Neuronal Processes involved in Reading: Brain imaging Studies and Implications for Developmental Dyslexia

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Wydell & Butterworth (1999) presented a case study of AS, an English-Japanese bilingual adolescent boy with monolingual dyslexia in English. In order to account for the dissociation between his ability to read Japanese (both Kana and Kanji) and English, Wydell & Butterwoth postulated the Hypothesis of Transparency and Granularity. The hypothesis predicted that the occurrence rate of developmental dyslexia, in particular the most common form of dyslexia in English, phonological dyslexia, in transparent shallow orthographies is low (e.g., Italian or Serbo-Croatian). It is also low in opaque deep orthographies with large granules of print-to-sound mapping (e.g., Kanji or Chinese). A developmental dyslexic individual may have certain cognitive deficits (e.g., poor short-term memory) which may have a genetic origin. However, this deficit does not necessarily cause dyslexia in every language. The determining factor is in the orthography (see Wydell & Butterworth (1999) for more detail).

The recent brain imaging study with PET by Paulesu et al (2000) lends further support to the hypothesis. Namely they suggest that different orthographies can powerfully shape neurophysiological systems. Italians rely more on a sub-lexical procedure which can be localized to the left superior temporal region (including the left planum temporale - at the temporoparietal junction, a brain area that has been linked to phonological processing). In contrast, English subjects rely more on a lexical/semantic procedures to a left frontal and a posterior inferior temporal regions.
Although both Italian and English subjects activate these areas, experience might optimize their use of these procedures for the orthography they use. Thus, the left superior or temporal, posterior inferior temporal and frontal areas are sensitive to the orthographic consistency of a given language, and these areas are critically involved in reading (i.e., derivation of phonology from orthography). This suggests that each orthography requires slightly different but specific neural populations from each other for reading. This is intuitively plausible, since English orthography for example requires finer tuning of grapheme-to-phoneme mapping compared to shallow orthographies such as Italian. For example, given examples like mint/pint; love/clove; bead/head; dough/tough/bough/cough, it is apparent that the grapheme-to-phoneme mapping is not straightforward (see Wydell & Butterworth for more detail). Then, it is not surprising to see a bilingual individual who is a fluent reader in one language but dyslexic in the other, like AS.
Rumsey et al (1997) reported in their PET study that English dyslexics activated less, compared to normal controls, a region near the left superior temporal area identified by Paulesu et al.

On the other hand, Salmelin et al (1996) using a different brain imaging technique called MEG (magnetoencephalography) revealed that in Finnish, another transparent alphabetic orthography like Italian, their dyslexics failed to activate the left inferior temporo-occipital region. Positron emission tomography (PET) studies in English (e.g., Petersen et al, 1990) suggested that this area is associated with word form perception.
Similarly, intracranial recordings of the inferior temporal sulcus and fusiform gyrus showed letter-string-specific responses within 200 ms after stimulus onset (Nobre, Allison, McCarthy & Wood, 1994). Salmelin et al. thus suggest that perception of words as specific units appears to be impaired in Finnish dyslexics.
According to Salmelin et al. (personal communication), their Finnish dyslexics were

identified as such BY their slower rate of reading or phonological processing. For example, the dyslexics were significantly slower than normal controls when they were asked to read the digits on a page sequentially one after the other as fast as possible (NB: Similar tasks have been used in conJunction with other tasks by other researchers to identify English or German dyslexics (e.g., Frith, 1999)). Salmelin et al. thus concluded that dyslexia (at least for Finnish) may be due to visual perceptual rather than phonological deficit.

In the same paper, Salmelin et al. also reported a striking difference between the dyslexics and normal subjects - the normal controls activated strongly the left temporal lobe, while the dyslexics did not activate this area at all in the time window between 200 and 400 ms after stimulus word presentation. Apart from reporting this finding, they did not further expand on it. This is probably because (my own speculation) they assumed that in the time course of activation, signals from temporo-occipital region were not sent forward to the later processor, the left termporal region, since no activation in the left inferior temporo-occipital region was observed.

It is difficult to generalize these findings from different imaging studies, and it is not even certain if they can be generalized. This is because many variables involved in the studies differ from study to study. For example, (a) definition or criteria used to identify dyslexic individuals may be different; (b) different orthographies were used; (c) different brain imaging techniques were utilized, (d) different experimental paradigms were used and so forth. In order to conduct A truly a cross-linguistic study into dyslexia or normal reading processes using brain imaging techniques, these variables will have to be well controlled (NB: Paulesu et al's (2000) is an exception).

It was thus decided to conduct two MEG studies to identify dynamic brain activation during reading with the same experimental paradigm using two different but transparent orthographies, namely Finnish and Japanese Katakana with normal Finnish and Japanese subjects respectively.

If the neurophysiological language system is only sensitive to the orthographic consistency then the neural activation pattern will be the same or at least very similar between the two shallow orthographies.

Similar brain areas would be activated for both orthographies.

However, if processing is sensitive to the characteristics or nature of the orthography, for example, if the orthography alphabetic or non-alphabetic, then slightly different activation patterns or differently activated areas may be observed.Only preliminary findings will be presented, since the data collection hasstill being carried out.