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Trait and state EEG indices of information processing in developmental dyslexia

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Abstract

A possible key to understanding the nature and specificity (or otherwise) of the difficulties experienced by children with developmental dyslexia can be found by comparing event-related EEG changes in tasks directly related to their reading difficulties with those in tasks where their performance is normal. Alpha, theta and beta activity at 28 electrode sites was measured in 19 children with developmental dyslexia and 22 age-matched children with normal reading ability, allowing comparisons at right and left frontal, temporal and parieto-occipital sites. EEG responses during a phonological processing task in which the dyslexic group significantly under-performed was compared with EEG responses during a visual search task (WISC Picture Completion) where the dyslexic children showed no deficit. There were significant Task × Group differences in task-related alpha desynchronisation, task-related beta left–right asymmetries and task-related frontal theta inhibition. In both tasks, EEG responses from the dyslexic group were characterised by a lack of task-related reduction from resting levels in the amplitude of alpha frequency responses. There was a marked parieto-occipital R > L asymmetry in beta activity in the dyslexic group, again in both tasks. Theta activity did discriminate between the two tasks in the dyslexic group. In the phonological task, task-related frontal theta in the dyslexic group was significantly different from the control group, with the former showing an increase in amplitude and the latter a decrease. In the visual task, there was no significant difference between the dyslexic and the control group, with both showing a task-related decrease in amplitude. The inter-task *variations* in EEG response in the dyslexic group paralleling variations in task performance are interpreted in terms of the varying engagement of a frontally-based attentional system. Inter-task *consistencies* of EEG response despite variations in performance are interpreted in terms of the continued application of a specific cognitive strategy.

Keywords: Dyslexia; EEG; Alpha, theta and beta responsivity; Frontal and parieto-occipital activation

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1. Introduction

Recent developments in the application of more sophisticated metrics to the analysis of electrical activity of the brain have produced what Gruzelier (1996) has described as a 'renaissance in the application and value of EEG methodology'. Within- and between-frequency comparisons using such metrics have generated more detailed descriptors of the association between varying EEG states and specific cognitive processes, such as alpha and attention and memory processes (Basar et al., 1997; Klimesch, 1997); delta and internal attention (Harmony et al., 1996); and theta and episodic memory (Klimesch et al., 1996, 1997). Sophisticated statistical modelling approaches can identify the underlying spatiotemporal dynamics of task-related variations in different EEG frequencies (Lehmann and Koenig, 1997; Anokhin et al., 1999) and have revealed the importance of gamma activity (Basar-Eroglu et al., 1996). Additionally, Klimesch et al. (1990) and Burgess and Gruzelier (1997) have demonstrated the localising potential of EEG measures, demonstrating that alpha and beta changes can validate the identity of discrete cortical areas independently indicated as involved in specific tasks.

Tracking EEG changes between and within specific types of tasks can therefore provide insights into the stages and strategies involved in carrying out such tasks. It also means that one can use such indices to investigate individual differences in task performance (Klimesch et al., 1996) or, where there are significant performance deficits, to gain insight into the source and nature of such difficulties (e.g. Samson-Dolifus et al., 1996; Rippon and Brunswick, 1998).

The present paper is an attempt to draw on such insights in the interpretation of EEG data obtained from a group of children with developmental dyslexia or specific learning difficulty, here defined as a difficulty in learning to read despite normal intellectual development and appropriate educational opportunities. The term specific learning difficulty refers to the discrepancy between children's poor performance in reading and related tasks when compared with their achievements in other academic areas. Cognitive models put phonological processing problems centre stage (Bradley and Bryant, 1983; Snowling, 1991), although other theorists emphasise processing speed (Nicolson and Fawcett, 1995) and working memory (Hulme and Roodenrys, 1995).

A range of techniques have been used to investigate structural and functional differences in brain organisation. A key aspect of neuropsychological models of dyslexia concerns a reduction in both structural and functional asymmetry in brain organisation and a range of measures have informed such models [see reviews by Boliek and Obrzut (1995) and Hynd et al. (1995)]. Some researchers have identified this reduction in asymmetry as arising from right hemisphere anomalies. Larsen et al. (1990), using MRI techniques, report a larger right than left planum temporale in dyslexics and Naylor et al. (1990) using rCBF techniques, also describe right hemisphere anomalies,

EEG measures could provide the link between the biological bases and the presenting cognitive 'symptoms'. During specific tasks, several studies report EEG differences between children with dyslexia and competent readers. Higher levels of theta and lower levels of beta in poor readers viewing words and letters were reported by Ackerman et al. (1995) and Flynn et al. (1992) reported lower levels of beta in dysphonetic dyslexics during reading tasks. Differences in task-related EEG asymmetries have also been reported, most commonly in the parietal areas, but the direction is not consistent. The beta differences reported by Flynn et al. (1992) occurred at *right* parietal and occipital leads in dysphonetic dyslexic compared to controls. Ortiz et al. (1992) found higher levels of *left* hemisphere alpha in the central, temporal and parietal regions and lower levels of *left* hemisphere beta 2 in the parieto-occipital regions in dysphonemic dyslexic children during a phonemic discrimination task.

However, there has been little or no attempt to link the new insights into the association between different frequency bands and specific cognitive processes to the observed EEG differences in children with developmental dyslexia. Linking