Evaluating DRC and PDP models of Reading by a Magnetoencephalography Study: Length and Lexicality Effects during Reading

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Abstract
Silent reading with occasional reading aloud Finnish words and nonwords were used in a Magnetoencephalography study to examine the neural correlates of length and lexicality. Length effects were observed in two spatially and temporally distinct cortical activations: in the occipital cortex at about 100ms, and also in the left superior temporal cortex between 200 and 600 ms. A significant lexicality effect was only evident in the later activation. On the basis of the obtained activation patterns, DRC and PDP models of reading were evaluated. It was concluded that neither models can satisfactorily account for the present MEG data.

Key words: length/lexicality effects in readng; magnetoencephalography (MEG); occipital cortices; left superior temporal cortex; reading models

Introduction

Cognitive behavioural research into reading has shown that in alphabetic languages, the letter-string length affects the naming latencies of words and nonwords: as string length gets longer, so do the naming latencies (e.g., Balota & Chumbley, 1985; Rastle & Coltheart, 1998; Weekes, 1997). For words, this length effect is modulated by word frequency: low-frequency words show a larger length effect than high-frequency words (Content & Peereman, 1992), and often high-frequency words show no length effect (Weekes, 1997).

Dual-route models of reading typically assume that reading involves both a lexical reading strategy which operates in parallel across the input string, and a sub-lexical reading strategy which requires sequential decoding of the string (e.g. Coltheart et al., 1993). It is also assumed that for a regular orthography such as Finnish, the emphasis is more likely to be placed on the sub-lexical reading strategy (e.g., Turvey et al., 1984; Hudson & Bergman, 1985). Length effects on naming latency therefore reflect the sequential sub-lexical reading strategy, and the size of the effects is determined by the extent to which sub-lexical processing is involved (Rastle & Coltheart, 1998).

In order to account for length effects with the connectionist models, Plaut (1998) developed a particular single-route connectionist model where serial processing mechanisms were implemented at two loci – at the visual input and the articulate output levels. The model assumes that when pronouncing a letter-string, the sequence of phonemes corresponding to its pronunciation are activated, while the position of the grapheme is tracked at the same time. If all the phonemes and their positions are generated correctly, the activations over the letter units remain fixed. Otherwise the model refixates the input string and tries again, often producing a length effect. Accordingly, the model generates a pronunciation phoneme-by-phoneme, also and invariantly producing a length effect. Seidenberg & Plaut (1998) thus argued that length effects on naming latency are due largely to peripheral mechanisms including visual and articulatory factors outside the central processors relating to orthography, phonology and semantics.

MEG measures the neuromagnetic fields generated by synchronous macroscopic activation in cortical pyramidal cells (Hämäläinen et al., 1993). Studies utilising MEG have provided information of cortical activation sequences during reading (e.g., Salmelin et al., 1996)

In the current MEG study, length and lexicality during reading were manipulated, in order to evaluate these theoretical models of reading.

Methods

4 male and 4 female Finnish adults participated in a reading task where the stimuli consisted of short (S, 4-letter) and long (L, 8-letter) Finnish words (W) and nonwords (NW). Cortical activation sequences were mapped using a Vectorview-306 whole-head MEG system.

Results

Signal processing during reading advanced from the posterior visual to temporal cortices bilaterally as with the existing MEG studies [4]. Two distinct regions of activation emerged: one in the occipital cortex, with the maximum deflection at about 100 ms (Fig. 1, upper), and the other in the left temporal cortex, showing sustained activation between 300 and 600 ms (Fig.1, lower). For the early occipital responses, a 2x2 (length by lexicality) ANOVA revealed a significant length effect in the peak amplitudes. In contrast, for the temporal responses, significant effects of both length and lexicality were evident in the duration of the activity. The length effect was far more pronounced for the nonwords.

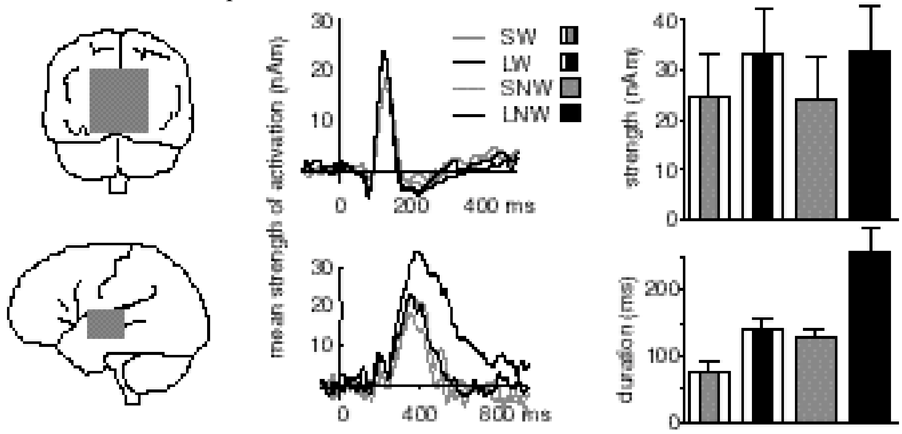

Figure 1. Occipital length (above) and left temporal length and lexicality effects (below).

Discussion

The length effect in the early occipital sources likely reflects the physical size of the stimulus, i.e. longer strings evoke larger neural populations. At this early occipital sources, there was no leicality effect. The later temporal sources showed both length and lexicality effects. The interpretation of the left superior temporal activation reflecting phonological processing is in keeping with several imaging studies of word processing (e.g., Bookheimer et al., 1995; Price, 1997; Price et al., 1996; Pugh et al., 1996; Rumsey et al., 1997; Fiez and Petersen, 1998; Paulesu et al., 2000). The reduced length effect for the real words is likely to reflect the influence of lexical/semantic processing. Imaging data lend some support to the left superior temporal activation playing a role in lexico-semantic processing (e.g. Just et al., 1996; Price et al., 1997), particularly in this time window (Helenius et al., 1998).

Dual-route models assume that the lexical and sub-lexical routes, which require qualitatively different processes, could be subserved by two distinct cortical networks. This interpretation is not supported by the present data. Also, Plaut's assertion of the later length effect essentially arising at the generation of output phonology at the peripheral level is difficult to reconcile with current MEG data. It appears that neither dual-rote models nor single-route connectionist models of reading can satisfactorily explain the current MEG data

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