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SHORT REPORT

Parafoveal processing of underlying phonological information during Korean sentence reading

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Abstract

The question of whether phonological information is integrated through the parafovea has remained unanswered particularly in Korean sentence reading. The current study used homophones with identical underlying phonological forms but with different orthography to examine phonological preview benefit effects in Korean. In an eye-tracking experiment using the boundary paradigm, target fixations were shorter (a) when the preview-target pairs were identical than when they were unrelated, (b) when the pairs were orthographically similar than when they were unrelated, and most importantly, (c) when the pairs were phonologically identical than when they were phonologically similar but different. These results indicate that underlying phonological information of a word, aside from orthographic information, is integrated through parafoveal preview during Korean sentence reading.

Keywords Preview benefit · Phonological preview benefit · Boundary paradigm · Korean sentence reading

Introduction

During sentence reading, readers acquire linguistic information of words not only through foveal attention but also from the parafoveal region. Since the 1970s, psycholinguistic research on parafoveal processing has primarily focused on how rapidly orthographic and phonological information of a parafoveal word is processed during the reading of Roman-script languages. Such studies used an eye-tracking experiment technique known as the *boundary paradigm* (Rayner, 1975). When the preview presents linguistic information that is similar to the target, its parafoveal processing tends to enable faster processing of the target word, an effect known as a preview benefit (Rayner, 1975).

Earlier studies on English sentence reading suggest a fairly robust preview benefit from an orthographic similarity between the preview and the target, as in *cahc–cake* as opposed to *picz–cake* (Balota et al., 1985). Studies on the preview benefit from phonological information, however, have reported disagreeing results. For instance, Rayner et al. (1980) showed that preview words that began with the same sound but with a different letter compared to the target (e.g., *write–rough*) did not yield a preview effect, suggesting no phonological preview benefit. In contrast, Pollatsek et al. (1992) found a shorter target fixation when the preview was a homophone of the target (*beech-beach*) compared to when they were only orthographically similar (*bench–beach*), which indicates a preview benefit from phonological information. Vasilev et al. (2019) conducted a meta-analysis of published and unpublished literature on phonological preview benefits to conclude that there is a modest but reliable phonological preview benefit effect in alphabetical languages such as English.

Considerably less attention has been paid to preview benefit in Korean, a non-Roman-script language. The Korean writing system has a shallow orthography, with highly regular letter-to-phoneme correspondences. As shallow orthographic depth enables fast phonological decoding during visual word recognition, it can be reasonably predicted that phonological information would have a significant impact on parafoveal processing of Korean words as it does in Roman-script languages. Despite this prediction, two recent studies on preview benefits during Korean sentence reading have indicated otherwise. Yan et al. (2019) examined the phonological/orthographic and semantic preview effects in Korean to find a greater benefit from phonological/orthographic previews (빠

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따 [p'at'a] 'stick' – 바다 [pada] 'sea') than from semantic previews (대양 [tɛjaŋ] 'ocean' – 바다 [pada] 'sea'). However, Yan et al. (2019) did not scrutinize independent effects of phonological similarity and orthographic similarity. That is, their phonological previews, e.g., 빠따 [p'at'a], were similar to the targets, e.g., 바다 [pada], not only in their phonological forms but also in their orthographic forms. Therefore, it is not certain whether their preview benefits came from the processing of their phonological or orthographic information in the parafovea. This limitation stems from the highly shallow orthographic depth of the Korean writing system that precludes orthogonal manipulation of orthographic similarity and phonological similarity between previews and targets, as can be done in logographic writing systems like Chinese (e.g., Liu et al., 2002; Pollatsek et al., 2000; Tsai et al., 2004). Noting this limitation, Baek et al. (2021) attempted to test an independent effect of a phonological similarity by comparing a condition in which the preview was only orthographically similar to the target (장군 [çaŋgun] 'general' – 장문 [çaŋmun] 'long text') to a condition in which the preview was not only orthographically similar but also phonologically identical to the target (작문 [çaŋmun] 'writing' – 장문 [çaŋmun] 'long text'). The results showed a significant preview benefit from an orthographic similarity, but there was no additional benefit from phonological identity, which contrasts with earlier findings that other alphabetic languages such as English and French, whose orthographic depth is not even as shallow as that of Korean, display a relatively strong phonological preview benefit (Henderson et al., 1995; Miellet & Sparrow, 2004; Pollatsek et al., 1992).

However, Baek et al.'s (2021) results alone do not conclusively prove a lack of a phonological preview benefit in Korean, as their experiment materials had their own caveat, too. Phonological theories in the generative linguistics framework distinguish two levels of representations (e.g., Chomsky & Halle, 1968; Kiparsky, 1982; Prince & Smolensky, 1993). An *underlying representation* is an abstract and discrete form that is part of our linguistic knowledge, and a *surface representation* is a concrete and continuous form that realizes the underlying representation. For instance, the English consonant /p/ is an abstract phonological category (conventionally written within slashes), which may surface in speech as different phonetic forms (written within squared brackets) depending on the context, such as an unaspirated [p] as in *spy* or an aspirated [p^h] as in *pie*. In Baek et al.'s (2021) phonological condition, the preview-target pairs have different underlying forms (작문 /çakmun/ vs. 장문 /çaŋmun/), but only after one of them undergoes phonological processes such as nasalization, they reach an identical surface form ([çaŋmun] for both words). Looking at the underlying representations, the orthographic condition and the phonological condition are not different from each other, in that both conditions have an orthographic and phonological similarity but no identity whatsoever. Consequently, although the lack of a difference between these two conditions indicates that the lexical information at the surface phonetic level is not processed in the parafovea, they do not say anything with regard to the processing of underlying phonological information.

One way to examine parafoveal processing of underlying phonological information independently from that of orthographic information is by using homophones as in Pollatsek et al. (1992). Although the Korean writing system tends to maintain a one-to-one correspondence between a letter and a sound, there are a few exceptions in the vowel system. The two vowel letters, ㅖ and ㅐ, originally represented mid front vowels /e/ and /ɛ/, respectively, but a number of empirical studies have found their merger into /ɛ/ in various dialects of contemporary Korean, particularly for young generations (Hwang & Moon, 2005; Jang & Shin, 2006; Julien & Jang, 2015; Moon, 2007; Shin, 2000, 2015). Consequently, the diphthongs ㅖ /je/ and ㅒ /jɛ/ have merged into /jɛ/, and also ㅞ /we/ and ㅙ /wɛ/ into /wɛ/, yielding three vowel letters ㅚ, ㅞ, and ㅙ mapping onto the same category /wɛ/. The present study used homophones containing these vowels as preview-target pairs in a boundary paradigm experiment to examine whether underlying phonological information of a word is processed in the parafovea during Korean sentence reading. Assuming that phonological information is processed parafoveally in the reading of alphabetic languages (Yan et al., 2009), we hypothesize that a preview that is phonologically identical to the target at the underlying level yields a beneficial effect on target word recognition during Korean sentence reading.

Materials and methods

Materials

Eighty bi-syllabic words (e.g., 외모 /wɛmo/ 'appearance') were used as target words. For each of the target words, four preview stimuli were created differing in their relationship with the target word (Fig. 1). In the Identical condition, the preview stimuli were the same word as the target word. In the Phonological condition, the preview stimuli were nonwords that not only were orthographically similar to the target words but also had the same phonological representation as the target word (왜모 /wɛmo/). The preview stimuli in the Orthographic condition were nonwords that were orthographically similar to the target words but were phonologically different (워모 /wʌmo/). The Unrelated condition was a control condition,

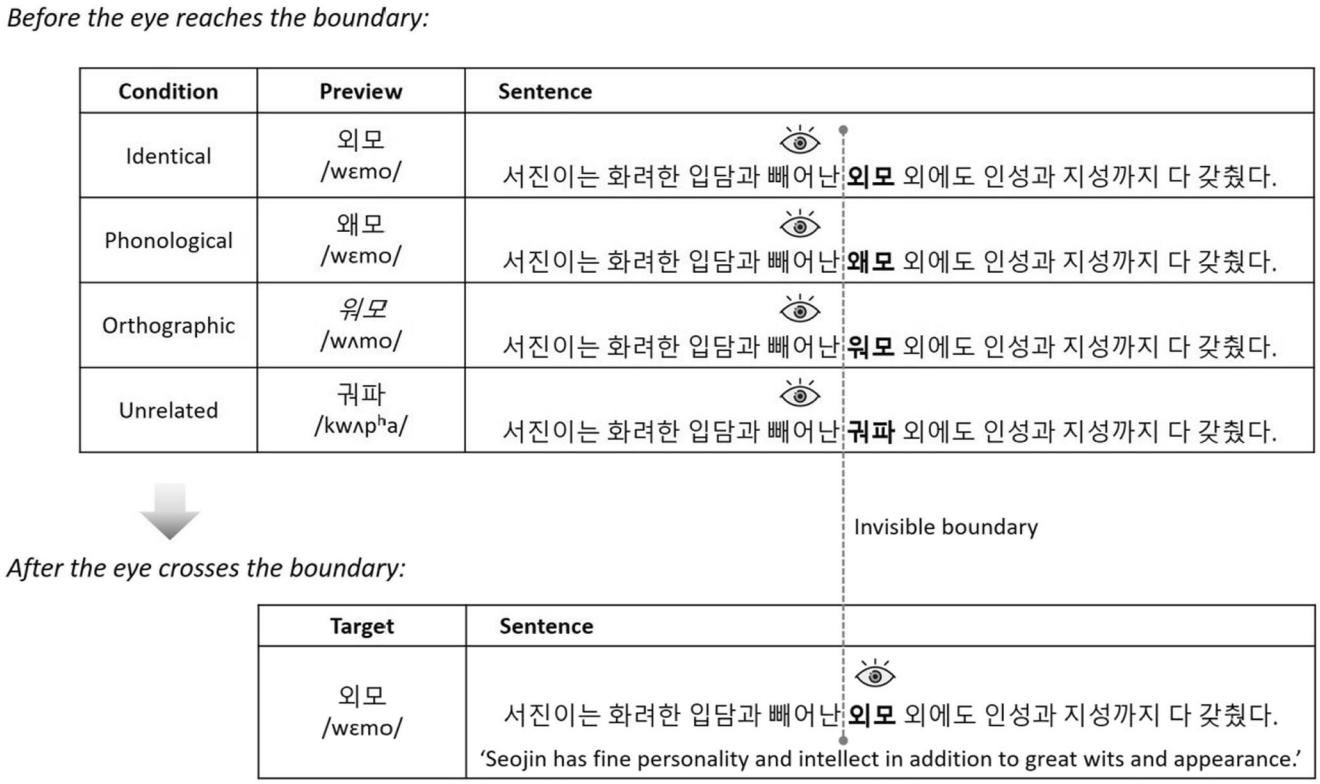

Fig. 1 Experiment conditions and example stimuli

in which preview stimuli were nonwords with no phonological or orthographic resemblance to the target words (궈파 /kwʌpʰa/). The targets and phonological previews were homophones containing the vowels ㅖ-ㅐ /ɛ/ (n = 43), ㅖ-ㅒ /jɛ/ (n = 19), or ㅚ-ㅞ-ㅙ /wɛ/ (n = 18).

A carrier sentence was created to contain each target word with a natural context. The average sentence length was 10.1 words (range: 9-13). The target word was located at the 5-8th word position in the sentences. Although a unit of space in the Korean writing system may consist of a stem word plus functional morphemes, all target words were standing in isolation, with no additional morpheme attached to them.

The 320 target-preview pairs (80 target words × 4 preview conditions) were divided into four lists of 80 trials with counterbalancing, so that a list contained only one preview condition for each of the 80 target words. In addition to the target trials, each list also contained 120 filler sentences that did not involve boundary-triggered stimulus change. Each participant was randomly assigned to one of the four lists and responded to 20 trials per condition (80 target trials in total).

Participants

Sixty-five young adult native speakers of Korean participated in the experiment (24 females, 41 males). All participants were in their early 30s or younger (M = 21.3, SD = 3.1), and therefore corresponded to the young generation that has been reported to have no distinction between /e/ and /ɛ/ (Hwang & Moon, 2005; Jang & Shin, 2006; Julien & Jang, 2015; Moon, 2007; Shin, 2000, 2015).

Procedure and analysis

An eye-tracking experiment was conducted following the typical procedure of boundary paradigm studies. Four eye movement measures on the target words were extracted and compared across preview conditions: single fixation durations (SFD), first fixation durations (FFD), gaze durations (GZD), and skipping rates. Details of the procedure and analysis methods are similar to those reported in Baek et al. (2021) and are provided in the supplementary material.

Results

Accuracy

Each participant's mean accuracy rates to comprehension questions ranged from 79% to 100%, and accuracy rates were above 96% on average in all four preview conditions. There was no statistically significant difference in response accuracies across conditions (Fs < 1, ns). This result confirms that the participants were paying attention to reading and

comprehending the sentences regardless of preview conditions.

Eye movement measures on target (*N*) words

Table 1 shows the means and standard errors of the four eye movement measures—SFD, FFD, GZD, and skipping rates—on the target word by preview conditions.

The three fixation measures, SFD, FFD, and GZD, were significantly shorter in the Identical condition than in the Unrelated condition (SFD: $\beta = -32.964$, $SE = 4.077$, $t = -8.086$, $p < .001$; FFD: $\beta = -33.171$, $SE = 4.146$, $t = -8.001$, $p < .001$, GZD: $\beta = -45.940$, $SE = 8.523$, $t = -5.390$, $p < .001$), which indicates that previewing the target word in the parafovea facilitated speedy processing of the target word. They were also significantly shorter in the two orthographically similar conditions (the Phonological and the Orthographic conditions) than in the Unrelated condition (SFD: $\beta = -19.645$, $SE = 3.518$, $t = -5.584$, $p < .001$; FFD: $\beta = -20.903$, $SE = 3.549$, $t = -5.889$, $p < .001$, GZD: $\beta = -37.278$, $SE = 7.287$, $t = -5.116$, $p < .001$). This result demonstrates that parafoveal preview of an orthographically similar stimulus also helped the processing of the target word.

Moreover, SFD and FFD in the Phonological condition were significantly shorter than SFD and FFD in the Orthographic condition (SFD: $\beta = -11.864$, $SE = 3.950$, $t = -3.004$, $p = .0027$; FFD: $\beta = -9.179$, $SE = 4.061$, $t = -2.260$, $p = .0239$), which indicates that the phonological identity between the preview and the target provided an additional benefit that is independent of the orthographic preview benefit. However, there was no significant difference between the Phonological condition and the Orthographic condition in GZD ($\beta = -12.085$, $SE = 8.360$, $t = -1.446$, $p = .148$).

Skipping rates tended to be fairly high in all conditions, with the averages ranging from 0.47 to 0.51. These numbers are not completely surprising, however, given that word length is one of the primary factors that determine whether to skip a word during sentence reading (Brysbaert & Vitu, 1998; Koh & Yoon, 2007; Rayner & McConkie, 1976), and that bisyllabic words in Korean in particular have been found to be skipped as often as 43.9% of the times (Koh & Yoon, 2007). Since all preview stimuli were bisyllabic, consisting of two characters in writing, the relatively high skipping rates indicate that the participants were able to process the sentences without fixating on the targets due to their short length. Also, there was no significant difference in skipping rates in any of the condition contrasts. This null effect of preview conditions on target word skipping is well precedented by studies on short Chinese words consisting of one character (Liu et al., 2002; Tsai et al., 2004) and short English words consisting of 4–5 letters (Pollatsek et al., 1992), in which cases preview effects were demonstrated exclusively by durational measures. Although further research is needed regarding how word skipping is modulated by a variety of linguistic factors in Korean reading, it tentatively suggests that the fine-grained phonological information in parafovea has little impact on the decision of whether to skip the word or not (Vasilev et al., 2019).

Eye movement measures on *N* − 1 words

Table 2 shows the means and standard errors of the three early eye movement measures—SFD, FFD, and GZD—on the $N-1$ words, which immediately preceded the target word, by preview conditions. For all of these three measures, there was no significant difference in any of the contrasts between conditions. These results confirm that the significant differences in the target word fixation measures, reported in the previous section, are not triggered by irrelevant factors such as sentence context or target word predictability but actually represent the effects of parafoveal processing of preview words.

Discussion

Results of the current study replicated earlier findings on the parafoveal preview benefit from an identical or an orthographically similar stimulus in Korean (Baek et al., 2021; Yan et al., 2019), and more importantly, revealed that previewing a phonologically identical stimulus also has an advantageous

Table 1 Means and standard errors of SFD, FFD, GZD, and skipping rates on the target (*N*) word by preview conditions

Condition	SFD (ms)		FFD (ms)		GZD (ms)		Skipping rates	
	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Identical	196.6	2.5	199.0	2.8	215.6	9.3	0.51	0.01
Phonological	203.2	2.9	206.4	3.0	218.1	4.3	0.48	0.01
Orthographic	215.3	3.1	216.1	3.0	231.8	4.3	0.47	0.01
Unrelated	228.3	3.7	231.4	3.7	261.0	5.9	0.48	0.01

Table 2 Means and standard errors of the three eye movement measures—SFD, FFD, and GZD—on $N-1$ words by preview conditions

Condition	SFD (ms)		FFD (ms)		GZD (ms)	
	Mean	*SE*	Mean	*SE*	Mean	*SE*
Identical	193.9	2.6	195.9	2.5	220.9	4.1
Phonological	199.2	2.8	202.0	2.8	225.9	4.3
Orthographic	194.8	2.7	196.9	2.6	219.7	4.1
Unrelated	196.1	2.8	197.0	2.7	228.8	4.8

effect on target word processing. In an earlier similar study, Baek et al. (2021) examined parafoveal processing of phonological information in Korean by studying a preview benefit effect from words that had the same surface forms as targets (작문 /çakmun/ vs. 장문/çaŋmun/, both pronounced as [çaŋmun] at the surface level). The preview effect found in their phonological condition was not significantly different from that found in their orthographic condition, in which preview stimuli were similar but not identical to targets in orthography as well as in underlying and surface forms (장군 /çaŋgun/ [çaŋgun] - 장문 /çaŋmun/ [çaŋmun]). Taking their results and the current findings together, it appears that underlying phonological information of words is accessed at an earlier stage of lexical processing, thus yielding a preview benefit, whereas surface phonetic information is processed at a later stage, if at all, and has little preview effect. It is thus likely that the phonological preview benefits found in other languages (e.g., Miellet & Sparrow, 2004; Pollatsek et al., 1992) are also the result of parafoveal processing of underlying phonological representations rather than surface phonetic forms of the preview materials. In other words, it is suggested that the phonological information acquired through grapheme-to-phoneme decoding during visual word recognition may be qualitatively different from the phonetic forms that are articulated during speech production or that are acoustically perceived during spoken word recognition.

A possible reason for the earlier processing of underlying phonological information than surface information during Korean word recognition is that Korean alphabets represent the underlying forms of words rather than their surface forms. For example, the second consonant in the word 작문 /çakmun/ is written as 'ㄱ', representing the sound /k/, and not as 'ㅇ', which would represent the sound /ŋ/. Orthographic forms thus guide more rapid processing of underlying information that they directly represent, and only later are surface forms processed, if at all. The precedence of underlying representations over surface representations is very much in line with the key language-universal assumption shared by generative phonological theories that surface representations are derived from underlying representations via the mediation of phonological rules (e.g., Chomsky & Halle, 1968; Kiparsky, 1982) or constraints (e.g., Prince & Smolensky, 1993).

Not only does this interpretation account for why Baek et al. (2021) failed to find a significant phonological preview benefit, but it also dovetails with Yan et al.'s (2009) argument that the type and priority among different information processed parafoveally depends on the nature of the writing system. In alphabetic writing systems such as English, French, and Korean, phonological decoding occurs pre-lexically across saccades during sentence reading. Moreover, the magnitude of beneficial effects of parafoveal phonological processing on target word recognition compared with orthographically similar controls appears to be similar across these languages—GZD differences of 14 ms in English (Pollatsek et al., 1992), 15 ms in French (Miellet & Sparrow, 2004), and 13 ms in Korean (the current study), though more empirical research in Korean should be accumulated.

The results reported here provide implications on how eye-movement control models during reading should be advanced. Although prominent models like E-Z reader (Reichle et al., 1998) or SWIFT (Engbert et al., 2005) propose that linguistic factors such as word frequency or predictability play a crucial role in driving eye movements during reading, they do not incorporate how phonological representation of words shown in a foveal or a parafoveal region influences eye movement control during reading. Recently, Snell et al. (2018) proposed the OB1-Reader model to integrate models of word recognition and of eye movement control in text reading. In the OB1-Reader, orthographic codes like open bigrams are in charge of processes of word identification, which in turn modulate attentional control during normal reading. However, the OB1-Reader also did not implement how phonological information is processed during reading. A couple of concerns seem worth pointing out with respect to implementing phonological processing in models of eye movement control during reading. First, phonological processing in a parafoveal region has a limited effect on word recognition during reading due to the loss of visual acuity (Vasilev et al., 2019). Second, it is substantially difficult to separate the role of phonological processing from that of orthographic processing in languages using alphabetic writing systems. Accordingly, future models should delicately deal with how orthographic and phonological information influence word recognition and eye-movement control during reading.

The current study is the first to find that phonological information of a word is integrated through parafoveal preview during Korean sentence reading. Although Yan et al. (2019) have reported a phonological preview effect, their results do not show a true effect of phonology alone, as they did not separately manipulate orthographic and phonological similarity of stimuli. By using homophones with identical underlying phonological forms, the present study found evidence of parafoveal processing of phonological information in Korean aside from a possible confounding effect of orthography.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.3758/s13414-022-02499-y.

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