $F2\ (2,94) = 8.59$, $p < .001$; and gaze duration, $F1(2, 106) = 12.29$, $p < .001$, $F2(2,94) = 10.84$, $p < .001$. Paired-t testes showed the same pattern for all of these measures in that fixation times in the identical preview condition were shorter than in the control condition (which reflects the typical preview benefit): first fixation duration (247 ms vs. 277 ms), $t1(53) = 4.81$, $p < .001$, $t2(47) = 4.27$, $p < .001$; single fixation (251 ms vs. 282 ms), $t1(53) = 4.09$, $p < .001$, $t2(47) = 3.19$, $p < .01$; and gaze duration (282 ms vs. 331 ms), $t1(53) = 4.33$, $p < .001$, $t2(47) = 3.93$, $p < .001$. Moreover, fixation times in the reverse preview condition were also shorter than in the control preview condition: first fixation duration (250 ms vs. 277 ms), $t1(53) = 4.37$, $p < .001$, $t2(47) = 3.78$, $p < .001$; single fixation (246 ms vs. 282 ms), $t1(53) = 5.28$, $p < .001$, $t2(47) = 3.72$, $p < .01$; and gaze duration (290 ms vs. 331 ms), $t1(53) = 3.56$, $p < .001$, $t2(47) = 3.53$, $p = .001$.

What is of most interest is that, there were no statistical differences between the identical and reverse preview conditions in any measures, as the difference between these two conditions was only 3 ms in first fixation duration, -5ms in single fixation, and 8 ms in gaze duration, *F*s < 1, *ps* > .3. In other words, target words that were preceded by a reverse preview word, which was plausible in the context, led to comparable reading time to the case when they were preceded by an identical preview word. Remember that in Experiment 1, when the reverse preview words for the DT words were implausible in the context, readers were significantly slowed down in the reverse preview condition as compared to the identical preview condition (e.g., gaze duration on the target word was 18 ms longer in the reverse preview condition than in the identical preview condition). In sum, the insignificant difference between the identical and the reverse preview condition suggested that plausibility information of a preview word has an important effect on the processing of the target word.

Late Eye Movement Measures

The main effect of preview was not significant in either late measure, *F*s <1, *ps* > .8. The second pass reading time averaged 97 ms, 99 ms, and 95 ms, and the percentage of regressions-in averaged 22%, 22 %, and 24 % in the identical, reverse and control word condition, respectively.

Pre-target and post-target region

As in Experiment 1, I examined parafoveal-on-foveal effects by analyzing first fixation duration, single duration, and gaze duration on the pre-target region. No significant effects were found in these measures, *F*s < 1, *p*s > .4. Across the three preview conditions, the skipping rate was about 15%, and the reading times on the pre-target region averaged 235 ms, 239 ms, and 269 ms, in first fixation duration, single fixation and gaze duration, respectively.

Again, no significant effects related to preview manipulation were observed in the post-target region, *F*s < 1. 8, *ps* > .15. Across the three preview conditions, the skipping rate was about 17%, and the reading times on the post-target region averaged 247 ms, 249 ms and 296 ms, in first fixation duration, single fixation and gaze duration, respectively.

Word Frequency Effects

As noted, word frequency could be very different between a target word and its reverse word. Therefore, separate post-hoc analyses were conducted to assess the role of word frequency in preview effects as in Experiment 1. First, each reverse word was coded to identify it as either the lower or higher frequency member in relation to the target word. A paired t test was then run on the above mentioned dependent measures, to compare the reverse preview effect across the two word frequency conditions. The effects of word frequency were not significant across any of these measures (all Fs < 1, $ps >.4$). Furthermore, the role of word frequency of the target words and the reverse words was explored using regression techniques. Again, this analysis suggested the reverse preview effect does not differ as a function of either the relative frequency of the reverse preview word to the target word, or the word frequency of the target word, or of reverse word, since the unstandardized beta coefficient never differed significantly from zero (all $ps > .3$).

Discussion

Experiment 2 tried to differentiate whether semantic information or plausibility information plays a more important role in parafoveal processing with DT transposed words. There were three kinds of preview words: (1) identical, (2) reverse, and (3) control. Unlike the manipulation in Experiment 1 when the reverse preview word was implausible in the sentence, the reverse preview word in Experiment 2 fit as well as the target word. As in Experiment 1, the control preview words were implausible, and this yielded the longest reading time on the target word. The most important finding was that all eye movement measures on the target word did not differ between the identical and the reverse preview condition, which was in contrast to the DT words in Experiment 1. This pattern was the same as that on the ST words.

Experiment 1 and 2 taken together indicated a strong effect of plausibility in the parafovea: when the reverse preview words were plausible in context (ST target words in

E1, and DT target words in E2), first fixation duration, single fixation duration, and gaze duration on the target word did not differ between the identical and reverse preview condition. These effects could not be due to the overlap of orthographic information between the target words and their reverse words because when the reverse preview was implausible in context (DT words in E1), fixation times on the target word were significantly longer in the reverse condition than in the identical condition.

We know that the plausibility effect is based on semantic information: if readers do not know what the word means, it is impossible for them to integrate it with the sentence context and then show a plausibility effect. Nevertheless, readers did not encounter difficulties when the meaning of the preview word was different from the target word if this preview word fit in the context. An inference that could be made is that plausibility information has a stronger effect than semantic information in the parafovea. This is a novel finding with respect to preview processing in reading Chinese.

Unlike in Experiment 1 which indicated that second pass reading time on the DT words was marginally longer in the reverse preview condition than in the identical preview condition, Experiment 2 did not find any preview effects in late eye movement measures, which was the same as that on ST words. As discussed in Experiment 1, readers may misperceive the reverse preview word as the target word. Then they would encounter conflicts after they got to the second part of the sentence when the reverse preview word did not fit in the sentence. But when the reverse word fit in the context, they would not encounter conflicts from misperceiving the reverse word as the target word.

Considering the study by Yang, Wang et al (2010) which failed to find semantic preview benefit for Chinese characters, the majority of which were compound characters, it could be because of the fact that the semantically related and unrelated preview words were implausible in the context. Readers were slowed down by the implausible preview word in these two conditions, and this plausibility effect was so strong that the semantically relatedness effect was masked. Is it possible that the semantic preview effect would be observed when the semantically related and unrelated preview words were both plausible in the context? Experiment 3 examined this possibility with single-character target words.

CHAPTER 4

EXPERIMENT 3:

IS THERE SEMANTIC PREVIEW BENEFIC FROM A PLAUSIBLE WORD?

Motivation

As mentioned in the Introduction, the semantic preview effect was observed on integrated characters (Yan et al, 2009). However, Yang, Wang et al. (2010) used both compound and integrated characters (the majority of which were compound characters, 36 of 54) as target words, and failed to find a hint of semantic preview benefit (not even a numerical trend). It is noted that in these two studies, the semantically related and unrelated preview words did not fit into the context. There is a possibility that it is easier to obtain semantic preview benefit from integrated characters than compound characters, as suggested by Yan et al because integrated characters are mapped closer to meaning than compound characters. This possibility needs to be examined by further studies.

Nevertheless, following Yang, Wang et al (2010), I would like to explore whether semantic preview effects would be observed on general characters (including both compound and integrated characters, with the ratio of them similar to that in all characters in Chinese which is 80% compound characters and 20% integrated characters) when the semantically related and unrelated preview word are plausible in the context. As shown by Experiment 1 and 2, plausibility plays an important role in the parafovea as readers were slowed down by an implausible preview word. Thus, plausibility effects could mask the semantic preview effect when the semantically related and unrelated preview words were implausible. I expected that plausible preview words may help to observe a semantic preview benefit such that readers fixate for less time on the target word when it has a plausible and semantically related preview word than when it has a plausible and semantically unrelated preview word.

A desired design for Experiment 3 is 2 (Plausibility of the preview word: plausible or implausible) X 2 (Semantic relation between the preview word and the target word: related and unrelated). That is, with respect to the semantic relation to the target word and plausibility in the context, there are four kinds of preview words: (1) related & plausible, (2) unrelated & plausible, (3) related & implausible, and (4) unrelated & implausible. In addition, there should be an identical preview condition as in Experiment 1 and 2. However, it is not realistic to have these 4 kinds of target words embedded into one sentence with their lexical properties controlled. Since it has been clearly shown in Yang, Wang, et al. (2010)'s study that there was no preview benefit from a related & implausible word in comparison to an unrelated & implausible, I left out the related & implausible condition and focused on comparing the difference between the related & plausible and unrelated & plausible conditions. Following Yang, Wang, et al. (2010), Experiment 3 used single-character words as target words.

As a result, there were four types of previews with respect to their semantic relation to the target word and context: (1) identical, (2) related & plausible, (3) unrelated & plausible, and (4) unrelated & implausible. First, via this design I can examine whether the *related & plausible* preview provide as much benefit as the target word by comparing the difference between the *related & plausible* condition and the *identical* preview condition. Second, and the main interest of this experiment, I can examine the semantic preview benefit by comparing the difference between the *related & plausible* condition and the *unrelated & plausible* condition. Finally, the design also allowed me to check whether the plausibility effect was repeatable by comparing the *unrelated & plausible* condition with the *unrelated & implausible* condition.

Method

Participants.

Forty-eight undergraduate students from the South China Normal University, who were all naïve concerning the purpose of the experiment and did not participate in the other experiments, participated either for course credit or cash. They all had normal or corrected to normal vision and were native readers of Chinese.

Design & Stimuli.

Sixty experimental sentences were developed; each of them had a single-character target word embedded in the middle, which was at least 4 characters from the beginning and 3 characters from the end of the sentence. As mentioned above, one reason for using single-character target words is to follow up on Yang, Wang, et al. (2010), another reason is to aviod the difficulties of controlling the frequency and stroke number of component characters within two-character words acrosss conditions. In addition to the *identical* preview condition, three kinds of preview words were created: *related & plausible, unrelated & plausible,* and *unrelated & implausible* (as discussed above). An example sentence (with the target word, *related & plausible, unrelated & plausible*, and *unrelated & implausible* preview words being underlined) and its English translation is:

4. 陈健*拎着*一*箱*<u>鞋/袜/桔/潭*</u>来到*我*经营*的*小*店*里*。

(Chen Jian* carry* one* box* *shoes / socks / oranges / ponds* *arrive* I* run* of* small * store* inside)

Chen Jian brought a box of shoes / socks / oranges / ponds to my little store.

Word frequency and number of strokes were matched between target words and the three types of preview words as closely as possible. The frequencies of occurrence for the target, *related & plausible*, *unrelated & plausible*, and *unrelated & implausible* previews averaged 321 (SD = 637), 249(SD = 362), 226 (SD = 318), and 307 (SD = 564) per million, with mean log frequencies of 1.96, 1.97, 1.94, and 1.97, respectively; $F < 1$. The average number of strokes for these conditions was 8.9 (SD = 3.0), 9.2 (SD = 3.3), 8.7 (SD = 3.3) and 8.6 (SD = 2.8); $F(3, 177) = 1.3$, $p > .2$. Table 5 presents the stimulus characteristics for each condition.

A counterbalanced design was employed in which each of the 60 sentence frames was read only once by each participant, with 15 sentences in each preview condition. In addition, 40 filler sentences were added into the materials set. Each participant read 9 practice sentences followed by the 100 sentences in a random order.

Apparatus and Procedure.

These were identical to Experiment 1.

Normative Data.

All of the target words and preview words were highly familiar to readers (overall mean = 4.5), according to the familiarity norm in which sixteen participants were asked to rate the familiarity of the target words and their three kinds of preview words on a 5-

point scale (where 1 means “extremely unfamiliar” and 5 means “extremely familiar”). There were no significant differences across conditions (Fs < 1). Also, a predictability norm was conducted for which ten participants were recruited. Less than 10% of the time, the target words or their previews words were predicted by participants and there were no difference across conditions (Fs <1).

Furthermore, a semantic relatedness study was conducted in which eighteen students who did not participate in the eye-tracking portion of the experiment were asked to rate the semantic relatedness between each of the target words and the *related & plausible*, *unrelated & plausible*, and *unrelated & implausible* preview words on a 5-point scale (where 1 = unrelated; 5 = highly related). The results indicated that there was a significant main effect of semantic relatedness, F (2, 118) = 301.4, $p < .001$. The *related & plausible* preview words were more semantically related to the target words (M = 3.82, SD = .71) than the *unrelated & plausible* preview words (M = 1.63, SD = .41), and the *unrelated & implausible* preview words (M = 1.56, SD = .53), *ts* > 19, $p < .001$. There was no significant difference between the latter two conditions, *p*s > .2.

In addition, a plausibility rating study was conducted to make sure that the plausible preview words fit well into the sentence. Forty participants read the 60 experimental sentences and rated how well the target word or the preview word fit in the sentence on a 5-point scale (where 1 = highly implausible; 5 = highly plausible). The plausibility of the sentences for the target word, *related & plausible*, *unrelated & plausible* and *unrelated & implausible* previews averaged 3.63 (SD = .32), 3.63 (SD = .34), 3.60 (SD = .36), and 2.40 (SD = .67), respectively. The main effect of plausibility was significant, $F(3,177)$ = 124.3, $p < .001$. Pair-wise t-tests indicated the plausibility of sentences with the *unrelated*

& implausible preview word was significantly lower than the other conditions, *ts* > 11.8, *p*s < .001; there were no other significant differences, *ps* > .4.

Results

All participants scored 80% or better in response to the comprehension questions, averaging 88%. The eye-movement data were again trimmed using the same procedures and cutoffs outlined in Experiment 1, leading to the removal of 13% of the data.

Just as in the first two experiments, several eye-movement measures were analyzed on the target region to examine the difference across conditions, as well as on the pretarget region for parafoveal-on-foveal effects, and on the post-target region for spillover effects. For all of these dependent measures, analyses of variance (ANOVAs) were carried out on the data via both participants (F1) and items (F2), with preview condition (*identical*, *related & plausible, unrelated & plausible*, and *unrelated & implausible*) as independent variables. Three paired-t tests were conducted to address the three questions described above: (1) *identical* versus *related & plausible*, to examine whether the *related & plausible* preview provide as much benefit as the target, (2) *related & plausible* versus *unrelated & plausible*, to examine a semantic preview effect, and (3) *unrelated & plausible* versus *unrelated &implausible*, to examine a plausibility preview effect.

Although the targets were single-character words, analyses were conducted on a two-character region basis because there were considerable missing data due to the high skipping rates for individual Chinese characters (about 50% in first pass reading). Therefore, character n-1 and n-2 were combined as the pre-target region, character n and n+1 were combined as the target region, and character n+2 and n+3 were combined as the post-target region. Participant means as a function of preview on the target region are shown in Table 6. For completeness, data on the single-character target word are included; nevertheless, I will not discuss the effects of preview manipulation on this character as they are not quite reliable due to the fact that half of the time this character was skipped.

<u>Early Eye Movement Measures</u>

Skipping. As in the above two experiments, the skipping rate on a two-character region was about 10% overall, and it did not differ across the four conditions, Fs < 1.2, ps > .3.

Fixation times. The main effect of preview was highly significant in all reported measures: first fixation duration, $F1(3, 141) = 5.16$, $p < .01$, $F2(3,177) = 4.90$, $p < .01$; single fixation, $F1(3, 141) = 6.33$, $p < .001$, $F2(3,177) = 5.43$, $p < .01$; and gaze duration, $F1(3, 141) = 8.53$, $p < .001$, $F2(3,177) = 6.55$, $p < .001$. The duration on the target region increased from the *identical, related & plausible, unrelated & plausible,* to *unrelated & implausible* conditions, with the shortest fixation times in the *identical* condition and the longest in the *unrelated & implausible* condition.

The first paired t test revealed that the first fixation duration and gaze duration were longer in the *related & plausible* preview condition than in the *identical* preview conditon. This effect was significant by items and marginally signficant by participants in first fixation duration, $t1(47) = 1.86$, $p = .069$, $t2(59) = 2.03$, $p < .05$, and significant by participants and marginally signficant by items in gaze duration , $t1(47) = 2.31$, $p < .05$, $t2(59) = 2.32$, $p = .072$. Howeve, there was no signficant difference in single fixation duration, ts< 1.5, *ps* > .1. The second paired-t test comparing the *related & plausible* and the *unrelated & plausible* preview condition revealed a weak semantic preview effect in single fixation duration, which was shorter in the *related & plausible* condition (271 ms) than the *unrelated & plausible* (283 ms), $t1(47) = 1.78$, $p = .082$, $t2(59) = 1.38$ $p > .1$[7]. This effect was not significant in the other measures, *ts* < 1.1, *ps* > .2. The third paired- t test comparing the difference between the *unrelated & plausible* and the *unrelated & implausible* preview condition showed a strong plausibility effect in gaze duration, $t1(47) = 2.55$, $p < .05$, $t2(59) = 2.32$, $p < .05$, as gaze duration was shorter in the *unrelated & plausible* (347 ms) condition than in the *unrelated & implausible* condition (366 ms). However, this effect was not evident in first fixation duration, *ts* < 1, *ps* > .7 or single fixation duration, *ts* < 1.5, *ps* > .1.

Supplementary Analysis. To examine why semantic preview benefit was only weakly apparent in single fixation, and not in gaze duration, I computed (as per Reingold, Yang, & Rayner, 2010): (1) the probability of readers making more than one fixation on the target word (*probability of a refixation*), (2) the duration of the first of multiple first-pass fixations *(first of multiple fixation duration)*, and (3) the summed duration of subsequent first-pass fixations (*remainder fixation duration*) on the target region.

The main effect of preview was significant in the probability of refixation, $F1(3, 141) = 4.78$, $p < .01$, $F2(3,177) = 4.10$, $p < .01$, with means of .25, .26, .27, and .33 in the *identical, related & plausible*, *unrelated & plausible*, and *unrelated & implausible* conditions, respectively. It was significantly higher in the *unrelated & implausible* condition than the *unrelated & plausible* conditions, $t1(47) = 2.65$, $p < .05$, $t2(59) = 2.47$, $p < .05$. The main effect of preview was not significant in *first of multiple fixation* *durations,* Fs < 1, *ps* >.5, with means of 254 ms, 257 ms, 263 ms, and 268 ms in the *identical, related & plausible, unrelated & plausible,* and *unrelated & implausible* conditions, respectively. For the *remainder fixation duration*, the preview effect was marginally significant by items, $F1(3, 114) = 1.39$, $p > .2$, $F2(3,126) = 2.30$, $p = .08$. The *remainder fixation duration* was significantly longer in the *related & plausible* condition (276 ms) than the *identical* condition (252 ms), $t1(40) = 2.34$, $p < .05$, $t2(45) = 2.28$, $p < .05$, with 259 ms in both the *unrelated & plausible* condition and the *unrelated & implausible* condition. There were no other significant differences. The fact that the semantic preview effect weakly observed in single fixation duration disappeared in gaze duration is probably because the *related & plausible* preview word yielded longer *remainder fixation durations* when readers made more than one fixation on the target region.

Late Eye Movement Measures

For second pass reading time, the main effect of preview was marginally significant $F1(3, 141) = 2.40$, $p = .07$, $F2\ (3, 177) = 2.55$, $p = .057$. This effect was driven by the longer duration in the *unrelated & plausible* condition (88 ms) than in the *unrelated & implausible* condition (55 ms), $t1(47) = 2.47$, $p < .05$, $t2(59) = 2.89$, $p < .001$. The second pass reading time in the *identical* and the *related & plausible* condition were 64 ms and 67 ms, respectively. There were no other significant differences, $ts < 1.5$, $ps > .1$.

Similarly, the main effect of preview was marginally significant in regressions-in, $F1(3, 141) = 2.65$, $p = .051$, $F2\ (3, 177) = 2.56$, $p = .057$. Regressions-in in the *unrelated & plausible* condition (20%) was significantly higher than in the *unrelated & implausible* condition (14%), $t1(47) = 2.45$, $p < .05$, $t2(59) = 2.71$, $p < .001$. There were no other significant differences as the regressions-in in the *identical* and the *related & plausible* conditions was 16%.

The effects on second pass reading time and regressions-in suggested that the *unrelated & plausible* preview word induced difficulties in the post-lexical processing of the target word. This pattern is different from what was observed in early eye movement measures, which showed that a plausible preview word provided more benefit than an implausible word. It is a puzzle in the current study what made this effect.

Pre-target and post-target region

Again, no significant effects of preview manipulation were found in the pre-target region, Fs < 1.5, ps > .2. Across the four preview conditions, the skipping rate was about 15%, and the reading times averaged 223 ms, 224 ms, and 257 ms, in first fixation duration, single fixation and gaze duration, respectively.

No significant effects related to preview manipulation were observed in the post-target region either, Fs < 1.7, ps > .15. Across the four preview conditions, the skipping rate was about 20%, and the reading times averaged 241 ms, 240 ms, and 273 ms in first fixation duration, single fixation and gaze duration, respectively.

Discussion

Experiment 3 examined the effect of semantic relatedness and plausibility on preview processing with four kinds of previews: (1) *identical*, (2) *related & plausible*, (3) *unrelated & plausible*, and (4) *unrelated & implausible*. It addressed the three questions outlined in the beginning of the chapter. First, the *related & plausible* preview words did not provide as much preview benefit as the identical preview words (there were marginally statistical difffernces between these two conditions in first fixation duration and gaze duration). This effect is not surprising as the *related & plausible* preview words differed from the target word in orthography. Second, the semantic preview benefit was very weak, as the only difference found between the *related & plausible* preview condition and the *unrelated & plausible* condition was in single fixation duration, and this effect was marginally significant only by subjects (p= .082). Finally, a strong plausibility effect was revealed in gaze duration, as it was statistically shorter in the *unrelated & plausible* than in the *unrelated & implausible* preview condition. In sum, consistent with the first two expeirments and also Wang et al. (2009), Experiment 3 showed a strong plausibilty effect. However, different from the hyphothesis that a semantic preview benefit would be observed when the semantically related and unrelated preview words fit into the context, the effect was quite weak. This result was somehow surprising as the plausibility effect is based on the processing of semantic information, but the plausibility effect was more evident than the semantic effect.

The results of Experiment 3 are somewhat different from that of Yang, Wang, et al (2010) regarding the semantic preview effect although the target characters were of similar properties across these two studies. In Yang, Wang, et al's study, in which the semantically related and unrelated preview characters were implausible, there was no hint of semantic preview benefit in any eye movement measures. However, a weak semantic preview effect was observed in single fixation duration in Experiment 3, when the related and unrelated preview words fit into the context. Although one should not make strong inferences from this weak effect, to some extent, it suggested that plausible preview word helps to show a semantic preview effect.

But, the fact that the semantic preview benefit effect disappeared in gaze duration indicates that the amount of preview benefit from a related preview word is attenuated when Chinese readers make more than one fixation on the target region. In other words, when readers were able to process the target word with a single fixation (which happened 72% of the time), a *related & plausible* preview word provided facilitation for the processing of the target word as compared to an *unrelated & plausible* preview word. However, when they had to make more than one fixation before leaving the target word, this facilitation went away as a *related & plausible* preview word yielded longer *remainder fixation durations*. The pattern of data wherein an effect was observed in single (or first) fixation duration but not in gaze duration is not typical, but it is also not without precedent. For example, Pollatsek et al. (1992) observed such a pattern in a study dealing with phonological preview benefit and, more recently, Rayner, Castelhano, and Yang (2010) observed a preview benefit effect in older readers on first fixation that disappeared in gaze duration. In the latter study, it was found that older readers were much more likely to refixate the target word prior to making a saccade to another word and that *first of multiple fixation duration* and *remainder fixation duration* were longer for the older readers than the younger readers across all conditions (including the identical preview condition). Thus, the preview benefit effect was attenuated for older readers in gaze duration. Rayner et al. concluded that on most trials (80%) older readers obtain preview benefit that is comparable to younger readers, but on the remaining trials the preview benefit is attenuated because their processing is slower and they need to refixate the word to fully process it.

Looking back to the plausibility effects in Experiment 3, what is worth mentioning is even though the plausible preview words did not have any overlap in orthographic information with the target word, the plausibility effect was still robust. But there was also cost without the valid orthographic information, as first fixation duration and gaze duration on the target region were marginally significantly longer in the *related & plausible* preview condition than in the identical preview condition (In Experiments 1 and 2, fixation times on the ST or DT target words in the reverse preview condition did not differ from that in the identical preview condition when the reverse words were plausible). Taking the results of the three experiments together, plausibility has a strong effect on parafoveal processing, and such effects could be enhanced by valid orthographic information for the processing of the target word.

CHAPTER 5

EXPERIMENT 4:

DOES A PLAUSIBLE PREVIEW WORD INDUCE MISREADING?

Motivation

There has been a lot of evidence for contextual influence on word recognition. For example, research on semantically ambiguous words indicated that previous context can influence the activation of word meaning (e.g., Ehrlich & Rayner, 1981; Rayner & Duffy, 1986; Duffy, Morris, & Rayner, 1988; Rayner & Frazier, 1989; Binder & Rayner, 1998; Kambe, Rayner, & Duffy, 2001; Sereno, O'Donnell, & Rayner, 2006; Rayner, Cook, Juhasz, & Frazier, 2006). Moreover, contextual effects were also observed on words that are not ambiguous (e.g., Schustack, Erlich, & Rayner, 1987; Duffy, Henderson, & Morris, 1989; Morris & Folk, 1998). For example, Schustack et al. (1987) had participants read sentences with a target noun that was either preceded by a semantically related verb or a neutral verb while their eye movements were recorded. Gaze duration on the target word was shorter when it was preceded by a semantically related verb than a neutral verb. This result suggests that a local context (a lexically related word in the sentence) can influence lexical processing.

As the first three experiments in the current study consistently indicated that lexical processing of the target word was affected by the plausibility of its preview word, Experiment 4 aimed to examine whether the plausibility of the preview word would affect word recognition in the parafovea. That is, it asks whether or not readers are more likely to encode a plausible preview word than an implausible preview word and go with the plausible preview word because it fits in the sentence. In other words, if they encode the meaning of the plausible preview word they might simply not encode the target word (even if they fixated on it) because the meaning they have encoded fits and they just go on their way.

In Experiment 4, there were three types of previews: (1) identical, (2) initially plausible, which was a plausible continuation of the pretarget text; however, the post-target text in the sentence was incompatible with it, and (3) implausible, which was not a plausible continuation of the pre-target text, nor compatible with the post-target text. If the preview benefit effect from a plausible word is robust across experiments, we should observe preview benefit from the initially plausible preview word as compared to the implausible preview word. Moreover, if readers went with the initially-plausible preview word and did not actually read the target word, there would be more regressions back to the target word location (which was occupied by a preview word initially) when readers get to the second part of the sentence (after the target word) because they would encounter conflicts between the post-target context with the initially-plausible preview word. As mentioned in the introduction, I will refer to this effect as a misreading effect because readers went with the meaning of the plausible parafoveal word and didn't correctly encode the target word.

Method

Participants.

Thirty-three undergraduate students from the South China Normal University, who were all naïve concerning the purpose of the experiment, participated in the eye-tracking portion of this experiment either for course credit or cash. They all had normal or corrected to normal vision and were native readers of Chinese.

Design & Stimuli.

Forty two two-character words were selected and embedded into 42 sentence frames as target words. They were always in the middle of the sentence, with at least 4 characters from the beginning and 3 characters from the end of the sentence.

As mentioned above, each target word was paired with an initially plausible and an implausible preview word. Given a target word 讲演(speech), the sentence and its English translation (with the target word and its initially-plausible and implausible preview words being underlined) were:

5. 李*教授*的*讲演/护照/功率*受到*听众的*热烈*欢迎*。

(Li* Professor* of* *speech/passport/output power** passive form* audience's* warmly* welcome*.)

Professor Li's speech/passport/output power was very popular.

The initially-plausible preview word 护照(passport) was a plausible continuation of the pre-target text (from the beginning of the sentence to the character prior to the target word), but it turned out to be implausible in the sentence when readers got to the second part of the sentence. The implausible preview word 功率 (output power) was not compatible with the pre-target text, nor the post-target text. Lexical properties, including word frequency, character frequency of the component characters, and number of strokes of these two kinds of preview words were closely matched with the target word. There were no significant difference regarding these propertied across three conditions, Fs <1.

Table 7 presents the stimulus characteristics. Moreover, to avoid any orthographic and homophonic benefit from the initially-plausible and the implausible preview words, such similarities between these preview words and the target words were controlled.

A counterbalanced design was employed in which each of the 42 sentence frames was read only once by each participant, with 14 sentences in each preview condition. In addition, 36 sentences from an unrelated experiment and 42 filler sentences with no display changes were added into the material set. Totally, each participant read 9 practice sentences followed by the 120 sentences in a random order.

Apparatus and Procedure.

These were identical to Experiment 1.

Normative Data.

All of target words and preview words were highly familiar to readers (overall mean = 4.2), according to the familiarity norm in which participants were asked to rate the familiarity of the target words and their two kinds of preview words on a 5-point scale (where 1 means "extremely unfamiliar" and 5 means "extremely familiar"). There were no significant differences across conditions (Fs < 1). Also, the predictability norm which was identical to that in Experiment 1 indicated that all target words and their preview words were very low predictable: the two-character word or the first character of the word were predicted less than 5% of the time by participants.

More important, each sentence was normed for plausibility in two ways. First, fifteen participants read the 42 completed sentences in one of the three preview conditions offline and rated on a scale of 1 to 5 how well each target word or its preview word fit within its sentence frame (1 = highly implausible; 5 = highly plausible). Sentences were counterbalanced so that every participant saw each sentence frame only once, and a third of the sentences with the target word, a third of them with an initially-plausible preview word, and a third with an implausible preview word. The results showed that there was a significant effect of plausibility, $F(2,82) = 89.91$, $p < .001$. Sentences with the target words were rated more plausible (M = 3.6, SD = .62) than those with *initially-plausible* previews (M = 2.4, SD = 58.), and those with *implausible* previews (M = 2.3, SD = .55.), *t*s > 12.0, *p*s < .001. There was no significant difference between the later two conditions, *p*s > .2.

A second plausibility rating study was conducted on the first part of the sentences[8]. Another 15 participants were presented the first part of the sentences up to (and including) the target word or its preview words and were asked to rate the plausibility of the sentence (assuming that the sentence will end with a second part) on a 5-point scale (where 1 = highly implausible; 5 = highly plausible). The plausibility of the sentences with the target word, *initially plausible,* and *implausible* previews averaged 3.70 (SD = .81), 3.51 (SD = .88), and 2.38 (SD = .64), respectively. The main effect of plausibility was significant, $F(2,82) = 44.73$, $p < .001$. Sentences with the target words and the initial-plausible preview words were rated more plausible than those with *implausible* preview words, *t*s > 6.9, *p*s < .001. There was no significant difference between the target words and the initially-plausible conditions, *ts* < 1.5, *ps* > .15.

All participants enrolled in these rating studies were undergraduate students from the South China Normal University. They did not participate in the main experiment and they only participated in one of these rating studies.

Results

All participants scored 75% or better in response to the questions, averaging 89%. The eye-movement data were again trimmed using the same procedures and cutoffs outlined in Experiment 1, leading to the removal of 13.9% of the data. As in Experiment 1, eye-movement measures reflecting early and late processing were computed on the target word to examine a plausibility preview benefit, as well as on the pretarget region for parafoveal-on-foveal effects, and on the posttarget region for spillover effects.

For all of these dependent measures, analyses of variance (ANOVAs) were carried out on the data via both participants (F1) and items (F2), with preview condition (identical, initially-plausible, and implausible) as independent variables. Paired-t tests were conducted between conditions when they were appropriate. Readers should spend more time fixating the target words in the implausible preview condition than in the identical (reflecting the typical preview benefit) and in the initially-plausible preview condition (reflecting plausibility preview benefit). Moreover, if plausible preview words in the parafovea would bring misreading effects, readers would be more likely to regress back to the target word, and thus make longer second pass reading times in the initially-plausible preview condition than the other conditions. Participant means as a function of preview on the target word are shown in Table 8

Early Eye Movement Measures

Skipping. The average skipping rate was about 5% across three conditions, with no significant effect of preview manipulation, Fs < 1, ps > .4.

Fixation times. The main effect of preview was significant in most of the measures: first fixation duration, $F1(2, 64) = 7.36$, $p < .01$, $F2(2,82) = 4.92$, $p < .05$; single fixation, $F1(2, 64) = 5.12$, $p < .01$, $F2(2,82) = 2.05$, $p > .1$; and gaze duration, $F1(2, 64) = 23.19$, $p < .001$, $F2(2,82) = 13.42$, $p < .001$.

Fixation durations in the initially-plausible condition were longer than in the identical preview condition. However, this effect was only significant in gaze duration (293 ms vs. 328ms), $t1(32) = 4.24$, $p < .001$, $t2(41) = 2.70$, $p = .01$; but not in first fixation duration (251 ms vs. 257ms) and single fixation duration (256 ms vs. 262ms), $ts < 1.2$, $ps > .2$. Similar to the data pattern observed in Experiment 3 wherein gaze duration was significantly longer in the *related & plausible* preview condition than the *identical* preview condition, this result suggested that when a plausible preview word was different from the target word in orthography, it did not provide as much facilitation as the identical preview word to the processing of the target word.

A significant plausibility preview effect was observed as fixation durations were longer in the implausible preview condition than in the initially-plausible preview condition: first fixation duration (271 ms vs. 257ms), $t1(32) = 2.18$, $p < .05$, $t2(41) = 1.98$, $p = .054$; single fixation duration (276 ms vs. 262ms), $t1(32) = 1.69$, $p = .1$, $t2(41) = 1.10$, $p > .2$; and gaze duration (351 ms vs. 328ms), $t1(32) = 2.64$, $p < .05$, $t2(41) = 2.38$, $p < .05$. Furthermore, a typical preview effect was revealed by longer fixation durations in the implausible preview condition than in the identical preview conditions: first fixation duration (271 ms vs. 251ms), $t1(32) = 5.32$, $p < .001$, $t2(41) = 3.39$, $p < .01$, single fixation, (276 ms vs. 256ms), $t1(32) = 4.20$, $p < .001$, $t2(41) = 2.19$, $p < .05$, and gaze duration (351 ms vs. 293ms), $t1(32) = 6.64$, $p < .001$, $t2(41) = 5.31$, $p < .001$.

Late Eye Movement Measures

Second pass reading time and regressions-in were the most important measures to examine misreading effects. The main effect of preview was significant: for second pass reading time, $F1(2, 64) = 5.23$, $p < .01$, $F2(2,82) = 3.85$, $p < .05$, for regressions-in $F1(2, 64) = 3.21$, $p < .05$, $F2(2,82) = 3.94$, $p < .05$. The initially-plausible preview condition had the longest duration (98 ms) and most regressions (24%), with the implausible preview being intermediate (69 ms for second pass reading time and 19% for regressions-in), and the identical shortest second reading time (57 ms) and least regressions-in (15%). Paired t test indicated a significant difference between the initially-plausible and the identical preview conditions for second pass reading time, $t1$($t1(32) = 3.04$, p $p < .01$, $t2(41) = 3.18$, $p < .01$, and regressions-in, $t1(32) = 2.25$, $p < .05$, $t2(41) = 3.43$, $p < .01$. Second pass reading time in the initially-plausible condition was longer than in the implausible condition by participants, $t1(32) = 2.03$, $p = .05$, $t2(41) = 1.26$, $p > .2$. There were no other significant differences, $ts < 1.4$, $ps > .1$.

Pre-target and post-target region

Again, no significant effects of preview manipulation were found in the pre-target region, $F\text{s} < 1.5$, $ps > .2$. Across the four preview conditions, the skipping rate was about 10%, and the reading times averaged 224 ms, 225 ms, and 266 ms, in first fixation duration, single fixation and gaze duration, respectively.

No significant effects related to preview manipulation were observed in the post-target region, either, Fs < 1.7, ps > .15. Across the four preview conditions, the skipping rate was about 18%, and the reading times averaged 238 ms, 240 ms, and 281 ms, in first fixation duration, single fixation and gaze duration, respectively.

Discussion

Experiment 4 examined whether a plausible preview word would yield a misreading effect such that readers encoded the plausible preview word and misread the target word with three kinds of preview words, (1) identical, (2) initially-plausible and (3) implausible. In addition to the typical preview benefit that reading times on the target words were longer in the implausible preview condition than the identical preview condition, a robust effect of plausibility was reflected by significantly longer reading times in the implausible condition than in the initially-plausible condition. These results are consistent with those from Experiment 1 and 2 that an implausible preview word yielded longer fixation times on the target word than a plausible preview word. Moreover, gaze duration in the initially-plausible preview condition was longer than in the identical preview condition, which is due to the fact that an initially-plausible preview word was different from the target word in orthography (similar to the comparison between the *identical* and the *related & plausible* preview condition in the Experiment 3). The pattern of data wherein a preview effect was significant in gaze duration but not in single (or first) fixation duration is not uncommon in the literature on reading Chinese. For example, Yan et al (2009) observed a phonological preview benefit in gaze duration but not in first fixation, and Yang, Wang, Xu et al, (2009) found evidence for preview benefit from a second word in the parafovea in gaze duration but not in first fixation duration. Since gaze duration reflects relatively later processing in comparison to first fixation duration (and single fixation duration), information obtained from the preview word could be further integrated with the information obtained from the target word. Thus, the preview effect could be stronger in gaze duration than in the first fixation duration.

A more important finding in Experiment 4 is reflected by late eye movement measures: (1) readers were more likely to regress back to the target word and made longer second pass reading time on it in the initially-plausible preview condition than in the identical preview conditions; (2) second pass reading time in the initially-plausible preview condition was longer than in the implausible condition in the participant analysis, and (3) there were no statistical differences between the identical and the implausible conditions for these two late measures. Remember that the disruption from an implausible preview did not show an effect in the late eye movement measures in Experiment 1 and 2 (e.g., second pass reading was comparable between the control and the identical conditions for the DT words). Therefore, the difference between the initially-plausible and identical preview condition is probably because readers initially read the initially-plausible preview word and just went with this word occasinally. Then they encountered conflicts when they got to the second part of the sentences and thus regressed back to the target word. In short, these results suggest that word recognition in the parafovea is affected by contextual information: readers were more likely to encode a plausible preview than an implausible word because it fit in the sentence, and they did not actually encode the target word in this case. Nevertheless, it is not clear from the current study how often misreading would happen.

In sum, Experiment 4 revealed robust plausibility preview effects even when the preview word turned out to be implausible in the sentence. In addition, it suggested that contextual information also affect word process in the parafovea in that a plausible preview word is more often to be identified than an implausible preview word. Across the four experiments in the current dissertation, there is convergent evidence that the plausibility of a preview word has a strong effect on the lexical processing of the target word when it is later fixated.

CHAPTER 5

GENERAL DISCUSSION

Summary of Findings

Four eye-tracking experiments were conducted to explore preview processing of semantic information and plausibility information, as well as orthographic information within normal silent reading. In Experiments 1 and 2, transposed words (both ST and DT words in Experiment 1 and only DT words in Experiment 2), were embedded into sentence frames along with three kinds of preview words: (1) identical, (2) reverse, and (3) control. In Experiment 1, the reverse preview words for the ST target words were plausible, while the reverse preview word for the DT target words were implausible. Fixation durations on the ST target words were comparable between the identical and the reverse preview conditions, wherein the reverse preview words led to longer fixation durations on the DT target words than the identical preview words. In Experiment 2, another set of sentence frames was developed, so that the DT target words and their reverse words fit equally well in the sentence. Interestingly, fixation durations on the DT words were comparable in the identical and the reverse preview conditions, showing an identical pattern of preview effects to the ST words in Experiment 1. Together, these results suggest that the plausibility of a preview word has an important influence on the lexical processing of the target word. Furthermore, across two experiments, the control preview words led to longer fixation durations on the target words than the reverse preview words, which was due to the fact that the reverse preview words provided useful orthographic information for the processing of the target words.

Using one-character words as targets, Experiment 3 confirmed that fixation durations on a target word were shorter when it was preceded by a plausible preview word than an implausible preview word. Although the plausible preview words did not share orthographic information with the target words (unlike the reverse preview word for the ST and DT words in Experiments 1 and 2), the plausibility preview effect was robust. However, a semantic preview effect was only weakly observed in single fixation duration via participant analysis. Plausibility information, instead of semantic information, was more evident in preview effects.

Experiment 4 examined whether a plausible preview word would induce more of a misreading effect than an implausible preview word. Readers were more likely to regress back to the target word and made longer second pass reading times in the initial-plausible condition than in the identical preview condition, which suggested that they may misread the initially-plausible preview word as the target word, and encountered integration difficulties when they got to the second part of the sentence. There were significant differences between an identical preview condition and an implausible preview condition, which was a common finding across the four experiments. Moreover, fixation duration on the target words was shorter in the initial-plausible preview condition than in the implausible preview condition, again, showing a plausibility preview effect.

<u>The Nature of Plausibility Preview Effects</u>

Across four experiments, the current study found a robust preview benefit from a plausible preview word compared to an implausible preview word. Regardless of whether the plausible preview word was similar to the target word in orthography and semantic meaning or not, the plausibility preview effect was evident (at least in gaze duration). Moreover, a plausible preview word is more likely to induce a misreading effect than an implausible preview word. These results imply that contextual effects on word recognition occur at a very early stage, even before the word is fixated.

With respect to the contextual effects on word recognition in the parafovea, it has been shown that readers obtained larger preview benefits from high-predictable target words than low-predictable target words (Balota et al., 1985). In one of Balota et al.'s experimental sentences "Since the wedding was today, the baker rushed the wedding cake / pies to the reception", *cake* was the high-predictable target word and *pies* was the low-predictable target word. Each target word had four kinds of previews: visually similar, semantically related, visually dissimilar, and anomalous, which were *cahc*, *pies*, *picz*, and *bomb*, respectively, for the target word *cake*, and *picz*, *cake*, *cahc*, and *bomb*, respectively for the target word *pies*. The results showed robust preview benefits from the visually similar previews, which were larger for high-predictable target words than low-predictable target words. However, the semantically related preview word did not provide facilitation to the processing of the target word as compared to the anomalous preview word for either the high or low predictable words, suggesting semantic information from parafoveal words has no effect on identifying the target word (see also Drieghe, Rayner, & Pollatsek, 2005; Rayner et al., 1986).

It is important to note that the design of Balota et al. (1985)'s study is different from the current study. There were two kinds of target words in Balota et al (1985)'s study, and the orthographic preview benefit was larger for high predictable words than low predictable words. However, in the current study, the plausible and implausible words were previews for the same target word, and they yielded different pattern of eye movements on the target words. Moreover, all the target words (and their preview words) were low-predictable (less than 5% of the time they were predicted). The nature of the plausibility effects found in the current study could be different from that of a predictability effect.

Usually, when there is a preview benefit from a certain type of information (e.g., orthographic, phonological or semantic information), it is suggested that such information was obtained from the preview word and then integrated with the target word and thus showed facilitation on the processing of the target word as compared to an unrelated preview word (e.g., Rayner et al., 1982; Briihl & Inhoff, 1995 for orthographic preview benefit; Pollatsek et al., 1992 for phonological preview benefit). However, it is not straightforward that such an explanation applies to the preview benefit yielded by plausible preview words, because the words are likely to be skipped if they were identified in the parafovea. About a third of English words, half of one-character and 10% of two-character words in Chinese are skipped during reading (see Yang, Wang, Xu et al., 2009, Yen et al., 2008, and Rayner 2009 for a review).

On the other hand, the plausibility effect may reflect the likelihood co-occurrence of two words (the pre-target word and the preview word). A plausible preview word must more often co-occur with the pre-target word than an implausible preview word. Therefore, if the preview word was a possible continuation of the pre-context, reading processing would go smoothly; however, if the preview word was not a possible continuation of the pre-context, readers would encounter some strange information in the parafovea.

Indeed, there is evidence suggesting that Chinese readers are able to determine the continuation of the character(s) in the parafovea. For example, Li, Rayner, and Cave (2009) found that Chinese readers were more accurate in reporting a 4-character string when it was a word than when it consisted of two two-character words. Li et al. (2009) also found contextual influences on character recognition: the accuracy in reporting two related words [e.g, 美满(happy) 婚姻 (marriage)] was significantly higher than two unrelated words [e.g.,急速(rapid)切实(practical)]. Apparently, the manipulation of context in Li et al's study was on a local coherence between two words, which was similar to the relation between a pretarget word and a preview word in the current study. Therefore, the plausibility effect was actually due to the fact that the preview word was locally incoherent in the implausible preview condition, and coherent in the plausible preview condition. This effect could be similar to a frequency effect, such as the co-occurrence of the pre-target word and the implausible preview word was relatively low (even zero, perhaps), while the co-occurrence of the pre-target and the plausible preview was potentially higher than zero. Nevertheless, further experiments are needed to test the feasibility of this explanation for the plausibility preview effect.

The Generality of Semantic Preview Effects

So far, there are three experiments examining the semantic preview effect in reading Chinese sentences (Yan et al., 2009, Yang, Wang, et al., 2010, and the current Experiment 3). The only strong evidence for a semantic preview benefit was observed on integrated characters (Yan et al., 2009), where the semantically related and unrelated preview words were not plausible. Using a similar design, however, Yang, Wang, et al.,

(2010) failed to find such an effect when the majority of the targets were compound characters. Unlike these two studies where the preview words were implausible in the sentence, Experiment 3 made the semantic related and unrelated preview characters plausible, and found a hint of semantic preview effect in single fixation duration. Note that the target characters used in Experiment 3 were similar to those in Yang, Wang et al.'s study.

The inconsistent results across these three studies seem to be due to stimulus differences and plausibility manipulation of the preview words. While the targets in Yan et al., (2009)'s study were integrated characters, most of the targets in Yang, Wang, et al., (2010) and the current Experiment 3 were compound characters. As suggested by Yan et al., the integrated target characters in their experiment are mapped more closely to meaning than to phonology, and thus maximized chances of observing a semantic preview benefit effect. Moreover, target characters were much more frequent, and less complicated in Yan et al.'s study than the other two experiments.

Furthermore, the plausibility of the preview characters could also affect the existence of a semantic preview benefit, when the majority of target characters were compound characters. A semantic preview effect was weakly observed when the semantically related and unrelated preview characters were plausible. However, such an effect was only evident in single fixation duration but not other early eye movement measures. The inconsistency across eye movement measures may reflect that the processing underlying those measures is of a different nature. Although it has been widely accepted that gaze duration reflects later processing than first fixation duration and single fixation duration (Rayner, 1998, 2009 for a review), it is not obvious why readers sometimes identify a word with a single fixation but sometimes, they need to make two or more fixations. Moreover, it is very obscure how parafoveal information is integrated with foveal information: does the integration start as soon as foveal processing starts, or does it wait until a certain amount of information has been obtained from the fovea? The answer to this question may help us to understand the results of Experiment 3 that semantic preview benefit only weakly appeared in single fixation duration.

Hence, semantic preview benefit doesn't seem to be a general effect in reading Chinese. Further studies are needed to confirm to what extent this effect depends on the layout of a character (integrated or compound), visual complexity, frequency, the plausibility of the related and unrelated preview words, and the number of fixations readers made on the target words/characters.

The Implication of Orthographic Preview Effects

Orthographic preview benefits were also found in the current study. When the preview words shared two characters with the target words, they yielded shorter fixation duration than the preview words that did not share any orthographic information with the target words. There is also evidence for orthographic preview benefits in the literature: Liu et al. (2002) and Tsai et al. (2004) found that fixation duration on the target character was shorter when it was preceded by a visually similar preview character than a visually dissimilar preview character. Note that the manipulation of orthographic similarity in the previous studies and the current study was different. While orthographic characteristics were manipulated on a single character, and the preview benefit was observed from a visually similar preview character in the previous studies, in the current study the preview benefit was from the same two characters of the target word, although the order of these two characters was reversed. The orthographic preview benefit observed in the current study has an interesting implication of how characters within a word in the parafovea are processed. That is, Chinese readers are able to detect whether two characters in the parafovea form a word and are able to process this word as a whole.

This implication was supported by a recent study by Yang, Staub, Li, and Rayner (2010), which revealed that while the eyes are fixating on a given character, Chinese readers are able to assess whether the present character and the next character form a lexical unit. In their study, 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 two-character 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 at the point at which it appeared, whereas the two-character word was always plausible. First-pass reading times were significantly inflated on a region including the implausible one-character word and the preceding character. However, the plausibility manipulation on the initial character of a two-character target word did not yield significant effects on reading of this word or its component characters, on any eye movement measure. These results further suggested that word segmentation must take place very early in the course of processing in reading Chinese, and processes of semantic integration are performed on a word-by-word basis, instead of a character-by-character basis.

Parafoveal Processing and Models of Eye Movement Control during Reading

With accumulating evidence on the relation between word recognition and eye movements, several computational models of eye movement control in reading have been developed (see Reichle, Rayner, & Pollatsek, 2003 for description and evaluation of these models). According to how many words in the perceptual span could be processed at a time, these models could be sorted into two groups: serial attention shift (SAS) models and guidance by attentional gradient (GAG) models. Based on their respective assumptions, different predictions could be made concerning parafoveal processing. I will summarize the critical assumption of these models, as well as their prediction related to parafoveal processing.

SAS Models.

SAS models like the E-Z Reader model (Pollatsek, Reichle, & Rayner, 2006; Rayner, Reichle, & Pollatsek, 1998, 2005; Reichle et al., 2003; Reichle, Pollatsek, Fisher, & Rayner, 1998) assume that: (1) lexical processing in reading is guided by a spatial attentional system that processes one word at a time and, therefore, the next word is processed only after the lexical processing of the currently fixated word n is completed; and 2) saccadic programming is decoupled from the shifts of attention. That is, the program for a saccade to the next word is initiated by the completion of the first stage of lexical processing (L1, which corresponds to being at the identification of the orthographic form of the word) on the current fixated word; and the attention shift to the next word is initiated by the completion of the second stage of lexical processing (L2, which involves the identification of a word's phonological and/or semantic forms so as to enable additional linguistic processing). Since attention shifts immediately but it takes

125 ~ 150ms for saccade programming and 25ms for actual saccadic eye movement, attention can shift to the next word n+1 and start L1 on it when the eyes fixate on word n (performing a preview processing of word n+1). As attention is allocated to one word at a time, readers generally only obtain preview benefit from one word in the parafovea, and the processing of two words would not interact with each other. Moreover, lexical processing of a parafovea word usually does not go deep enough to identify this word given such processing is restricted to a certain amount of time. As a consequence, preview benefit does not extend to high level information, such as semantic information (Reichle, Liversedge, Pollatsek, & Rayner, 2009, for a review on reading alphabetic languages). In sum, in the SAS models, preview benefit is mostly obtained from one word in the parafovea, and preview processing does not extend to high level information.

GAG Models.

On the other hand, in GAG models such as SWIFT (Engbert, Nuthmann, Richter, & Kliegl, 2005; Engbert, Longtin, & Kliegl, 2002; Kliegl & Engbert, 2003), lexical processing is distributed over a number of words in the perceptual span (ranging from one word to the left and two words to the right of a fixation) via a gradient of attention. Saccadic programming is initiated by a random timer, but difficulty with lexical processing can intervene to delay saccades that might otherwise move the eyes forward. Hence, two words in the parafovea (which fall into the perceptual span) could be processed during a fixation in GAG models. Moreover, although processing efficiency decreases as a function of the distance from the fovea, high level information such as semantic information can also be obtained from parafoveal words. However, similar to the SAS models, GAG models did not implement the influence of contextual information on word recognition.

Extension of SAS and GAG Models to Chinese Reading.

The two main models, namely E-Z Reader (Reichle et al., 1998) and SWIFT (Engbert et al., 2005) were proposed to account for the control of eye movements in reading alphabetic languages originally. However, Rayner, Li, and Pollatsek (2007) have extended the E-Z Reader model to Chinese reading, and maintained processing assumptions originally suggested for English reading that attention shifts and saccade targeting are on the word basis. One the other hand, although there is no modified version of GAG models for Chinese reading, the finding of semantic preview benefit (Yan et al., 2009), which was consistent with the prediction from GAG models, has been taken as evidence that the mechanism underlying reading Chinese is more consistent with a parallel rather than a serial attention shift model (Yan et al., 2009, Yan et al., in press). Nevertheless, as discussed above, it is an open question whether semantic preview benefit is a common effect in reading Chinese. Furthermore, the debate between the SAS and GAG models also involves the issue of whether Chinese readers obtain preview benefit from two words in the parafovea. But it is not straightforward which kind of models make a better account of the data (see Yang, Wang, Xu, et al., 2009, Yan et al., 2010; Yang, Rayner, et al, 2010).

In terms of the plausibility preview effects observed in the current study, neither the SAS nor the GAG models take such effects into account: they did not implement assumptions that allow the reading system to react differently to a plausible preview word compared to an implausible preview word (including the misreading effects from a plausible preview word). These models can likely be improved upon to take into account both bottom-up information (from the actual physical stimulus) and top-down information (form constraints imposed from the pre-context of the target word, or from the local coherence between the pre-target and the preview word) in the parafoveal processing.

Furthermore, the word-based processing assumptions for the reading of alphabetic languages may not apply to the reading of Chinese. As emphasized in the introduction, there are no explicit marks between words, and Chinese readers have to rely on contextual information to segment words on-line. The question that how Chinese readers segment strings of characters into words is still mysterious. Moreover, information is more densely packed in Chinese than English; thus, Chinese readers could be more effective in using parafoveal information and conduct substantially deeper processing of a parafoveal character than is the case with a parafoveal word in alphabetic languages (see Yang, Staub, et al 2010). For these particular characteristics of written Chinese, the plausibility preview benefit could be a language-specific phenomenon in reading Chinese, which doesn't generalize to the reading of alphabetic languages. In fact, there is no reported evidence for such an effect in the reading of alphabetic languages so far.

Therefore, in trying to extend those models to explain eye movement data during Chinese reading, the distinctive characteristics of written Chinese (in comparison to English) must be kept in mind. Actually, an attempt has been made to address how Chinese readers segment character stings into words by Li et al (2009), who proposed an interactive model to account for this processing. They suggested that the top-down information from a word would help to identify the component characters within this word. This study also showed local coherence between two words helps to identify these words. Although this model was created on the basis of word recognition data, instead of reading data, it may be enlightening for the models of eye movement control to implement the mechanism of word segmentation for reading Chinese.

Parafoveal-on-foveal Effects in Reading Chinese.

What is worth mentioning is, another critical difference between SAS and GAG models relates to parafoveal-on-foveal effects. As mentioned in Experiment 1, these effects refer to the possibility that characteristics of the word to the right of fixation can exert an influence on the processing of the currently fixated word. Therefore, when the eyes were fixating on the pre-target word, these effects refer to influence from the characteristics of the preview word may have on the processing of the pre-target word. In GAG parallel models, the expectation is that properties of the word to the right of fixation (the preview word) can influence the duration of the fixation on the pre-target word. In SAS models, on the other hand, since lexical processing is serial, there should be no evidence of parafoveal-on-foveal effects of a lexical origin.

Across four experiments, the current study failed to find parafoveal-on-foveal effects on the pre-target word, which seems to be consistent with the E-Z Reader model. However, a parafoveal-on-foveal effect has been reported in the literature. For example, Yen, Radach, Tzeng, Hung, and Tsai (2009) found that gaze duration on the pre-target word was longer when the preview word was masked than when it was visible at the first 140 ms during a fixation on the pre-target word (This study also found that there was more disruption on the processing of the target word when it was masked as compared to when it was visible at the beginning of the 140 ms during the fixation on the pretarget word). Moreover, Yang, Wang, Xu et al (2009) also reported parafoveal-on-foveal effects on the character prior to the target character.

The inconsistent finding across experiments regarding the parafoveal-on-foveal effects is puzzling. Actually, in English, there is controversy concerning the validity of lexical parafoveal-on-foveal effects (see Rayner & Juhasz, 2004; Rayner, White, Kambe, Miller, & Liversedge, 2003; Starr & Rayner, 2001). For example, Hyönä and Bertram (2004) found that long compound words in the parafovea yielded shorter gaze durations on the fixated word in one experiment, while long parafoveal words yielded longer gaze durations on the fixated word in a follow-up experiment in an alphabetic language. A similar phenomenon was also observed by Cui, Wang, Yan and Bai (2010), who recently found that first fixation duration and gaze duration on the fixated character with high-frequent parafoveal characters were longer than those with low-frequent characters in one experiment while the direction of these effects reversed in another experiment.

Conclusion

Previous studies on parafoveal preview processing have confirmed word recognition begins before readers fixate the target word during reading. The current study furthers this line of research by showing that the processing of the target word was easier when it was preceded by a plausible preview than an implausible preview word. Moreover, a plausible preview word is more likely to induce misreading effects than an implausible preview word. This plausibility effect could be explained in two ways: (1)

readers are able identify the preview words and integrate it with the context, and (2) this plausibility effect is actually due to the likelihood co-occurrence (or local coherence) of the pre-target word and the preview word. The current research also indicated that plausible preview words were helpful in finding a semantic preview benefit, although it is still an open question whether the semantic preview effect is a common effect in reading Chinese. Furthermore, a special orthographic preview was observed as the reverse preview word enhanced the size of preview benefit, implying that parafoveal words could be processed as a whole.

Finally, it is worth mentioning, for the distinctive characteristic of written Chinese (in comparison to English), the semantic and plausibility preview benefit observed in the current study could be a language-specific phenomenon that doesn't generalize to the reading of alphabetic languages, like English.

Notes

[1] With respect to the fixation point, the region within the central 2 degrees of vision is defined as the fovea. The region extends from 2 degree to 5 degrees on either side of fixation is the parafovea. Acuity is very good in the fovea and it is not so good in the parafovea.

[2]In contrast, Deutsch and her colleagues (Deutsch & Frost, 2005, Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003) have observed that word processing in Hebrew significantly benefits from having a parafoveal preview of the words' morphological root. This contrast may reflect the language-specific characteristics of Hebrew; since Hebrew morphology is significantly richer (than English morphology), and thus can be more easily detected in the parafovea.

[3]Nevertheless, using a combination of the fast priming and the boundary display change paradigm, Hohenstein, Laubrock, and Kliegl (in press) recently observed a semantic preview benefit with a parafoveal prime duration of 125 ms. Interestingly, the semantic preview effect disappeared with longer prime duration. Therefore, the authors suggested that semantic preview benefits are time dependent, and the facilitation of a semantic preview word was only shown in the early stage of the processing of the parafoveal word.

[4]When regions larger than a single word are examined; the measure is usually referred to as first pass reading time (see Rayner, 1998, 2009). While the regions analyzed in the present experiments are technically larger than a single word, for simplicity I will use the term gaze duration to refer to the sum of all fixations in the region before moving to another region.

[5]I also computed the go-past time, which includes the amount of time that the reader looked at the target region and any time spent rereading earlier parts of the sentence before moving ahead to inspect new parts of the sentence. It showed a similar pattern to gaze duration.

[6]As it is noted that there are two sets of experimental sentences and half of the subjects read the first set and the other half of subjects read the other set of sentences, I included "group" as a between subject design factor into the analysis, and thus conducted a 2 (group)* 3(preview) ANOVA via both participants and items. The main effect of group and the interaction between group and preview were not significant (Fs <1). In addition, the group effect is of no direct interest in the experiment; therefore, I only report the analysis on the preview factor.

[7]This effect was significant in the analysis using a liner mixed-effects model (LMM) specifying subjects and items as crossed random effects. Additionally, I analyzed data using LMM and found a similar pattern of results to the ANOVAs in all of the experiments.

[8]The same plausibility rating had been also done for the first three experiments, and the results showed the same pattern as the plausibility norming on the whole sentence.

Table 1.

Lexical Properties of Preview Conditions for Experiment 1.

	Identical & Reverse preview	Control preview
	ST word	
Word frequency	21 (34)	17 (26)
Log word frequency	.81 (.75)	.71 (.78)
Character frequency		
1st character	786 (1390)	885 (1804)
2nd character	786 (1390)	852 (1567)
Log character frequency		
1st character	2.42 (.71)	2.44 (.68)
2nd character	2.42 (.71)	2.47 (.64)
Number of strokes		
1st character	9.1 (3.7)	9.1 (3.4)
2nd character	9.1 (3.7)	8.5 (2.6)
	DT word	
Word frequency	64 (155)	60 (158))
Log word frequency	.92 (.86)	.88 (.85)
Character frequency		
1st character	1290 (1745)	1242 (1674)
2nd character	1290 (1745)	1224 (1536)
Log character frequency		
1st character	2.68 (.72)	2.67 (.72)
2nd character	2.68 (.72)	2.65 (.74)
Number of strokes		
1st character	7.5 (3.0)	7.8 (2.9)
2nd character	7.5 (3.0)	7.2 (2.5)

Notes: Numbers in parentheses are standard deviations. Frequency is measured as character/word per million from a Chinese Dictionary (Corpus from China Daily, 1998).

Table 2.

Participant Means (and Standard Deviation) as a Function of Word Type and Preview on the Target Word for Experiment 1.

Preview	Identical	Reverse	Control
		ST word	
Early Measures			
Skipping rate (%)	12 (15)	12 (16)	11 (14)
First fixation duration (ms)	248 (39)	253 (42)	257 (44)
Single fixation (ms)	249 (44)	256 (45)	259 (47)
Gaze duration (ms)	286 (54)	293 (62)	317 (67)
Late Measure			
Second pass time (ms)	67 (60)	60 (57)	71 (56)
Regressions-in (%)	16 (13)	17 (15)	18 (15)
		DT word	
Early Measures			
Skipping rate (%)	16 (18)	13 (13)	11 (14)
First fixation duration (ms)	241 (41)	250 (44)	268 (48)
Single fixation (ms)	246 (50)	251 (48)	270 (52)
Gaze duration (ms)	280 (69)	298 (70)	328 (75)
Late Measure			
Second pass time (ms)	49 (59)	73 (73)	58 (62)
Regressions-in (%)	14 (17)	17 (13)	13 (12)

Table 3.

Lexical Properties of Preview Conditions for Experiment 2.

	Identical & Reverse preview	Control preview
Word frequency	64 (144)	61 (148)
Log word frequency	1 (.85)	.99 (.83)
Character frequency		
1st character	1540 (2029)	1470 (1900)
2nd character	1540 (2029)	1504 (1835)
Log character frequency		
1st character	2.77 (.7)	2.76 (.69)
2nd character	2.77 (.7)	2.77 (.71)
Number of strokes		
1st character	7.1 (3.1)	7.5 (2.6)
2nd character	7.1 (3.1)	6.9 (2.5)

Notes: Numbers in parentheses are standard deviations. Frequency is measured as character/word per million from a Chinese Dictionary (Corpus from China Daily, 1998).

Table 4.

Participant Means (and Standard Deviation) as a Function of Preview on the Target Word for Experiment 2.

Preview	Identical	Reverse	Control
Early Measures			
Skipping rate (%)	10 (16)	9 (15)	11 (13)
First fixation duration (ms)	247 (37)	250 (39)	277 (53)
Single fixation (ms)	251 (40)	246 (39)	282 (59)
Gaze duration (ms)	282 (57)	290 (65)	331 (87)
Late Measure			
Second pass time (ms)	97 (87)	99 (94)	95 (93)
Regressions-in (%)	22 (15)	22 (19)	24 (20)

Table 5.

Lexical Properties of Preview Conditions for Experiment 3.

Preview	Identical	Related & plausible	Unrelated & plausible	Unrelated & implausible
Word Frequency	321 (637)	249 (362)	226 (318)	307 (564)
Log Frequency	1.96(.72)	1.97 (.66)	1.94 (.68)	1.97 (.73)
Number of strokes	8.9 (3.0)	9.2 (3.3)	8.7 (3.3)	8.6 (2.8)

Notes: Numbers in parentheses are standard deviations. Frequency is measured as character/word per million from a Chinese Dictionary (Corpus from China Daily, 1998).

Table 6.

Participant Means (and Standard Deviation) as a Function of Preview on the Target Character and the Target Region for Experiment 3.

Preview	Identical	Related & plausible	Unrelated & plausible	Unrelated & implausible
	Target character (character n)			
Skipping rate (%)	48 (20)	48 (20)	42 (16)	49 (20)
First fixation duration (ms)	251 (36)	260 (45)	269 (48)	269 (51)
Single fixation (ms)	253 (36)	260 (45)	269 (46)	271 (55)
Gaze duration (ms)	260 (41)	273 (54)	274 (50)	283 (59)
	Target region (character n and n+1)			
Early Measures				
Skipping rate (%)	11 (12)	9 (10)	8 (9)	9 (11)
First fixation duration (ms)	258 (32)	267 (39)	273 (41)	279 (42)
Single fixation (ms)	265 (38)	271 (46)	283 (44)	293 (53)
Gaze duration (ms)	322 (67)	344 (80)	347 (73)	366 (77)
Late Measures				
Second pass time (ms)	64 (64)	67 (69)	80 (81)	55 (58)
Regressions-in (%)	16 (13)	16 (13)	20 (15)	14 (12)

Note. Values in parentheses represent standard deviations.

Table 7.

Lexical Properties of Preview Conditions for Experiment 4.

Preview	Identical	Initial-plausible	implausible
Word frequency	22 (40)	24 (43)/	22 (39)
Log word frequency	0.64 (.94)	0.83 (0.78)	0.63 (0.98)
Character frequency			
1st character	794 (1305)	802 (1345)	817 (1117)
2nd character	794 (1305)	772 (1390)	769 (1275)
Log character frequency			
1st character	2.47 (.69)	2.48 (0.67)	2.55 (0.62)
2nd character	2.47 (.69)	2.49 (0.59)	2.48 (0.64)
Number of strokes			
1st character	9.3 (3.5) /	9.2 (3.0)	8.9 (3.1)
2nd character	9.3 (3.5)	9.4 (3.3)	9.1 (3.5)

Notes: Numbers in parentheses are standard deviations. Frequency is measured as character/word per million from a Chinese Dictionary (Corpus from China Daily, 1998).

Table 8.

Participant Means (and Standard Deviation) as a Function of Preview on the Target Character and the Target Region for Experiment 4.

Preview	Identical	Initial-plausible	implausible
Early Measures			
Skipping rate (%)	5 (8)	4 (7)	6 (11)
First fixation duration (ms)	251 (30)	257 (35)	271 (39)
Single fixation (ms)	256 (32)	262 (40)	276 (46)
Gaze duration (ms)	293 (54)	328 (66)	351 (71)
Late Measure			
Second pass time (ms)	57 (55)	98 (78)	69 (58)
Regressions-in (%)	15 (14)	24 (21)	19 (13)

Figure 1.

Example of the boundary display change paradigm with Chinese.

(1) 我想到一个|改良的方案来处理这个问题。
*

(2) 我想到一个|改良的方案来处理这个问题。
*

(3) 我想到一个|改良的方案来处理这个问题。
*

(4) 我想到一个|适合的方案来处理这个问题。
*

(5) 我想到一个|适合的方案来处理这个问题。
*

Note: In the line (1) to (3), the control word preview (改良, improved, which was underlined) is initially displayed in the target location. When the reader's eyes crossed the invisible boundary location (|) located just to the left of the target word, the preview is replaced by the target word (适合,suitable, which was underlined), see line (4) and (5). The asterisks represent the fixation locations.

The English translation of this sentence is: *I came up with a suitable project to solve this problem)*。

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