WRITING SYSTEMS RESEARCH, 2014
Vol. 6, No. 1, 94–104, http://dx.doi.org/10.1080/17586801.2013.843440

Can parafoveal-on-foveal effects be obtained when reading an unspaced alphasyllabic script (Thai)?

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One controversial question in the field of eye movements and reading is whether there is evidence of parafoveal-on-foveal effects. This is an important issue because some models of eye movements in reading make quite different predictions in this respect (e.g., E-Z Reader vs. SWIFT models). The aim of the current study was to investigate if parafoveal-on-foveal effects occur when reading Thai, an unspaced, alphasyllabic orthography. Word frequency (high and low) of the word to the right of the currently fixated word was manipulated to examine if it would influence processing of the fixated word. Thirty-six participants read single sentences while having their eye movements monitored. There was no evidence of the effect of word frequency of the parafoveal word on fixation duration measures of the foveal word, as assessed by $p(H_0|D)$ values—except for a marginal effect in the skipping rates. Thus, the present data are in line with previous studies using spaced Indo-European languages which have found small/null results for parafoveal effects of word frequency during one-line sentence reading.

Keywords: Eye movements; Parafoveal-on-foveal effects; Reading; Thai; Unspaced script; Word frequency.

Traditionally, reading research has focused on Roman script and a small number of European languages, in particular English. However, recently there has been a rapidly growing interest in investigating more diverse languages and scripts. By including a broader range of languages and scripts, we can build more comprehensive and representative universal models of reading (see Frost, 2012, for a recent review). The alphasyllabaries of South and Southeast Asia offer rich opportunities to further this endeavour. In this context, Thai with its distinctive characteristics offers extremely interesting opportunities for research on reading mechanisms and processes.

Thai has an alphabetic script with syllabic characteristics as it has implicit vowels for some consonants. Consonants are written in a linear order, but vowels can have a non-linear configuration; they can be written above, below or to either side of the consonant as full letters or diacritics, and commonly combine across the syllable to produce a single vowel or dipthong. Several vowels precede the consonant in writing but phonologically follow it in speech (e.g., แบน <ɛːbn> “*flat*” is spoken as /bɛːn/), whereas other vowels are spoken in the order that they are written, as occurs in English (e.g., บาท “*Baht*” is spoken

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as /ba:t/). This non-alignment of vowels is a characteristic shared by other Brahmi-derived scripts. However, in contrast to the Indic scripts, Thai is a tonal language, which is a characteristic it shares with other regional neighbours (e.g., Chinese, Burmese and Vietnamese).

An additional distinctive feature of Thai is that it does not normally have interword spaces, hence when reading, words have to be segmented using other cues besides spaces. The lack of these salient visual word segmentation cues implies that during normal reading there is a degree of ambiguity in relation to which word a given letter belongs to (an example in English: adegreeofambiguityoccurswithoutinterwordspaces). Due to the lack of interword spaces and the non-linear alignment of vowels, there is an associated level of ambiguity in relation to which word a given letter belongs to and which lexical and sublexical components constitute a "*word*"—note that the special role of a word's initial letter position which occurs in Indo-European languages seems to be much weaker in Thai (see Winskel, Perea, & Ratitamkul, 2012). As there is a degree of ambiguity of where a word starts and ends due to these characteristics and word n and word n + 1 are adjoining (and closer to the fovea), this may potentially lead to more parallel processing of adjacent words occurring when reading Thai than in Indo-European languages.

One approach used to investigate this possible occurrence of parallel processing of words is to examine if there are parafoveal-on-foveal effects when reading; in other words, whether there is an effect of the lexical or sub-lexical characteristics of the nonfixated parafoveal word on the currently fixated word (for a recent review, see Drieghe, 2011) when reading information is obtained from two sources; the word that is being currently fixated (the foveal word, or word n) and the next word in the text (the parafoveal word or word n + 1). In the absence of foveal information, information solely from the parafovea is not sufficient for reading (Just & Carpenter, 1987). However, many high-frequency words can be lexically processed by the parafovea (i.e., without fixating on the word). Hence, such words are more likely to be skipped than low-frequency words, especially when the eyes are close to the target word on the fixation prior to the skipping (Drieghe, Brysbaert, Desmet, & De Baecke, 2004; Henderson & Ferreira, 1993; Hyönä & Bertram, 2004). Alternately, many difficult long (or low-frequency) words are lexically processed using multiple fixations and longer durations. Research has shown that readers do acquire orthographic and phonological information from the parafovea when reading prior to the word being fixated (e.g., Chance, Rayner, & Well, 2005; Inhoff, 1989; Inhoff & Rayner, 1986; Kambe, 2004; Kennedy, 2000; Kennison & Clifton, 1995; Rayner, 1998; Rayner, Inhoff, Morrison, Slowiaczek, & Bertera, 1981; Reichle, Rayner, & Pollatsek, 2003; White, Rayner, & Liversedge, 2005).

These parafoveal-on-foveal effects are of great theoretical interest as they can potentially support either a serial or parallel processing view of lexical processing when reading. According to the E-Z Reader model (Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle et al., 2003), words are sequentially attended to one at a time when reading. Hence, the lexical-semantic properties of the adjacent nonfixated word do not affect the processing of the fixated word. In contrast, the SWIFT model (Engbert, Longtin, & Kliegl, 2002; Engbert, Nuthmann, Richter, & Kliegl, 2005) assumes that lexical processing is spatially distributed across words with a competition for processing resources. So the fixated and the nonfixated word can be processed simultaneously. Thus, empirical evidence of parafoveal-on-foveal effects would support this parallel processing model over the serial, E-Z Reader model.

Word-frequency is one of the main lexical characteristics that have been investigated, with mixed results. Evidence for parafoveal-on-foveal effects has been found using reading-related tasks that do not involve continuous reading (e.g., Kennedy, 1998, 2000;

Kennedy, Pynte, & Ducrot, 2002, 2004). Kennedy (1998), for example, found that gaze duration on the fixated word was shorter when the parafoveal word was a low-frequency word in comparison to a high-frequency word. The interpretation made was that infrequent words attracted an early saccade. Additional evidence for parafoveal-on-foveal effects has been found in large corpus studies. Kennedy and Pynte (2005) investigated eye movements when reading using an English and French corpus. When the fixated word was six letters or less in length, they found significant effects of the frequency of the parafoveal word, so that with low-frequency parafoveal words gaze durations on the fixated words was 12ms longer in comparison to high-frequency parafoveal words. However, this did not occur for longer words of 8–12 letters. Kliegl, Nuthmann, and Engbert (2006), in a large corpus study, reported an 8 ms shorter single fixation duration for high-frequency words than low-frequency parafoveal words for short fixated words (less than six letters in length) but not for longer words. However, the reverse was found for gaze duration, parafoveal frequency effects were apparent for long but not short words. These results indicate that foveal word length is an important factor in relation to the existence of parafoveal-on-foveal effects. More recently, Wotschack and Kliegl (2013) have found a similar frequency effect of the parafoveal word on single fixation duration for participants reading the Potsdam sentence corpus, with longer durations with low-frequency than high-frequency parafoveal words.

In a reading experiment, Hyönä and Bertram (2004, Experiment 4) reported that low-frequency parafoveal words in Finnish were associated with shorter fixations on the fixated word in comparison to high-frequency words. However, this effect was only found for long compound words. They also found that refixation probability on word n increased with long low-frequency compound words. They explained these results in terms of a "*magnet*" or pull effect on the saccade by the low-frequency words. They also found that word n was skipped more often when the parafoveal word had an infrequent initial constituent. However, it is important to note that their results were not entirely consistent across the different experiments conducted. In addition, other studies have failed to find parafoveal-on-foveal effects for lexical frequency (e.g., Calvo & Meseguer, 2002; Henderson & Ferreira, 1993; Perea & Acha, 2009; Rayner, Fischer, & Pollatsek, 1998; Schroyens, Vitu, Brysbaert, & d'Ydewalle, 1999; White, 2008). Results indicate that a parafoveal-on-foveal effect is likely to be restricted to instances where the eyes are very close to the parafoveal preview where visual acuity is adequate for parafoveal processing to occur (Drieghe, 2011; White, 2008; White & Liversedge, 2004).

As Drieghe (2011) points out, there are methodological difficulties associated with examining these parafoveal-on-foveal effects in scripts with interword spaces, as the eyes need to be close to the unfixated parafoveal word. This problem can be overcome to some extent by investigating reading in scripts that do not have interword spaces. One option is to employ Chinese, an unspaced logographic language. The evidence in this respect is mixed. One recent study in Chinese (Bai, Hu, & Yan, 2009) reported no evidence in favour of parafoveal-on-foveal effects, while other studies (e.g., Cui, Wang, Yan, & Bai, 2010; Yan, Zhou, Shu, & Kliegl, 2012) have revealed some evidence for parafoveal-on-foveal effects. One second option—which is the one employed here—is to examine parafoveal-on-foveal effects in an alphabetic script (similar in this respect to Indo-European languages), Thai, which does not have interword spaces and has non-aligned vowels. As stated previously, due to these characteristics, there is an associated level of ambiguity in relation to which word a given letter belongs to, which may potentially lead to more parallel processing of words occurring in Thai.

There has been some interesting and relevant research conducted on the processing of spaced/unspaced compound words in alphabetic orthographies, which may be relevant for the present study. For example, recently Juhasz, Pollatsek, Hyönä, Drieghe, and Rayner

(2009) examined parafoveal preview effects in unspaced and spaced English compound words (e.g., basketball) using the boundary paradigm (Rayner, 1975). They found a larger parafoveal preview effect of the second lexeme for unspaced in comparison to spaced compound words, which was similar to results found in Finnish (Hyönä, Bertram, & Pollatsek, 2004). One suggestion they made to explain this anomaly is that processing of letter information in the unspaced compound may be occurring in parallel. On this basis, we could expect a greater likelihood of lexical and sublexical parallel processing to occur when reading unspaced Thai.

As can be seen from the review, there are inconsistencies in the literature. By investigating orthographies without interword spaces and non-linear characteristics, we may gain greater insights into parafoveal-on-foveal effects. In order to investigate the possible occurrence of parafoveal-on-foveal effects when reading Thai, we manipulated word frequency (high and low) of the word to the right of the currently fixated word to see if it would influence processing of the fixated word. If we find a consistent parafoveal-on-foveal effect on fixation durations, then this would provide quite strong evidence against the assumption of serial processing in the E-Z Reader model—favouring the SWIFT model; in contrast, lack of evidence of parafoveal-on-foveal effect would provide support for the assumption of serial processing of the E-Z Reader model. The experimental sentences were constructed so that the sentence frames were identical for each high- and low-frequency target word. Thus, the foveal word was identical for each matched pair of parafoveal words.

METHOD

Participants

Thirty-six Thai participants were recruited from Chulalongkorn University, Bangkok, Thailand and tested at the Center for Research in Speech and Language Processing (CRSLP). All participants had normal or corrected to normal vision. Participants were paid to participate.

Materials

Thirty-six sentence frames were prepared. Participants read 72 sentences with each of the high- and low-frequency critical words (n) (half five letters and half six letters in length) embedded in the same sentence frames. (The conventional way of measuring word length in eye tracking studies is using a horizontal measure, which corresponds with visual acuity and letter span measures.) Thus, the preceding word ($n-1$) and following word ($n+1$) to the critical word were identical in both frequency conditions. Presentation of the high- and low-frequency word sentences was counterbalanced across subjects. Word frequencies were obtained from the Thai one million word database (Luksaneeyanawin, 2004). High-frequency (hf) Thai words ranged in frequency from 52–1822 words per million, $M = 318$ per million, whereas the low-frequency (lf) words were selected from the frequency range of 2–52 words per million, $M = 36$ per million. Word $n-1$ ranged in length from three to nine letters with a mean of 4.89 letters and $n+1$ words ranged from three to 10 letters with a mean of 5.14. In Thai, there are five misaligned vowels that occur orthographically prior to the consonant they phonologically follow and five vowels that occur after the consonant where orthography and phonology are aligned or congruent. The ratio of occurrence of the misaligned to aligned vowels is 1:4 (see Winskel & Iemwanthong, 2010, for more detailed information). In the current experiment, the location and number of misaligned vowels was similar in the different conditions. An example sentence pair is given below (the manipulated target word is in bold and the preceding and following words are underlined).

High-frequency condition:

คุณแม่ขับรถส่งลูกไปเรียน**หนังสือ**ใกล้ๆบ้าน

Mother drove her child(ren) to school (which was) near home

Low-frequency condition:

คุณแม่ขับรถส่งลูกไปเรียน**อนุบาล**ใกล้ๆบ้าน

Mother drove her child(ren) to kindergarten (which was) near home

Apparatus

The test stimuli were presented using the EyeLink II tracking system (SR Research Canada). The eye tracker is an infra-red video-based tracking system. It has two cameras for each eye with two infra-red LEDs for illuminating each eye mounted on a headband. The cameras sample pupil location at a rate of 250 Hz; equivalent to a temporal resolution of 4 ms. The eye tracker monitored movements of the right eye, although viewing was binocular. Sentences were displayed on a single line of the computer screen in Courier Thai 14 point. From a viewing distance of 61 cm from the computer screen, three letters occupied approximately one degree of visual angle.

Procedure

At the beginning of the experiment, the eye-tracking system was calibrated for the participant. Each trial started with a fixation point on the left-hand side of the monitor, the location of which coincided with the location of the first letter in the sentence. Participants were instructed to read silently for comprehension and to press a response key as soon as they finished reading the sentence. Sentence reading latencies were calculated from the appearance of the sentence on the screen until the key press. Each participant read 12 practice trials followed by 72 experimental trials. Sentences were presented in a fixed random order. Comprehension was checked on approximately 10–15% of trials during the experiment by presenting participants with a question which could be answered by yes or no. The mean error rate on the comprehension questions was 4%.

Data analyses

Fixations shorter than 80 ms that were within one character of the next or previous fixation were incorporated into that fixation. Additional fixations shorter than 80 ms and longer than 1200 ms were removed from the analysis. This resulted in the exclusion of 2% of trials. Analyses of word $n-1$, n, and $n+1$ were conducted.

RESULTS

Repeated measures analyses of variance (ANOVAs) were computed for the frequency conditions, for participants (F_1) and items (F_2). The eye fixation measures were first fixation duration, gaze duration (the sum of fixations on a word before leaving it), total fixation duration (the sum of all fixations within a word) for the critical word n and $n+1$, and probability of skipping, frequency of refixations and landing positions were analysed for word n – 1. Given that the E-Z Reader model predicts a null parafoveal-on-foveal effect, it is important to obtain a measure of how confident we are when maintaining the null hypothesis, In those cases, we calculated the probability of the null hypothesis being true, given the obtained data, $p(H_0|D)$ (Masson, 2011; see also Wagenmakers, 2007). Masson (2011) argued that positive evidence that the null hypothesis is true given the obtained data occurs when $p(H_0|D) > .75$, while strong evidence is obtained with probability values above .90 (see also Raftery, 1995).

Reading measures for the critical word n

Table 1 shows the different reading measures for n – 1, n, and n+1 as a result of manipulating the frequency of word n. First, for the critical target word n, there was a sizeable word-frequency effect for gaze duration (29 ms) ($F_1(1,35) = 16.85$, $p < .001$, $\eta_p^2 = .325$; $F_2(1,71) = 8.28$, $p < .01$, $\eta_p^2 = .106$) and total viewing duration (46 ms) ($F_1(1,35) = 25.99$, $p < .001$, $\eta_p^2 = .426$; $F_2(1,71) = 8.83$, $p <$ 01, $\eta_p^2 = .112$) for the critical word n. First fixation duration was significant for participants (6 ms) ($F_1(1,35) = 5.16$, $p < .05$, $\eta_p^2 = .128$) but not for items ($F_2(1,71) = 1.64$, *ns*). Skipping rate was marginally higher for high-frequency than low-frequency words (hf = .13; lf = .10) ($F_1(1,35) = 3.66$, $p = .064$, $\eta_p^2 = .095$; $F_2(1,71) = 3.18$, $p = .079$, $\eta_p^2 = .043$).

TABLE 1
Reading time measures for word n – 1, n and n + 1. Mean fixation duration measures (in ms) and skipping rate as a function of word frequency (high frequency [HF], low frequency [LF]) of word n. For word n – 1, the fixation durations are prior to fixation on the critical word n for all data, for saccades launched from word n – 1, and for short words (n – 1 < six letters) launched from word n – 1. Standard deviations are in parentheses

	n – 1			*n*	*n+ 1*
	All data	*Saccades launched from word n – 1 only*	*Short words only (< 6 letters)*	*(high/low frequency word)*	
First fixation duration					
HF	202	203	204	208	222
	(26)	(27)	(25)	(29)	(33)
LF	202	200	202	214	224
	(28)	(29)	(29)	(30)	(32)
Gaze duration					
HF	249	246	238	240	281
	(46)	(47)	(41)	(43)	(57)
LF	253	250	242	269	277
	(59)	(60)	(56)	(63)	(62)
Total fixation duration					
HF	–	–		271	303
	–	–	–	(67)	(71)
LF	–	–	–	317	309
	–	–	–	(94)	(78)
Skipping rate					
HF	.18	–	.22	.13	.17
	(.10)	–	(.13)	(.11)	(.13)
LF	.14	–	.16	.10	.18
	(.10)	–	(.11)	(.10)	(.13)

Parafoveal-on-foveal effects

Parafoveal-on-foveal effects were assessed by examining the duration of the fixation measures on word n – 1 prior to fixating on the critical word n. The influence of the critical word on the fixation duration prior to fixation of it were calculated for all of the data and for only the 91% of cases in which saccades were launched from word n – 1.

Analyses of all the data

For all of the data, we found no signs of an effect of word-frequency for first fixation duration (both *F*s < 1, $p(H_0|D)$ = .85 and .89 for participant and item analyses respectively), single fixation duration (*F*s < 1, $p(H_0|D)$ = .84 and .86 for participant and item analyses respectively), or gaze duration (both *F*s < 1, $p(H_0|D)$ = .83 and $p(H_0|D)$ = .89 for participant and item analyses respectively). Skipping rate was significant for participants ($F_1(1,35) = 9.43$, $p < .01$, $\eta_p^2 = .212$) but not for items ($F_2(1,71) = 2.17$, p = .15) with readers more likely to skip word n – 1 when word n was a high-frequency than low-frequency word (hf = .18; lf = .14). To further examine this apparently conflicting finding, and given that skipping is a categorical binomial variable, the Laplace approximation was employed to fit the binomial data using a linear mixed effect model that had participants and items as random intercepts—this was the optimal model in a series of models of decreasing complexity. These analyses failed to show an effect of word-frequency on the probability of skipping word n – 1: $z = -1.34$, $p = .18$. Finally, regressions to word n – 1 were not influenced by frequency of the critical word n (high frequency: M = 0.08, SD = 0.09 and low frequency: M = 0.10, SD = 0.10) (*F*s < 2, $p(H_0|D)$ = .53 and .54 for participant and item analyses respectively).

Analyses of all the saccades launched from word n – 1

In the following analysis, trials were selected where saccades were launched from word n – 1. Similar results emerged. There was no effect of word-frequency for first fixation duration (*Fs* < 1, $p(H_0|D)$ = .80 and .88 for participant and item analyses respectively), single fixation duration (*F*s < 1, $p(H_0|D)$ = .86 and .89 for participant and item analyses respectively) or gaze duration (*F*s < 1, $p(H_0|D)$ = .82 and .89 for participant and item analyses respectively).

If we are going to find evidence of parafoveal-on-foveal effects, previous research indicates that this is more likely to occur with short words due to limitations on visual acuity. In the next analysis, trials with word n – 1 that were six letters or less in length were selected. This resulted in a further removal of 22% of the trials from the analysis. Again, similar results emerged. There were no signs of an effect of word-frequency for first fixation duration (*F*s < 1, $p(H_0|D)$ = .86 and .87 for participant and item analyses respectively), single fixation duration (*F*s < 1, $p(H_0|D)$ = .86 and .87 for participant and item analyses respectively) or gaze duration (*F*s < 1, $p(H_0|D)$ = .84 and .87 for participant and item analyses respectively). For short words, skipping rate was significant for participants ($F_1(1,35) = 9.61$, $p < .01$, $\eta_p^2 = .215$) but not for items ($F_2(1,57) = 2.94$, p = .09) with readers more likely to skip word n – 1 when word n was a high-frequency than low-frequency word (hf = .22; lf = .16)—note that if we use the linear mixed effect model that had participant intercepts and item intercepts as random factors on the probability of skipping the word n – 1, the effect of word-frequency failed to show an effect of word n – 1: $z = -1.63$, $p = .10$.

In order to examine if frequency of the target word affected landing position on word n – 1, we conducted an additional analysis of variance. We did not find a significant effect of word frequency on landing position on the pretarget word (hf = −5.49; lf = 5.39 number of pixels from centre of word) (*F*s < 1, $p(H_0|D)$ = .85 and .89 for participant and item analyses respectively).

Word n + 1 measures

Analysis of word n+1 was included to examine potential spillover effects from the effect of the word frequency manipulation on word n+1. There was no evidence of spillover effects on word n+1 from the frequency manipulation on word n for first fixation duration (*F*s < 1, $p(H_0|D)$ = .83 and .89 for participant and item analyses respectively), single fixation duration (*F*s < 1, $p(H_0|D)$ = .81 and .89 for participant and item analyses respectively), gaze duration (*F*s < 1, $p(H_0|D)$ = .84 and .89 for participant and item analyses respectively) and total fixation duration (*F*s < 1, $p(H_0|D)$ = .82 and .86 for participant and item analyses respectively). There was also no significant effect of word-frequency on skipping rate (*F*s < 1, $p(H_0|D)$ = .86 and .89 for participant and item analyses respectively). Notably, previous reports of spillover effects have typically involved very low-frequency words (see Kennison & Clifton, 1995; Rayner, 1998; Reichle et al., 1998)—in the present experiment, the average frequency of the low-frequency words was 36 occurrences per million (it was 316 occurrences per million in the high-frequency words). It may well be the case that spillover effects are more easily detected when the target words are somewhat unfamiliar.

In sum, from the statistical analyses conducted there were no signs of an effect of word frequency on prior fixation measures. The only exception was the data from the participant analyses in the skipping rate, which did indicate that words preceding a high-frequency word were more likely to be skipped than words preceding a low-frequency word. Although the effect was not significant in the item-analyses or in the linear mixed-model analyses, it does suggest that there may be some parafoveal-on-foveal processing in particular when the n − 1 word is short.

DISCUSSION

The aim of the current study was to investigate if there was evidence of parafoveal-on-foveal effects when reading Thai, an unspaced orthography. Thai is a good candidate for parafoveal-on-foveal effects, due to its lack of interword spaces and non-aligned vowels, which are associated with a level of ambiguity in relation to which word a given letter belongs to and which lexical and sublexical components constitute a "*word*". However, despite the presence of the usual word-frequency effect on the critical word (n), there was no evidence of parafoveal-on-foveal effects of word-frequency on fixation durations. Similar results were also found with short words (n − 1) of six or fewer letters. Note that we also found compelling evidence that the null hypothesis is true given the obtained data (i.e., $p(H_0|D)$ values ranging from .80 to .89; see Wagenmakers, 2007). These results are in agreement with a recent study (Winskel et al., 2012), where we also failed to find parafoveal-on-foveal effects when reading Thai. Winskel et al. (2012) investigated if initial letter position has a privileged role in comparison to internal letters for visual-word recognition in Thai as it does in Roman script. The degree of disruption caused when reading sentences with target words with internal letter transpositions [e.g., porblem] in comparison to initial letter transpositions [e.g., rpoblem]) was examined. Results revealed that there was no apparent difference in degree of disruption caused when reading initial and internal transposed-letter nonwords. The explanation we proffered was that letter position encoding in Thai is relatively flexible and that actual identity of the letter is more critical than letter position. An alternative explanation is that there might instead be more parallel processing of the transposed letter manipulations. However, when we examined reading times (fixation durations and skipping rate) on word n – 1, we did not find evidence of parafoveal-on-foveal effects. Taken together, these results appear to favour models such as the E-Z reading model where lexical processing is considered to be a sequential process.

We acknowledge, however, that in the current experiment somewhat contradictory results emerged for skipping rate, as we did find an effect of word-frequency of the parafoveal word on the probability that the target word would be skipped in the analysis by participants—in particular when the n – 1 word was short. Skipping rate was marginally higher for high-frequency than low-frequency words for these short words (hf = .22; lf = .16), as reflected in the analyses by items (p = .09) and in the analyses using linear mixed effects (p = .10). These skipping rate results, even though small, indicate some support for parafoveal-on-foveal effects, so we can't rule out these effects entirely and the possibility that fixated and non-fixated words are processed in parallel in Thai—at least for short words. Thus, although the current results on fixation times offer support to serial processing models (e.g., E-Z Reader model: Reichle et al., 1998, 2003) over parallel processing models (e.g., the SWIFT model: Engbert et al., 2002; Engbert et al., 2005) of reading, further research using a larger number of short words may be necessary to elucidate the observed trend towards a parafoveal-on-foveal effect in the skipping rates in Thai.

The present results are in line with previous studies, which have found mixed results for parafoveal effects of word-frequency. Some experimental studies have not found evidence of parafoveal-on-foveal effects of word frequency in Roman script (Calvo & Meseguer, 2002; Henderson & Ferreira, 1993; Perea & Acha, 2009; Rayner et al., 1998; Schroyens et al., 1999; White, 2008). Other studies have found contradictory results (Hyönä & Bertram, 2004) and the large corpus studies (Kennedy & Pynte, 2005; Kliegl et al., 2006; Pynte & Kennedy, 2006; Wotschack & Kliegl, 2013) have found effects of word frequency. It appears from the research so far conducted that these lexical frequency effects when they are found are relatively small. Bear in mind that the detection of parafoveal-on-foveal effects appear to be limited to instances where the eyes are very close to the parafoveal preview where visual acuity is adequate for parafoveal processing to occur (Drieghe, 2011; White, 2008; White & Liversedge, 2004). Moreover, Wotschack and Kliegl (2013) have shown recently that individual age-related differences and experimental manipulation of task demand (manipulation of comprehension question difficulty) can influence the reading strategies adopted by readers, namely the skipping rate on first-pass reading and regressive eye movements, which in turn can affect whether parafoveal-on-foveal effects are found or not in the data.

In summary, to build a more comprehensive and universal model of reading, it is essential to investigate reading in diverse languages and their orthographies—both similarities and dissimilarities. We believe that the scripts of South and Southeast Asia with their distinctive characteristics offer extremely interesting opportunities to gain further insights into common and language-specific reading processes and mechanisms. The present experiment has failed to find any definite signs of parafoveal-on-foveal effects while reading Thai—similar to most published one-line sentence reading studies in spaced Indo-European languages. To assess not only the potential influence of word frequency but other parafoveal-on-foveal effects, further research needs to be conducted. In this light, White (2008) found that orthographic familiarity of nonfixated words influenced the probability of skipping words and fixation durations on the fixated word in English. Orthographic familiarity might also play a more critical role in Thai than in Indo-European languages, as frequently occurring or salient or distinctive letters may function as parafoveal word segmentation cues in the unspaced text. One other possibility, as suggested by a reviewer, is that the location of refixations on a word might be influenced by the position of the vowel (misaligned vs. aligned). There is also the possibility that the landing position of saccades is more leftward in alphasyllabic than alphabetic orthographies. These issues might be fruitful foci for future research on Thai and other alphasyllabic writing systems. To conclude, we believe that further crosslinguistic comparisons between alphasyllabic and alphabetic writing systems (e.g., both with monolinguals and with balanced/unbalanced bilinguals) will shed more light on the issues raised in this debate on serial versus parallel processing of lexical processing when reading.

Manuscript received 27 December 2012
Revised manuscript received 7 September 2013
First published online 21 October 2013

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