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Research Report

Phonological oddballs in the focus of attention elicit a normal P3b in dyslexic adults

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Abstract

Difficulties in phonological processing have been proposed to be the core symptom of developmental dyslexia. Phoneme awareness tasks have been shown to both index and predict individual reading ability. In a previous experiment, we observed that dyslexic adults fail to display a P3a modulation for phonological deviants within an alliterated word stream when concentrating primarily on a lexical decision task [Fosker and Thierry, 2004, Neurosci. Lett. 357, 171–174]. Here we recorded the P3b oddball response elicited by initial phonemes within streams of alliterated words and pseudo-words when participants focussed directly on detecting the oddball phonemes. Despite significant verbal screening test differences between dyslexic adults and controls, the error rates, reactions times, and main components (P2, N2, P3a, and P3b) were indistinguishable across groups. The only difference between groups was found in the N1 range, where dyslexic participants failed to show the modulations induced by phonological pairings (/b/–/p/ versus /r/–/g/) in controls. In light of previous P3a differences, these results suggest an important role for attention allocation in the manifestation of phonological deficits in developmental dyslexia.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Developmental dyslexia; Event-related potential; Phonological oddball; Phoneme awareness; Attention

1. Introduction

Developmental dyslexia is a disorder characterized by literacy difficulties independent of social influences and incommensurate with an individual's intelligence or sensory abilities [11]. Literacy difficulties associated with dyslexia can be identified in the early school years [4], they persist throughout childhood [20] and into adulthood [6,7,24,44]. Some remediation programs have been shown to increase reading accuracy, although reading fluency appears to be less prone to improvement [48]. Nevertheless, behavioral symptoms and neurophysiological differences have been demonstrated in high performing dyslexic adults [25], even those successfully pursuing university studies [24].

Among the fundamental cognitive mechanisms suggested to influence the acquisition of literacy skills, the fluent control of segmental phonology has been one of the most long standing [41]. Although awareness of the phonological units of speech is seemingly not required for spoken language acquisition [19], it correlates with reading skill and predicts the later reading abilities of pre-literate children [36,53]. Consequently, different authors argue that phonological processing has a central part to play in developmental dyslexia [41,46,50]. More specifically, numerous cross-sectional and longitudinal studies suggest that deficient phoneme awareness is a core symptom, and may even be a cause, of dyslexia [5,36].

In addition to traditional behavioral approaches, event-related potentials (ERPs) provide the opportunity to test specific hypotheses concerning the cognitive processes

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taking place during stimulus perception, evaluation, and response planning by tracking average electrical signals produced by the brain over the scalp. Components such as the auditory N1 and P2 offer insight into aspects of stimulus perceptual processing (e.g., [12]) and the building of transient working memory representations (e.g., [9]). Modulation of the N2 component (mismatch negativity, MMN) provides an index of automatic change detection in the context of attended or passive auditory oddball paradigms (series of identical stimuli or 'standards' interrupted by low probability stimuli 'deviants'; [33]). The classical P300 is observed in similar oddball contexts, but only when the stimuli are consciously attended to [47]. Completely unexpected stimuli different from standards and deviants within an oddball stream ('novel' task-irrelevant stimuli) elicit a somewhat different P300 peaking slightly earlier over fronto-central regions ('novelty P300'; [47]). Studies of classical and 'novelty' P300s have led to the differentiation of two subcomponents within the P3 wave: (a) the P3a more visible over fronto-central electrodes and thought to index automatic shifts of attention [17]; and (b) the P3b more visible over centroparietal electrodes and thought to index target detection and working memory updating [40]. In the auditory modality, P3a/P3b complexes have been studied using pure tone oddballs (e.g., [13]), phonological oddballs (e.g., [16,34]), and lexical oddballs (e.g., [39]). Because the P300 indexes awareness of stimulus change, it has been studied in dyslexic individuals in an attempt to characterize potential attentional deficits. For example, Holcomb et al. [26] reported a reduction of the P300 effect to a pure tone oddball in dyslexic children and individuals with attention disorder as compared to matched controls. Others, however, have failed to observe this difference [3,14,43].

In light of the phonological deficit hypothesis introduced earlier, it is surprising that verbal material has scarcely been used in comparison to simpler acoustic stimuli such as pure or harmonic tones in P300 experiments involving dyslexic participants. In a previous study [18], we found that the P3a elicited by phonological oddballs in adult participants performing a lexical decision task (LDT) was absent in dyslexic adults matched for level of education. Since the participants were not explicitly instructed about the phonological oddball manipulation, but rather focused on the LDT, we speculated that the P3a observed in controls indexed spontaneous attentional shifts towards deviant phonemes (see for instance [17]). Thus, the absence of a P3a modulation in dyslexic participants indicated that they were either (a) not aware of the phonological difference between standards and deviants despite having the resources to attend to them, or (b) not able to free up attentional resources required by the LDT to enable detection of the phoneme change [18].

In order to discriminate between these two hypotheses, we used the same phonological oddball context as before [18], but the phonological differences were placed directly in the focus of attention by requesting phonological decisions rather than lexical ones. Two different phonological contrasts–narrow, /b/–/p/ and wide, /r/–/g/–were used to test for possible effects of phonemic distance (Table 1). Voicing was considered a critical phonemic feature as normal adults find it harder to distinguish phonemes that vary only in voicing than in other articulatory characteristics [32]. In line with our previous study [18], we hypothesized that a specific phoneme awareness deficit would result in a significant reduction of the P3 modulation when attention is paid to phoneme oddballs directly. However, we expected a modulation of the P3b rather than the P3a since the phonological oddball was the target (rather than a distracter). Alternatively, indistinguishable performance and P3b response to phoneme oddballs in the focus of attention would suggest an important role of attention in the emergence of the phonological deficit. In addition, we expected to observe a larger P3b modulation for the /r/–/g/ than the /b/–/p/ phonological contrast in both groups, since discrimination difficulty is known to influence the P3b effect [28].

2. Materials and methods

2.1. Participants

Twelve developmental dyslexic adults (mean age 20 ± 1 year, 4 males) and 12 control adults (mean age 19 ± 1 year, 4 males) took part in the experiment which was approved by the University of Wales Bangor ethics committee. All participants were right-handed native English speakers. Dyslexic volunteers were referred by the Bangor Dyslexia Unit. All had a record of reading difficulties and were diagnosed dyslexic on the basis of a battery of standardized tests that focused on the discrepancy between verbal and nonverbal performance [49]. Participants matched for level of education were administered an additional dedicated battery of subtests to assess differences in reading and spelling (Table 2). Subtests were taken from the Dyslexia Adult Screening Test (DAST, [35]), WAIS-III [51], and Wide Range Achievement Test (WRAT-3, [52]). In addition, the Barkley current symptom scale [2] was used as a self-report measure of Attention Deficit Hyperactivity Dis-

Table 1
Example words and pseudo-words for phonological contrasts (/b/–/p/, first row and /r/–/g/, second row) with mean lexical frequency (CobLog[a])

Standards			Deviants		
Frequency	Example		Frequency	Example	
1.17 ± 0.38	basin	*bafin*	1.30 ± 0.07	packet	*pamet*
1.37 ± 0.41	rabbit	*raddit*	1.18 ± 0.32	gallon	*gatton*

Pseudo-words are italicized.
[a] The CELEX lexical database [1].