



Short Communication

Is the impaired N170 print tuning specific to developmental dyslexia? A matched reading-level study with poor readers and dyslexics



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ARTICLE INFO

Article history:

Accepted 29 September 2013

Available online 19 October 2013

Keywords:

Developmental dyslexia

Poor readers

Reading-level matched design

N170 print tuning

Phonological mapping deficit theory

ABSTRACT

Left N170 print tuning has been associated with visual expertise for print and has been reported to be impaired in dyslexics, using age matched designs. This is the first time N170 print tuning has been compared in adult dyslexics and adult poor readers, matched in reading level. Participants performed a lexical decision task using both word-like stimuli and symbol strings. In contrast to dyslexics, poor readers displayed similar N170 tuning to control expert readers, suggesting that impaired N170 specialization is a hallmark of developmental dyslexia. Our findings provide electrophysiological support for dyslexia being the result of abnormal specialization of the left occipito-temporal areas involved in the expert processing of print. Furthermore, as shown by correlations data and in accordance with the phonological mapping deficit theory, the impaired visual expertise for print described in dyslexics may have been caused by their core phonological deficits.

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1. Introduction

Visual expertise for print allows rapid identification of written words regardless of major variations in their physical characteristics such as their size, font, case, color, or location in the visual field. Event related potential (ERP) studies have associated the N170 component, which peaks at around 200 ms at occipito-temporal sites, with the expert processing of certain classes of visual stimuli. Some experiments have indeed pointed to increased bilateral N170 amplitude for pictures of birds, dogs (Tanaka & Curran, 2001) or cars (Gauthier, Curran, Curby, & Collins, 2003) compared to control stimuli in experts in these categories. Other studies have shown increased right N170 amplitude in response to faces compared to visual control stimuli (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Rossion, Joyce, Garrison Cottrell, & Tarr, 2003). Magnetoencephalographic (MEG) data have also shown increased inferior occipitotemporal cortex activation, with right hemispheric dominance, in response to faces than to other stimuli around 150 ms after stimulus presentation (Tarkiainen, Cornelissen, & Salmelin, 2002). In the field of reading research, several studies have reported left N170 print tuning in skilled readers (Brem et al., 2006; Maurer, Brem, Bucher, & Brandeis, 2005; see Maurer & McCandliss, 2007 for a review). Results showed larger N170 amplitude for word-like stimuli than for visual non-orthographic

stimuli such as symbol strings in adult expert readers. The N170 component has been associated with neural activity of the left inferior occipitotemporal cortex in MEG studies (Tarkiainen, Helenius, Hansen, Cornelissen, & Salmelin, 1999; Tarkiainen et al., 2002) and more specifically with the visual word form area (VWFA; Cohen et al., 2000) in studies combining ERP and functional magnetic resonance imaging (fMRI, Brem et al., 2006) or using ERP source analysis (Brem et al., 2006; Maurer et al., 2005).

Investigation of N170 print tuning has become of particular interest in reading disorders. Developmental dyslexia is defined as a specific impairment in reading acquisition that occurs despite normal intelligence and adequate schooling, and in the absence of other cognitive, sensorial, psychiatric, and motivational disorders (World Health Organization, 1993). Dyslexia has been associated with core phonological deficits (Ramus & Szenkovits, 2008; Snowling, 2000), with impaired integration of orthographical units into phonological units (Blau, van Atteveldt, Ekkebus, Goebel, & Blomert, 2009; Blomert, 2010; Rack, Snowling, & Olson, 1992; Sprenger-Charolles, Colé, Lacert, & Serniclaes, 2000). To date, investigation of visual expertise for print in dyslexia has led to two major findings. The first finding suggests that in dyslexics, N170 print tuning is characterized by a developmental delay. Two longitudinal ERP studies were carried out with dyslexic children (Maurer et al., 2007, 2011). Results showed N170 print tuning in control children during their first steps of reading acquisition (e.g., second grade, mean age of 8.3 years). In contrast, N170 specialization occurred later in dyslexics (e.g., fifth grade, mean age 11.5 years). This finding suggests a different developmental trajectory of N170 specialization in dyslexic children, with a need for

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additional reading practice. The second finding suggests a persistent deficit in N170 print tuning in dyslexia. First, ERP data in children (fourth to sixth grade, mean age 10.7 years; Araújo, Bramão, Faísca, Magnus Petersson, & Reis, 2012) as well as MEG (Helenius, Tarkiainen, Cornelissen, Hansen, & Salmelin, 1999) and fMRI findings (Paulesu et al., 2001; Richlan, Kronbichler, & Wimmer, 2009 for a meta-analysis) in adults suggest persistent deficits in the expert processing of print in dyslexia. Moreover recently, Mahé, Bonnefond, Gavens, Dufour, and Doignon-Camus (2012) have investigated N170 print tuning in dyslexic adults. Results showed a lack of N170 specialization in dyslexics, with no amplitude differences between word-like stimuli (i.e., words and nonwords) and symbol strings. Taken together, these results add new support to the hypothesis that the lack of visual expertise for print in dyslexics is not limited to the initial phase of reading acquisition. Impaired N170 print tuning could thus be considered as an electrophysiological correlate related to developmental dyslexia. However it should be noted that in all the studies mentioned above, dyslexics were always compared with age matched controls. In such a design differences recorded between groups can result from different reading experience between groups. The matched reading-level design is considered to be more efficient in isolating processing differences between typical and disabled readers (Backman, Mamen, & Ferguson, 1984; Bryant & Goswami, 1986). Key evidence for a specific impairment of visual expertise for print in developmental dyslexia would be discovering that this deficit exists over and beyond dyslexics' lower reading skills.

The aim of the present study was thus to test whether the impaired N170 print tuning previously reported in dyslexic readers is specific to dyslexia or not. We compared N170 print tuning in dyslexic and control adults with matched reading levels, referred to as poor readers. The poor readers had no history of developmental dyslexia but had low socio-economic status and poor reading habits. As in Mahé et al. (2012), N170 print tuning was investigated in a lexical decision task, by comparing ERP elicited by word like stimuli (i.e., high frequency words = HFW, low frequency words = LFW, pseudowords = PW and consonant strings = CS) and nonverbal stimuli (i.e., symbol strings = S). If N170 print tuning deficit is a characteristic of a general reading delay, we would expect to find impaired visual expertise for print in both poor readers and dyslexics. In contrast, if impaired N170 tuning is the hallmark of an atypical brain specialization specific to developmental dyslexia, poor readers should show similar N170 tuning as control expert readers. Such a result would suggest that dyslexia is a specific brain abnormality and not a disorder that corresponds to a particular interval along a continuum (Frith, 2001).

2. Results

2.1. Behavioral data

Mean correct RTs and error percentages were submitted to analysis of variance (ANOVA), with comparisons by group (dyslexics, poor readers and controls) and stimulus factors.

Analysis of the RTs for the three groups revealed a significant group effect ($F(2,35) = 4.9$, $p < .01$). Dyslexics responded more slowly (756 ms) than poor readers (641 ms), who responded more slowly than controls (609 ms). The main effect of the stimulus was also significant ($F(4,140) = 148.2$, $p < .001$). More importantly, the group $\times$ stimulus interaction was reliable ($F(8,140) = 5.1$, $p < .001$). Each group exhibited longer RTs for PW than for other stimuli (i.e., HFW, LFW, CS and S) with significantly greater differences for dyslexics (334 ms) than for both poor readers (223 ms; $F(1,35) = 7.1$, $p < .05$) and controls (183 ms; $F(1,35) = 14.4$, $p < .001$). Controls and poor readers groups did not differ from one another ($F(1,35) = 1.1$, $p > .10$).

Analysis of the percentage error for the three groups showed that the group effect was not reliable ($F(1,35) = 2.1$, $p > .1$). The main effect of stimulus ($F(4,140) = 32.9$, $p < .001$) and the group $\times$ stimulus interaction were significant ($F(8,140) = 2.1$, $p < .05$). In each group PW elicited more errors than other stimuli (i.e., HFW, LFW, CS and S) with significantly greater differences for dyslexics (21%) than for controls (8%; $F(1,35) = 4.1$, $p < .05$). Poor readers (12.3%) did not differ significantly from dyslexics ($F(1,35) = 1.9$, $p > .10$) or from controls ($F < 1$).

2.2. Electrophysiological data

N170 mean amplitude (135–255 ms at occipito-temporal sites) was analyzed by repeated measures ANOVA, with comparisons by group (dyslexics, poor readers and controls), stimulus (HFW, LFW, PW, CS and S) and electrode (left: P7, right: P8) factors. The ERP waveforms (Fig. 1) showed differences in N170 mean amplitude between word-like stimuli and S limited to the left site in both poor reader and control groups whereas this difference appeared to be lacking in dyslexics.

Analyses of the N170 mean amplitude revealed that the group effect was not reliable ($F < 1$). In contrast, the effect of stimulus ($F(1,35) = 6.9$, $p < .001$) and more importantly the group $\times$ electrode $\times$ stimulus interaction ($F(8,140) = 2.4$, $p < .01$) were both significant. In dyslexics, N170 amplitude did not differ ($F < 1$) between S (Left: -6.26 ± 3.35 ; Right: -5.94 ± 2.16) and word-like stimuli (Left: -6.25 ± 2.58 ; Right: -6.46 ± 2.63). In contrast, a larger N170 mean amplitude for word-like stimuli than for S was observed in both poor readers ($F(1,35) = 11$, $p < .01$) and controls ($F(1,35) = 21.7$, $p < .001$). This effect was limited to the left site (Controls word-like: -6.8 ± 3.85 ; Controls S: -4.69 ± 3.73 ; Poor readers word-like: -7.39 ± 1.81 ; Poor readers S: -5.77 ± 1.78) and was lacking to the right site (Controls word-like: -6.51 ± 4.6 ; Controls S: -6.12 ± 5.55 ; Poor readers word-like: -7.69 ± 2.97 ; Poor readers S: -6.8 ± 2.69). In the present study, all participants were right handed and therefore responded YES with the right hand and NO with the left hand. The left lateralization of N170 print tuning cannot be confused by the activation of motor preparation, however. Indeed, Fig. 1 reveals reliable N170 left print tuning when different hands were used for words (i.e., the right hand) and S (i.e., the left hand), as well as when same hands were used for nonwords (i.e., the left hand) and S (i.e., the left hand).

The word frequency effect (larger N170 for LFW than HFW) and the lexicality effect (larger N170 for words than for PW) were no significant ($F < 1$) in both poor readers (HFW: -7.48 ± 1.7 ; LFW: -7.29 ± 1.9 ; PW: -7.69 ± 1.77) and dyslexics (HFW: -6.26 ± 2.59 ; LFW: -6.29 ± 2.79 ; PW: -6.02 ± 2.22) in the left site. Dyslexics only showed a significant word frequency effect for the right site ($F(1,35) = 4.3$, $p < .05$; HFW: -5.98 ± 2.32 ; LFW: -6.75 ± 2.68). In contrast and as expected, controls displayed a significant word frequency effect ($F(1,35) = 5.1$, $p < .05$) and lexicality effect ($F(1,35) = 7.1$, $p < .01$) for the left site only (HFW: -6.84 ± 4 ; LFW: -7.47 ± 4.03 ; PW: -6.48 ± 3.83).

2.3. N170 correlations with behavioral data

Correlation scatterplots are illustrated in Fig. 2. The N170 print tuning, which corresponded to the negative word-like stimuli-S difference in the left occipito-temporal channel, was first calculated. A negative value indicated strong print tuning. Next, correlations were performed between N170 print tuning and behavioral data (i.e., reading skills, reading habits and phonological skills). Significant correlations were found between N170 print tuning and the reading level as well as reading habits, with strong print tuning related to high reading skills (i.e., $r = -0.39$ with the normative reading age; $r = 0.38$ with the reading time) and more regular

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