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Brief article

Parafoveal processing during reading is reduced across a morphological boundary

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ABSTRACT

A boundary change manipulation was implemented within a monomorphemic word (e.g., *fountaom* as a preview for *fountain*), where parallel processing should occur given adequate visual acuity, and within an unspaced compound (*bathroan* as a preview for *bathroom*), where some serial processing of the constituents is likely. Consistent with that hypothesis, there was no effect of the preview manipulation on fixation time on the 1st constituent of the compound, whereas there was on the corresponding letters of the monomorphemic word. There was also a larger preview disruption on gaze duration on the whole monomorphemic word than on the compound, suggesting more parallel processing within monomorphemic words.

1. Introduction

Much has been learned about eye movements during reading (see Rayner, 1998, 2009 for reviews), but some unresolved issues remain. Arguably, the issue capturing the largest amount of attention in recent years is if readers lexically process more than one word at a time. Studies using the boundary technique (Rayner, 1975, see Fig. 1) established that readers extract information from more than the fixated word. This is apparent from the fact that fixation times on a word are shorter when the letters of the word are visible when the word immediately to its left is fixated than when they were masked (Rayner, 1975). This *parafoveal preview benefit* illustrates that readers obtain information from words located in the parafovea and that more than one word can be processed on a fixation. Thus, the question of whether more than one word is processed at a time becomes whether parafoveal processing begins only after foveal processing has been concluded and attention has shifted to the next word or both words are processed in parallel. The first position has been assumed in serial models of lexical processing during reading such as the E-Z Reader model (Reichle, Rayner, & Pollatsek, 2003), whereas the parallel view is embodied in models such as SWIFT (Engbert, Nuthmann, Richter, & Kliegl, 2005).

This controversy has been fuelled by observations of *parafoveal-on-foveal* (PoF) effects (Kennedy, 2000; Murray, 1998) wherein characteristics of the word to the right of fixation influence the fixation duration on the currently fixated word. It is assumed that such effects are damaging to the serial assumptions of the E-Z Reader model. However, the existence of these effects is highly contested (see Rayner, White, Kambe, Miller, & Liversedge, 2003 for a review) and because the E-Z Reader model incorporates occasional mislocated fixations (Nuthmann, Engbert, &

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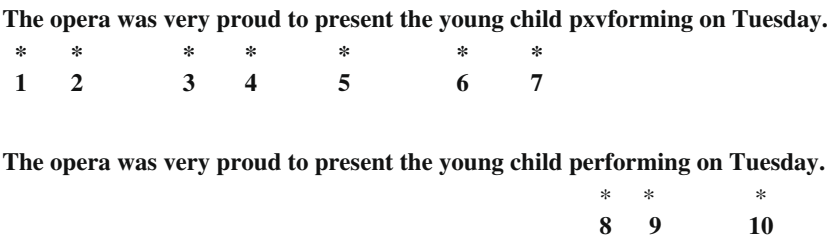

Fig. 1. An example of a boundary change experiment. In this example, the target word is *performing*. When the participant begins reading the sentence, the 2nd and the 3rd letter of the target word are replaced with visually similar letters (so that *pxvforming* is initially present). When the reader's eye movement crosses an invisible boundary at the end of the word preceding the target word, *pxvforming* changes to *performing*. The asterisks represent the location of each fixation (with the numbers indicating the sequence of fixations).

Kliegl, 2007), it can account for small and/or sporadic PoF effects (Drieghe, Rayner, & Pollatsek, 2008).

However, an important point is missing from this discussion. That is, much emphasis has been placed on whether serial or parallel models of lexical processing during reading are a better account of the results of *between-word* boundary change experiments that examine the benefit of previewing a word before it is fixated on processing time when it is fixated. Although the models differ in how the effect is accounted for, both naturally predict preview benefit in such a paradigm. In the current study, we focus on the processing that takes place *within* a word.

Data from recent experiments employing the boundary paradigm to examine lexical processing within compound words (Juhasz, Pollatsek, Hyönä, Drieghe, & Rayner, 2009; White, Bertram, & Hyönä, 2008) seem problematical for a parallel model. In these experiments, the 2nd constituent of an unspaced compound word was partially masked (*basketbadk* as a preview for *basketball*), and the resulting parafoveal preview benefit[1] on the 2nd constituent was considerably larger (100 ms in measures that included regressions out of the 2nd constituent) than typically observed between words (20–40 ms). However, this effect was restricted to measures on the 2nd constituent and there was no (within-word) PoF effect of the preview manipulation of the 2nd constituent on the initial viewing time on the 1st constituent. The lack of a PoF effect on the 1st constituent indicates that the initial encoding processes of longer compound words may be largely serial across the constituents. The hypothesis that the constituents of a compound word are, to some extent, independent processing units is also consistent with the fact that the frequency of the 1st and 2nd constituents each affect the fixation time on a compound word (Hyönä, Bertram, & Pollatsek, 2004; Pollatsek & Hyönä, 2005). However, other experiments have shown that the frequency of the whole compound word also influences gaze duration on the word (Juhasz, 2008; Pollatsek, Hyönä, & Bertram, 2000) and that the whole-word representation also plays a part in identifying these words. Pollatsek et al. (2000) proposed a race model in which a morphemic decomposition process and a whole-word direct-access occur in parallel, but with a preference for whole-word look-up when the compound is short, as research has shown constituent frequency effects to be more elusive for short Finnish compounds (Bertram & Hyönä, 2003).[2]

More generally, researchers agree that processing is parallel when it takes place *within* a morpheme (Rayner & Johnson, 2005) as long as the morpheme falls within the word identification span, extending 7–8 letter positions to the right of fixation (Rayner, 1998). However, the data just discussed indicate that constituents within morphemically complex words may not be processed in parallel. Thus, we wanted to determine whether the limit to what is processed in parallel during a fixation is determined by "deeper" properties of the input such as morphemic complexity rather than surface features such as length. To test this hypothesis, we implemented a boundary change manipulation *within* a monomorphemic word and compared it to a boundary change within an unspaced compound word.

The current experiment is the first to implement a boundary change manipulation in a situation in which lexical processing is uncontroversially parallel (i.e. within the currently fixated morpheme given adequate visual acuity). The "depth" hypothesis above makes the following predictions about the differences between processing of a monomorphemic and compound word of equal length.

1. The disruption of having an incorrect preview of the 2nd part of the word should be greater for the monomorphemic word than for the compound word. That is, we hypothesize that all letters of monomorphemic words are processed in parallel, whereas the 2nd constituent of the compound words would be processed in a shallower manner due to there being a priority of processing the first constituent first.
2. Thus (as with Juhasz et al., 2009), there should be little or no PoF effect of the preview manipulation on the 1st constituent of a compound, whereas there should be a substantial PoF effect on the corresponding letters of a monomorphemic word.

[1] Consistent with the literature, the term 'parafoveal preview' is used although due to the proximity of the 2nd constituent, it often will fall in foveal vision.

[2] Juhasz (2008) and Juhasz, Pollatsek, Hyönä, Drieghe, and Rayner (2009) examined compound processing in English, whereas the other studies in this paragraph examined Finnish compounds. Juhasz (2008) found that short English words are decomposed into their constituents during processing.