

## Children with dyslexia and right parietal lobe dysfunction: event-related potentials in response to words and pseudowords

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### Abstract

Hari and Renvall (*Trends Cogn. Sci.*, 5 (2001) 525) proposed that dyslexic children suffer from sluggish attention deployment due to a right parietal lobe dysfunction. To examine this hypothesis, good and poor readers (12, 11-year-old boys in each group) had to read familiar words (low attentional demand) and pseudowords (high attentional demand). The amplitude of the event-related potential at around 100 ms post-stimulus (N1) in response to words and pseudowords was used as measure of attention deployment. Consistent with the attention deficit/right parietal lobe dysfunction hypothesis, poor readers showed lower N1 amplitudes in response to pseudowords, but not in response to words at central sites of the right hemisphere. However, poor readers also showed lower N1 amplitudes to both words and pseudowords at left frontal sites suggestive of an early deficit in activating phonological codes. © 2002 Elsevier Science Ireland Ltd. All rights reserved.

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Evidence for right parietal lobe involvement in reading comes from a recent brain imaging study [6] with normal adult readers. Compared to same-case words with low attentional demands, both mIxEd-cAsE words and pseudowords (independent of case format) led to specific activation in a large area of the right parietal lobe, which is associated with disorders of visual attention [3]. The present study used the first middle latency component of the event-related potential (ERP) in response to visually presented words and pseudowords to examine the right parietal lobe dysfunction hypothesis of Hari and Renvall [2]. This component is a negatively deflected wave (N1) starting at about 70 ms and peaking shortly after 100 ms, the amplitude of which was found to be responsive to attentional demands [5]. From the above mentioned hypothesis it follows that dyslexic compared to normal readers should show reduced N1 amplitudes at sites corresponding to the right parietal lobe and that this should be particularly so for pseudowords with higher attentional demands.

Participants were German-speaking, right handed boys with good and poor reading skills (12 in each group) who were selected from a large longitudinal sample after obtain-

ing informed consent from both parents and child. At the time of participation, they were in Grade 5 and about 11 years old. The typical reading problem of the poor readers was impaired reading fluency and not errors, because German exhibits rather straightforward grapheme-phoneme relations [4]. The selection of the groups was based on an assessment of the longitudinal sample of 530 boys with an individually administered reading test in Grade 3. Poor readers had to score below percentile 10 on a combined reading fluency score, the good readers had to score at least close to average. For word material (text reading, word list reading), the reading rate of the poor readers was only 70 syllables per minute, that of the good readers was 181 syllables per minute. The poor readers exhibited non-verbal IQ scores in the normal range, mean 102, and were slightly older than the good readers with means of 139 and 135 months, respectively.

The EEG was recorded while participants read silently singly presented words and pseudowords. To enforce close attention to stimuli, each item had to be read out aloud in response to a prompt which followed item presentation. Item length was 7–8 letters (lower case, 3 cm high, distance to screen about 1.4 m). A trial consisted of the following events: fixation cross (500 ms); item (2000 ms); prompt (1000 ms); blank screen (1500 ms). The long item presentation time and the long interval between the items was

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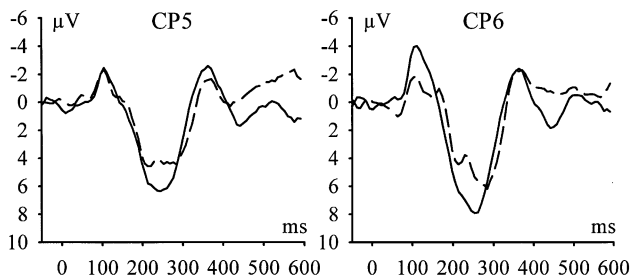


Fig. 1. Grand averages of the event related potential in response to pseudowords for good readers (solid line) and poor readers (dashed line) at a left and a right centroparietal site.

required to give dyslexic participant a chance to successfully read the pseudowords. Several practice trials familiarized participants with stimuli and procedure and, particularly, with holding back the reading response until appearance of the prompt.

Seventy five numberwords and 75 pseudowords were presented in blocks (order counterbalanced). The 75 numberwords consisted of 15 different words, each occurring five times. The German words for the numbers from 13 to 19 and for the decades from 20 to 90 were used. As in the English equivalents, these numberwords consist of two syllables. The pseudowords were constructed by replacing each syllable of the numberwords by a new similar syllable. To illustrate, vierzehn (14) was converted to sierzohm, vierzig (40) to sierzeb, achtzehn (18) to uchtzohm, achtzig (80) to uchtzeb and so on. For the poor readers, the pseudowords were still difficult to read within 2000 ms with only 63% correct, compared to 97% for the good readers. The numberwords posed little difficulty with even the poor readers showing close to perfect accuracy.

For the present analysis, based on N1 amplitude as a

measure of attention deployment, only components with negative deflection in the defined time range were analyzed. This led to the exclusion of all electrode sites more posterior than centroparietal, because at these sites the polarity of the first peaks were positive (occipital sites) or the polarity of the peaks varied between participants or the peak amplitudes were very small (parietal and parieto-occipital sites). Because of these and the already mentioned exclusion of the temporal sites, only fourteen sites were used for analyses. Fig. 1 illustrates the ERP waveform at left and right centroparietal sites in response to pseudowords. It also illustrates the right central N1 amplitude deficit of the poor readers.

Statistical analysis was based on individually determined peak amplitudes, which were measured relative to the prestimulus interval. For each participant, the peaks of the N1 component were determined automatically within a time window from 50 to 150 ms. In the case of two peaks or a broad peak, the latency of the N1 peaks at the majority of sites was taken as a guideline [7]. The mean N1 amplitudes for words and pseudowords of the good and poor readers at each of the 14 sites are graphically represented in the maps given in the first two columns of Fig. 2. The frontal electrode sites – represented by the first row of dots from left to right – are F3, Fz, F4; the frontocentral sites – second row left to right – are FC5, FC1, FC2, FC6; the central sites are C3, Cz, C4; the centroparietal sites are CP5, CP1, CP2, CP6. The differences between the good and the poor readers in mean N1 amplitude are represented in the maps given in the third column. Obviously, the reference of the colours of the difference maps differs from that of the preceding maps representing group means. From the difference map for words it is evident, that poor readers showed lower amplitudes at left frontal sites. *T*-test comparisons of means found the deficit to be reliable ( $P = 0.01$ ) at F3 and to be of

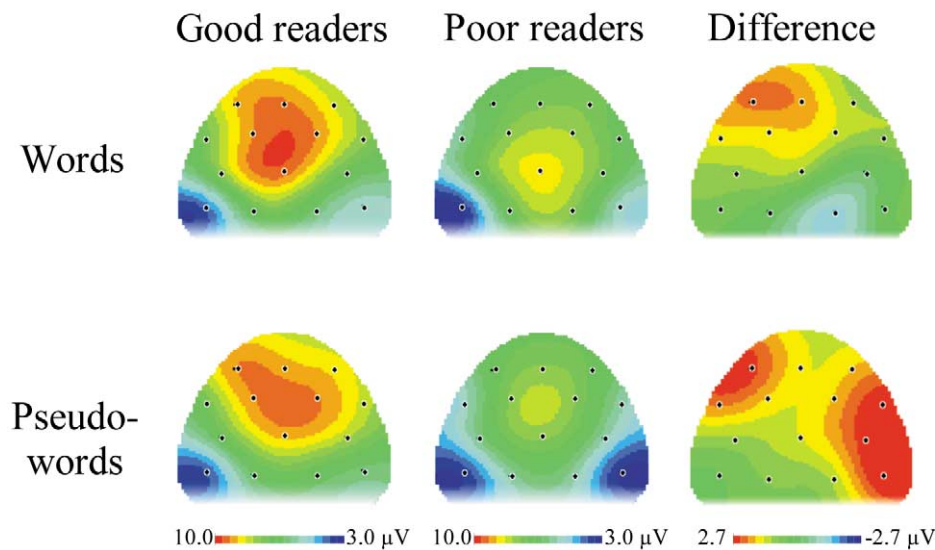


Fig. 2. Distribution of N1 amplitudes to words and pseudowords of good and poor readers and distribution of the amplitude differences between good and poor readers.

borderline reliability ( $P = 0.06$ ) at FC5. The difference map for pseudowords shows a different distribution. Again, the poor readers showed reliably ( $P < 0.05$ ) lower N1 amplitudes at the left frontal sites F3 and FC5. However the poor readers also showed lower N1 amplitudes (all  $P < 0.05$ ) at the right central sites FC6, C4 and CP6. To illustrate, at C4 the means for good and poor readers were  $-7.97$  (SD = 2.38) and  $-5.56$   $\mu\text{V}$  (SD = 2.39), respectively,  $t(22) = 2.57$ ,  $P = 0.018$ .

Further evidence on the functional significance of the right central region in attentional deployment and pseudoword reading came from a visual reaction time task which was administered 1 year before the EEG study as part of a longitudinal assessment. This task required children to press the left or right button of a box in response to a left or right oriented arrow on the monitor (seven practice, 20 test trial). Substantial correlations were only found between pseudoword elicited N1 amplitudes (absolute values) and visual reaction time, and these substantial correlations were only found at the right hemisphere sites FC6, C4, CP2 and CP6 with  $-0.41$ ,  $-0.52$ ,  $-0.42$ , and  $-0.54$ , respectively (all  $P < 0.05$ ). At the corresponding left hemisphere sites FC5, C3, CP1 and CP5, these correlations were all low and non-reliable:  $-0.16$ ,  $-0.13$ ,  $-0.24$ , and  $-0.10$ , respectively. From the reduced N1 amplitudes at left frontal sites, one would expect correlations between N1 amplitude differences at these sites and reaction times. However, this was not the case. Neither N1 amplitudes elicited by pseudowords at these sites nor N1 amplitudes elicited by words were associated substantially with the reaction time measure, all correlations  $< -0.28$ ,  $P > 0.05$ .

The general pattern of our ERP findings is consistent with the mini-neglect perspective on dyslexia proposed by Hari and Renvall [2]. According to these authors, dyslexia is caused, in part, by a problem with the automatic triggering and shifting of attention due to right parietal lobe dysfunction. Hari and Renvall came to this conclusion by examining behavioural evidence from low-level visual and auditory tasks which require processing of rapidly presented stimuli. The performance of dyslexic individuals – although less severely impaired – was likened to that of neglect patients and led to the inference of right parietal lobe dysfunction. The present ERP findings are consistent with the attention deficit/right parietal lobe dysfunction hypothesis. At right central electrode sites, the poor readers showed lower N1 amplitudes in response to pseudowords which require close attention to the letters and their sequence. Further support is provided by the specific associations between pseudoword elicited N1 amplitudes and visual reaction time at right central sites.

However, this support for the attention deficit/right parietal lobe dysfunction hypothesis has to be qualified. An alternative interpretation would be that the N1 amplitude deficit of the poor readers in response to pseudowords may not reflect a basic, biologically founded attentional deficit, but a deliberate strategy to reduce the visual input when proces-

sing pseudowords. The poor readers, when confronted with difficult pseudowords, may prefer to limit attention to a small number of letters, and it is this strategic choice which is reflected in reduced N1 amplitudes. The strategic reduction of attention may be due to lower efficiency in grapheme-phoneme coding. Here it is important to remember that the poor readers had difficulty to come up with correct readings of the present pseudowords within the presentation time of 2 s. A further qualification relates to the finding that the poor readers not only showed a right central N1 amplitude deficit in response to pseudowords, but also a left frontal deficit in response to both pseudowords and words. Interestingly, the left frontal N1 amplitude differences were unrelated to visual reaction time. One may reason that the left frontal N1 amplitude deficit of the poor readers reflects an early occurring deficit in the activation of phonological codes in response to letter strings. Such an interpretation would be consistent with findings from functional brain-imaging studies which found lower activation at left hemisphere regions when dyslexic persons had to read pseudowords e.g. [1,8,9].

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