Brain and Cognition 106 (2016) 42–54

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Responsivity to dyslexia training indexed by the N170 amplitude of the brain potential elicited by word reading

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ARTICLE INFO

Article history:
Received 21 September 2015
Revised 28 April 2016
Accepted 1 May 2016

Keywords:
Developmental dyslexia
Training
Reading fluency
Event-related potentials
N170
Visual word recognition

ABSTRACT

The present study examined training effects in dyslexic children on reading fluency and the amplitude of N170, a negative brain-potential component elicited by letter and symbol strings. A group of 18 children with dyslexia in 3rd grade (9.05 ± 0.46 years old) was tested before and after following a letter-speech sound mapping training. A group of 20 third-grade typical readers (8.78 ± 0.35 years old) performed a single time on the same brain potential task. The training was differentially effective in speeding up reading fluency in the dyslexic children. In some children, training had a beneficial effect on reading fluency ('improvers') while a training effect was absent in others ('non-improvers'). Improvers at pre-training showed larger N170 amplitude to words compared to non-improvers. N170 amplitude decreased following training in improvers but not in non-improvers. But the N170 amplitude pattern in improvers continued to differ from the N170 amplitude pattern across hemispheres seen in typical readers. Finally, we observed a positive relation between the decrease in N170 amplitude and gains in reading fluency. Collectively, the results that emerged from the present study indicate the sensitivity of N170 amplitude to reading fluency and its potential as a predictor of reading fluency acquisition.
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1. Introduction

Dyslexia is a specific reading disability characterized by dysfluent and inaccurate word recognition, spelling and phonological decoding (Lyon, Shaywitz, & Shaywitz, 2003). Reading dysfluency is one of the most persistent symptoms of developmental dyslexia (Shaywitz & Shaywitz, 2008). Fluent readers are able to develop visual expertise for fast and automatic identification of words, whereas dyslexic readers persistently fail to acquire fluent reading.

Neuroimaging studies identified two posterior neural systems, primarily in the left hemisphere, that are particularly important for the development of reading skills (Schlaggar & McCandliss, 2007). The first system is located in the left dorsal temporo-parietal region and relates to phonological processing and cross-modal integration of letters and speech sounds (Blomert, 2011; Van Atteveldt, Formisano, Goebel, & Blomert, 2004). The second system is located in the ventral left occipito-temporal region and involves areas in the middle and inferior temporal and occipital gyrus. Within this system the area located at the left lateral occipito-temporal sulcus has been called the "visual word form area" (VWFA) because of its suggested specialization for printed word recognition (Dehaene & Cohen, 2011; McCandliss, Cohen, & Dehaene, 2003).

Longitudinal studies suggested a model assuming that the left dorsal temporo-parietal system develops at the first stages of reading acquisition when letter-speech sound mappings are established, and later supports the specialization of the visual system for word recognition (McCandliss & Noble, 2003; Sandak, Mencl, Frost, & Pugh, 2004). Importantly, dysregulation of both the temporo-parietal and occipito-temporal systems have

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http://dx.doi.org/10.1016/j.bandc.2016.05.001
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been found in dyslexics (Blau et al., 2010; Brunswick, McCrory, Price, Frith, & Frith, 1999; Helenius, Tarkiainen, Cornelissen, Hansen, & Salmelin, 1999; Paulesu et al., 2001; Shaywitz & Shaywitz, 2008; Simos, Breier, Fletcher, Bergman, & Papanicolaou, 2000; Žarić et al., 2014).

1.1. Current study

The current study is concerned with the specialization of the occipito-temporal system associated with increasing reading fluency. Behavioral indices of reading fluency will be augmented by recording brain potentials associated with visual word recognition. The brain potential of interest is N170, an early brain potential component related to visual processing of print. N170 has a negative polarity and peaks around 200 ms after stimulus onset. N170 has been related previously to various forms of general visual expertise (Tanaka & Curran, 2001). Most interestingly, however, N170 has been shown to be sensitive to orthographic processing and its sources have been localized in the VWFA (Dien, 2009; Rossion, Joyce, Cottrell, & Tarr, 2003). In literate individuals, larger N170 amplitudes are found for words compared to strings of symbols, shapes or dots (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Maurer, Brem, Bucher, & Brandeis, 2005). Moreover, N170 responses appear to be sensitive to word similarity, being larger to letter-like stimuli (e.g., pseudofonts) compared to stimuli matched on low-level features (Bentin et al., 1999; Eulitz et al., 2000; Schendan, Ganis, & Kutas, 1998; Tarkiainen, Helenius, Hansen, Cornelissen, & Salmelin, 1999).

In a series of brain potential studies, Maurer and colleagues examined N170 amplitude differences to words vs. strings of icon-like symbols at different stages of reading acquisition in both typical readers and dyslexics (Maurer & McCandliss, 2007; Maurer et al., 2011). The data of typical readers indicated a significant left-lateralized N170 tuning effect that remains relatively stable during the first years of reading acquisition (Maurer et al., 2005). The N170 word-symbol differences in typically reading children were larger for 2nd grade children relative to kindergartners, but leveled off between 2nd grade and 5th grade (Maurer et al., 2011). This pattern of findings was taken to suggest an inverted "U" model of development of visual expertise, in which perceptual learning is critically important during the first two or three years of learning to read and then gradually declines as expertise develops. In the same series of studies, the dyslexic children in 2nd grade showed a reduced word vs. symbol difference in N170 amplitude as compared to normal readers. The authors interpreted the reduced word-symbol difference in dyslexics as a lack of visual specialization for print, reflecting a deficit in expertise for rapid word recognition. Related brain potential studies suggested, however, that the N170 difference between dyslexic and typical readers continues to persist in pre-adolescents (Araújo, Bramão, Faísca, Petersson, & Reis, 2012) and adulthood (Helenius et al., 1999; Mahé, Bonnefond, Gavens, Dufour, & Doignon-Camus, 2012). Moreover, Fraga González et al. (2014) reported a smaller N170 to words at the left vs. right hemisphere sites in typical readers that was absent in dyslexics. The latter observation was interpreted to suggest that visual decoding of words requires less effort in typical compared to dyslexic readers.

The primary goal of the present study was to examine whether a dyslexia training that purportedly increases reading fluency would alter N170 amplitude to words in dyslexic children. For this purpose, we examined a group of dyslexic children following a training expected to improve reading fluency in a relatively short period of time (around 5 months). The current training is an adaptation of an intervention program previously shown to have beneficial effects on reading fluency (Tijms, 2007). The training is inspired by a rapidly growing body of research suggesting a letter-speech sound binding deficit as the most proximal cause for dyslexia (e.g., Blau et al., 2010; Blomert, 2011). The training provides for systematic practice on regular and irregular letter-speech sound mappings at increasing levels of complexity, and its focus is on attaining automated letter-speech sound integration. Importantly, the focus of the training is not only on learning of letter-speech sound correspondences, but also emphasizes intensive exposure fostering automation of these associations.

The beneficial effects of the current training on reading fluency were evaluated in detail in a previous study (Fraga González et al., 2015). The primary aim of the current study was to assess whether the beneficial effects of the training on reading fluency are paralleled by a normalization of the dyslexic N170 amplitude pattern to the left-lateralized N170 amplitude pattern for word reading that we observed in typical readers in a previous brain potential study (Fraga González et al., 2014). In this study, we examined N170 amplitudes associated with word recognition in dyslexic and typical readers in 3rd grade. The analysis of N170 amplitudes showed smaller N170 amplitudes to words at the left vs. right hemisphere site in typical readers. This hemispheric difference in N170 amplitude was absent in dyslexic children. In view of the anticipated reading-fluency gains, we predicted the N170 amplitude lateralization pattern to normalize in our dyslexic sample after training; that is, N170 amplitude should decrease over the left compared to the right hemisphere (Fraga González et al., 2014).

A second goal of the present study was to evaluate training responsivity. It is estimated that around 2–6% of poor readers following special interventions in 1st or 2nd grade will remain having reading difficulties (Torgesen, 2000). Few brain potential studies related brain activity in dyslexics to intervention outcomes. Molfese and co-workers, using a visual word rhyming task, reported larger normalization of N170 and P1 amplitudes in 2nd grade responders but not in poor responders (Molfese, Fletcher, & Denton, 2013). This was supported by a MEG study showing occipito-temporal under activation in poor responders (Rezaie et al., 2011a). A more complex pattern of normalizing in responders, and compensatory changes in brain activity in poor responders was reported in another MEG study in children (Simos et al., 2007). In addition, another study reported that brain potentials (particularly in the 400–600 ms time window) to letter sound matching predicted reading gains after a short intervention in first-grade children (Lemons et al., 2010). Finally, Hasko and colleagues observed that fronto-temporal brain potentials in a phonological decision task were associated with intervention gains in third grade dyslexics (Hasko, Groth, Bruder, Bartling, & Schulte-Körne, 2014). The brain potential findings, currently available, led us to predict that the N170 would differentiate between responders vs. non-responders to the training focusing on improving reading fluency.

In brief, the aims of the present study were twofold. First, we will examine the N170 amplitude changes associated with a training designed to increase reading fluency in dyslexic children. We expect that after attaining higher levels of reading fluency, the N170 amplitude pattern in dyslexics will change towards the lateralized pattern previously observed in typical readers (Fraga González et al., 2014). Secondly, we will examine whether N170 amplitude changes associated with training will discriminate between improvers (i.e., dyslexics showing a beneficial effect of training on reading fluency), vs. non-improvers, (i.e., dyslexics showing no benefits). In this context, we will also assess whether N170 amplitude at pretest discriminates between improvers and non-improvers. If so, N170 amplitude may qualify as a neural marker for treatment sensitivity.

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