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Chi Yui Leung (pp. 16–27)

Can Japanese EFL Learners "See" Before They "Read"?

Chi Yui Leung
Nagoya University

Abstract

Based on empirical evidence from research assessing eye movements during reading, readers are not only aware of information from words fixated upon but also upcoming words. In other words, readers "see" words before they actually "read" them. However, this line of research, which relates to *parafoveal processing* during reading, has focused on first language reading but not on second language (L2) reading. Thus, the current study focused on the following: 1) providing a brief introduction to parafoveal processing, 2) introducing the methods for investigating parafoveal processing, and 3) giving an account of current literature on parafoveal processing during L2 reading. Of specific interest is to discuss whether and to what extent Japanese EFL learners make use of parafoveal information during reading.

Keywords: EFL reading, eye movements, parafoveal processing, perceptual span, gaze-contingent display change

1. Introduction

Eye tracking or eye-movement recording is a powerful method for investigating real-time language processing. Its application in reading studies has grown immensely along with technological advancements since the mid-1970s (Rayner, 1998, 2009a, 2009b). There are two major components for eye movements: saccades and fixations. Saccades are the eye movements that indicate *where* readers' eyes move, while fixations, during which the position of the eyes are relatively static and visual information is acquired, relates to information on *when* readers move their eyes.

Basic characteristics of eye movements for silent reading among native or first-language (L1) readers, according to Rayner (1998, 2009a, 2009b), are as follows. A fixation usually lasts for around 200–250 milliseconds. Saccades that follow textual reading direction (left to right in English), called progressive or forward saccades, usually have an average amplitude of 7–9 letters. Saccades made in the opposite direction to forward saccades (right to left in English) in the same line of text, called *regressions*, usually account for 10–15% of total saccades. Not all words during reading are fixated on; about 25–30% of words are skipped. Words that are short, more frequent, or easily predicted from a prior context are more prone to be skipped as compared to words that are longer, less frequent, or unpredictable from the context.

Whether to skip an upcoming word , word *n* + 1 (relative to the currently fixated word *n*), depends on certain attributes; the *n* + 1 word implies that some of the information from the word *n* + 1 can be *preprocessed* before any fixation is made toward it. This relates to the issue of *parafoveal processing*. Normally during reading, the visual area with the highest qualities, the *fovea*, is relatively small and roughly subtends the currently fixated word (2° in the center of vision). Information related to upcoming words is mostly from parafoveal vision (extending up to 5° on either side of fixation) in which visual acuity is comparatively lower. Nevertheless, as demonstrated by Henderson and Ferreira (1990), as well as Miellet, O'Donnell, and Sereno (2009), to what extent readers make use of parafoveal information depends on *attention* and not solely on visual acuity (for a review, see Schotter, Angele, & Rayner, 2012).

As demonstrated by Henderson and Ferreira (1990), a difficult, currently fixated word *n* (i.e., the foveal word) results in increased attention on the foveal word and diminished attentional resources allocated to parafoveal processing on the word *n* + 1 (i.e., parafoveal word). Since second language (L2) processing is slow and more effortful (e.g., Favreau & Segalowitz, 1982), differences in parafoveal processing between L1 and L2 reading are anticipated. However, most previous research has focused on L1 as compared to L2 reading.

The objectives of the present paper are threefold. First, a brief account of parafoveal processing[1] will be provided, followed by introducing a method for measuring the extent of parafoveal processing. Furthermore, current literature assessing parafoveal processing during L2 reading will be discussed.

2. Parafoveal Processing during Silent Reading

2.1 The Perceptual Span

During reading, the visual area from which a reader can obtain useful information during a fixation, called the *perceptual span*, roughly extends 3–4 letters to the left and 14–15 letters to the right of fixation among native English readers (Rayner, 1998, 2009a, 2009b). It is noteworthy that perceptual span size relates to average word length and number of words instead of merely the number of characters (Schotter et al., 2012). Within the perceptual span, parafoveal vision approximately captures an area of two upcoming words to the right of the fixated word, indicating L1-English readers can make use of visual information from roughly two words to the right of the foveal word (Rayner, 1986; Rayner, Castelhano, & Yang, 2009; Schotter et al., 2012). Nevertheless, information properties acquired during a fixation vary inside the perceptual span. The area that allows more precise letter identification is smaller than the overall perceptual span size is (Häikiö, Bertram, Hyönä, & Niemi, 2009).

The asymmetry of the perceptual span is based on the direction in which attention is allocated. English readers generally pay more attention to the right of fixation when reading English text, which is printed from left to right. Accordingly, during L1 reading for text printed from right to left, such as Hebrew, Arabic, and Urdu, the perceptual span is asymmetric to the left (Jordan et al., 2014; Paterson, McGowan, White, Malik, Adepidour, & Jordan, 2014; Pollatsek, Bolozky, Well, & Rayner, 1981). Nevertheless, when L1-English readers need to reread a sentence and are about to make a regression, the perceptual span expends farther to the left (Apel, Henderson, & Ferreira, 2012). Hence, as Apel et al. (2012) argued, the perceptual span is not a constant but varies during reading, depending on the direction attention is allocated during saccadic programming.

2.2 Influence on Where and When Readers' Eyes Move

The length of a word $n + 1$ is an important factor guiding location of the next fixation.[2] First, as pointed out earlier, shorter words tend to be skipped more frequently (e.g., Brysbaert, Drieghe, & Vitu, 2005; O'Regan, 1979, 1980; Plumber & Rayner, 2012; Rayner & McConkie, 1976). In addition, readers tend to make use of word length information for the word $n + 1$ (with the use of inter-word spaces) to decide the initial fixation position (e.g., Morris, Rayner, & Pollatsek, 1990; O'Regan, 1979, 1980; Plumber & Rayner, 2012). Usually, readers tend to fixate on a position between the beginning and center of the word $n + 1$, which is called the *preferred viewing location* (Rayner, 1979). This cannot be accomplished without parafoveal processing of word length information.

Parafoveal processing also influences when readers' eyes move, which decides fixation durations toward the word $n + 1$ and is related to how word properties are processed parafoveally. Facilitating effects (i.e., lower fixation durations) as a result of parafoveal processing toward the orthographic (e.g., Johnson, Perea, & Rayner, 2007; McConkie & Zola, 1979) and phonological properties (e.g., Ashby & Rayner, 2004; Ashby, Treiman, Kessler, & Rayner, 2006; Pollatsek, Lesch, Morris, & Rayner, 1992) of words $n + 1$ have been well documented. Nevertheless, such facilitating effects from the morphological, lexical, and semantic properties of words $n + 1$ have been subject to several controversies and vary across writing systems (see Schotter et al., 2012).

2.3 Individual Differences in Parafoveal Processing and the Perceptual Span

As parafoveal processing and the perceptual span are modulated by cognitive factors, researchers have been interested in whether readers' reading skills and cognitive abilities influence their use of parafoveal information (see Radach & Kennedy, 2004, 2013). Studies comparing children and adult readers' eye movements have reported that younger children's perceptual spans are smaller than are those of older children and adults (Häikiö et al., 2009; Rayner, 1986), suggesting developmental changes in reading skills in accordance with parafoveal processing. Additionally, reading speed (Ashby, Yang, Evans, & Rayner, 2012; Rayner, Slattery, & Bélanger, 2010), reading comprehension, and spelling skills (Veldre & Andrews, 2014) are all factors modulating the size of the perceptual span among young adult readers. Faster readers, and those with better reading skills, tend to make better use of parafoveal information than do slower and relatively unskilled readers, as slower and low-skill readers focus less attention on foveal processing (Rayner et al., 2010). Osaka and Osaka (2002) reported that readers with a larger working memory span might allocate their attention more efficiently than might readers with a smaller working memory span when parafoveal information is not available. Skilled deaf readers also have a perceptual span extending more than 14 characters to the right of fixation, which is larger than the spans of hearing readers (Bélanger, Slattery, Mayberry, & Rayner, 2012). Furthermore, variations in reading strategy might result in variable reliance on parafoveal information. For instance, older adult readers rely more on prior context because of deteriorated foveal and parafoveal processing, leading to a leftward shift in perceptual span (Rayner et al., 2009).

Based on these aforementioned findings, whereby the use of parafoveal information among L1 readers is sensitive to individual differences, the variability in parafoveal processing between L1 and L2 reading might be quite large. However, few studies have investigated parafoveal processing during L2 reading, which will be further discussed below. The following section introduces a methodology for investigating perceptual span.

3. Gaze-Contingent Display Change Technique

The dominant methodology for investigating parafoveal processing and perceptual span during reading is the gaze-contingent display change technique. This technique synchronizes the display of stimuli on a computer screen with the fixation position of a participant's eye. With this technique, researchers can manipulate how visual stimuli are displayed according to where participants' eyes move. This technique requires the use of a high-speed eye tracker as well as a high-refresh-rate monitor for more accurate eye movement recording. The EyeLink series of eye trackers (SR Research Ltd.) are widely used for this technique. In terms of computer monitors, CRT monitors remain popular. The moving window and boundary paradigms are the two major paradigms utilizing the gaze-contingent display change technique for investigating parafoveal processing.

3.1 Gaze-Contingent Moving Window Paradigm

McConkie and Rayner (1975) developed the gaze-contingent moving window paradigm (for a review, see Rayner, 2014). In this paradigm, an area of text that is visible to participants on a computer screen, called the *window*, moves according to participants' fixation position, with the characters or words outside the window masked. For instance, Figure 1 demonstrates a window condition consisting of two words (word *n* and word *n* + 1) visible to participants during a fixation. By manipulating the size of the window (in numbers of characters or words), the size of the perceptual span can be estimated by changes in reading speed in accordance with a change in window size.[3]

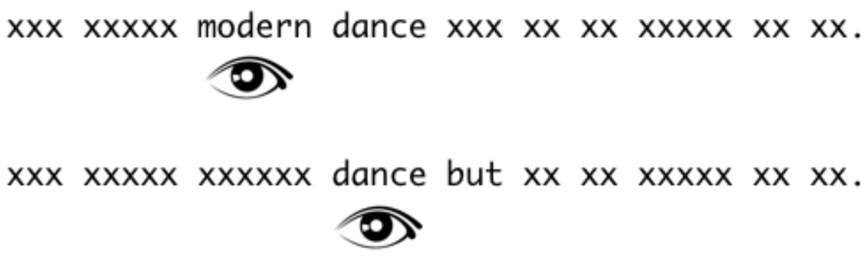

Figure 1. An example of the gaze-contingent moving window paradigm.

3.2 Gaze-Contingent Boundary Paradigm

Rayner (1975) developed the gaze-contingent boundary paradigm. In this paradigm, an invisible boundary is set in the text so that the stimulus display changes when the eyes move across the boundary (see Figure 2). It is particularly useful in investigating the *parafoveal preview benefit* by manipulating preview properties (e.g., "music" as a preview of the target word "dance" in Figure 2).

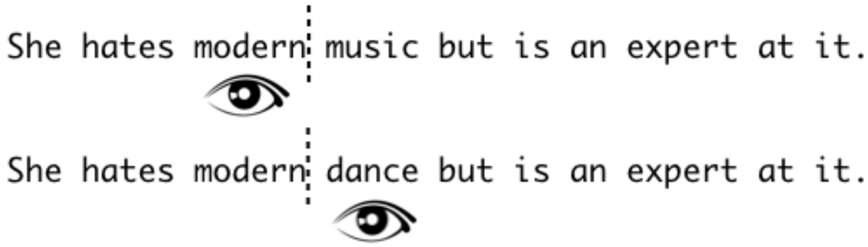

Figure 2. An example of the gaze-contingent boundary paradigm

4. The Perceptual Span during L2 Reading

4.1 The Perceptual Span among Highly Fluent Bilingual Readers

Although the gaze-contingent display change technique is the prominent technique for investigating parafoveal processing and perceptual span, only three studies appear to have adopted this technique for investigating perceptual span during L2 reading. Pollatsek et al. (1981), Jordan et al. (2014), and Paterson et al. (2014) investigated perceptual spans during silent reading among Hebrew-English, Arabic-English, and Urdu-English bilingual readers, respectively. Both perceptual spans during L1 and L2 reading were examined with the gaze-contingent moving window paradigm. The main findings were that although bilingual readers showed a perceptual span asymmetry toward the left during L1 reading (in which text was printed from right to left), the asymmetry reversed when reading English, which was their L2.

The primary objective of these studies lies with the asymmetry of a perceptual span, suggesting that this asymmetry depends on the general reading direction of the text (Jordan et al., 2014; Paterson et al., 2014; Pollatsek et al., 1981). These results indicate that the perceptual span during L2 reading, at least for the asymmetry, is independent from the perceptual span during L1 reading. Second, some data in these studies could be interpreted as the perceptual span during L2 reading being smaller than during L1 reading (Leung, Sugiura, Abe, & Yoshikawa, in press). However, as argued by Leung et al. (in press), there is a lack of direct comparisons between L1 and L2 reading in these aforementioned studies, and participant samples in these studies were limited to highly fluent bilingual readers who used English as a second language.

4.2 Measuring the Perceptual Span among Japanese EFL Readers

Leung et al. (in press) adopted the gaze-contingent display change technique to investigate perceptual spans during L2 reading among readers who used English as a foreign language (EFL) in Japan. The authors followed the gaze-contingent moving window paradigm used in an experiment from Rayner (1986) whereby five conditions with symmetric windows (5C, 11C, 17C, 23C, and 29C; the numbers in the abbreviations represent the number of visible characters in the window) and a baseline condition with no window (NW) were used (see Figure 3). This was done to compare perceptual span sizes between Japanese EFL (*N* = 42) and L1-English readers (*N* = 14).

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5C
  xxxxxxxxxxxxxxxxxx wantxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
                      *
11C
  xxxxxxxxxxxxxxxirl wants txxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
                      *
17C
  xxxxxxxxxxxxl girl wants to axxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
                      *
23C
  xxxxxxxxxiful girl wants to applxxxxxxxxxxxxxxxxxxxxxxxxxxx.
                      *
29C
  xxxxxxautiful girl wants to apply txxxxxxxxxxxxxxxxxxxxxxxx.
                      *
NW
  The beautiful girl wants to apply to go to a junior college.
                      *
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Figure 3. The moving window paradigm used in Leung et al. (in press). The asterisk represents the fixation position.

There were two major findings from Leung et al. (in press). First, while reading rates stopped increasing at the 29C window (i.e., no statistically significant difference in the reading rates between the 29C and NW conditions) among L1-English participants, the increase in reading rates among Japanese EFL readers stopped at the 17C window. This indicated that while results regarding perceptual span sizes replicated previous findings showing that L1-English readers have a perceptual span extending up to 14 characters to the right of fixation, Japanese EFL readers only had a perceptual span extending up to around 8 characters to the right. Second, when splitting the EFL participants into slower and faster groups using a median split based on average reading rates, the faster group showed a larger increase in reading rates with increasing window sizes up to the 17C window compared to the slower group. This suggests that faster

EFL readers tend to make better use of information from the same parafoveal area.

The results of Leung et al. (in press) demonstrated that Japanese EFL learners could make use of parafoveal information to facilitate reading, albeit with a smaller perceptual span than L1-English readers. On the other hand, the results with respect to the faster and slower EFL readers partially supports previous findings indicating that the use of parafoveal information is related to reading speed (Rayner et al., 2010). Slower EFL readers tend to devote more attention on foveal processing, with little attention drawn to parafoveal words (see also Yamashita & Ichikawa, 2010).

The aforementioned results do suggest that even highly fluent and proficient Japanese EFL readers (average reading rate: 176 wpm) may have a smaller perceptual span than do second grade L1-English children as reported in Rayner (1986). This leads to Leung et al.'s (in press) speculation that the relatively small perceptual span among EFL readers may not be solely an indication of processing ability or language proficiency but might also be due to reading strategy. The Japanese EFL readers might simply adopt "a more cautious strategy by paying attention to every word" (Leung et al., in press).

This strategy account suggests the possibility that explicit instructions or class activities related to reading strategies might influence reading performance via better use of parafoveal information. Hence, the underlying factors that account for individual differences in parafoveal processing and perceptual span among Japanese EFL readers deserves further clarification.

5. Closing Remarks

The present paper provided a brief introduction on the literature assessing parafoveal processing and the gaze-contingent display change technique. This was followed by a review of a recent study on perceptual spans among Japanese EFL readers that utilized the gaze-contingent moving window paradigm. The current state of the literature indicates that, similar to L1-English readers, Japanese EFL readers do "see" upcoming words before they actually "read" them. However, compared to L1-English readers, the size of the perceptual span during L2-English reading for Japanese EFL readers is small; the underlying factors for this result are not yet fully known.

Although eye tracking has been increasingly used by L2 researchers since the mid-1990s (for reviews, see Dussias, 2010; Frenck-Mestre, 2005; Keating, 2014; Roberts, 2012; Roberts & Siyanova-Chanturia, 2013), investigations on parafoveal processing during L2 reading with the gaze-contingent display change technique have lagged behind. Without a better understanding of parafoveal processing during L2 reading, interpretations of eye-tracking data among L2 reading studies might be limited. L2 researchers should be aware that, for instance, when analyzing eye-tracking data focused on a target word in a sentence, part of the word information might have been processed parafoveally, and the effects of parafoveal processing might be different between L1 and L2 readers. Further studies are thus required to address the L1-L2 differences in parafoveal processing during reading.

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Footnotes

1. For a detailed review on parafoveal processing, please refer to Schotter et al. (2012). This paper only gives a brief introduction on this topic for researchers interested in second language processing or reading.
2. Although other factors such as word frequency and predictability influence where eyes move, word length is considered the most influential factor (Schotter et al., 2012)
3. As reading rate is only a composite measure that depends on saccades and fixations (Rayner, 1986), other measures such as forward saccade lengths, number of fixations, and fixation durations are normally reported in studies using the gaze-contingent moving window paradigm.

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