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Mismatch negativity (MMN) elicited by duration deviations in children with reading disorder, attention deficit or both

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ABSTRACT

According to several studies auditory discrimination as measured by mismatch negativity (MMN) is compromised in participants with reading disorder. However, studies on duration discrimination have produced conflicting findings [Baldeweg, T., Richardson, A., Watkins, S., Foale, C., & Gruzelier, J., 1999. Impaired auditory frequency discrimination in dyslexia detected with mismatch evoked potentials. Annals of Neurology, 4, 1–9; Corbera, S., Escera, C., & Artigas, J., 2006. Impaired duration mismatch negativity in developmental dyslexia. Neuroreport, 17, 1051–1055]. Auditory sensitivity has not been as actively investigated among children with attention deficit, although attention problems often co-occur with dyslexia. The present study is a reanalysis of MMN data gathered from control children and children with reading disorder (RD) and/or attention deficit (AD). In our previous analysis [Huttunen, T., Halonen, A., Kaartinen, J. & Lyytinen, H., 2007. Does mismatch negativity show differences in reading disabled children as compared to normal children and children with attention deficit? Developmental Neuropsychology, 31, 453–470.], the only significant difference between the groups was in the lateralization of the MMNs in the RD and the control group: the MMNs of the RD group were more pronounced over the left hemisphere, while those of the control group appeared larger over the right hemisphere. A reanalysis was conducted to study whether the group definition criteria and/or overlap of the attention and reading deficits in the AD group might have affected the results. For this purpose participants were divided to four groups: control children, children with RD, children with AD, and children with both RD and AD. MMN was elicited by duration deviations in a continuous sound. Significant differences were observed in the MMN peaks between the control group and all clinical groups: the MMNs were diminished in the right hemisphere in the RD group, in all frontal and central channels in the RD + AD group, and the MMN peaks appeared earlier in frontal channels in the AD group.

1. Introduction

1.1. Reading disorder and the Finnish language

The term 'specific reading disorder' refers to impairments in the development of reading skills that are not explained by mental age, visual acuity problems, or inadequate schooling (WHO, 1990). Reading disorder (RD) has been studied in several language groups, and its prevalence is approximately 6% (Lyytinen et al., 1995; Pennington, 1990; Schaywitz et al., 1990). Phonological processing refers to the ability to use the sounds of one's language (phonemes) in processing spoken and written language (Wagner and Torgesen, 1987). It is often considered to be the core deficit in reading disorder. However, reading disorder seems to manifest itself differently in different languages varying in orthographic consistency and phoneme–grapheme correspondence (Landerl et al., 1997; Landerl, 1997). The Finnish language has perfect grapheme–phoneme fit, whereby each phoneme has its own letter. In other words, one sound corresponds to one letter and vice versa. Furthermore, the position of the grapheme does not affect the pronunciation of the word. For example, Landerl (1997) has shown that in the more orthographically consistent languages reading problems tend to demonstrate themselves as problems of reading speed rate than accuracy. Thus, in Finnish, reading problems mainly emerge in the form of slow reading. In addition to deficits in reading speed many Finnish people with reading disorder have problems in processing vowel and consonant length, which plays a central role in discriminating meaning in Finnish. For example, in the pair of Finnish words (*mato* = worm and *matto* = carpet) the longer consonant sound is written with repeated letter t and it has a silent closure stage (medial dental stop) which at a typical rate of speech is more than 100 ms longer than the short /t/ sound written with one letter t. The most common spelling error made by Finnish speaking with reading disorder is to write only one letter where two are needed (Lyytinen et al., 1995). It has been documented among the infants born at risk

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for dyslexia[1] that perception of phoneme length can be used as an indication of speech perception which may be a precursor of dyslexia (Leppänen et al., 2002 and Richardson et al., 2003; for a review of related findings, see Lyytinen et al., 2005 and recent results from the Jyväskylä Longitudinal study of Dyslexia; Lyytinen et al., 2004). For this reason investigation of the processing of duration is of special interest in Finnish participants with reading disorder.

1.2. Mismatch negativity and attention

Auditory discrimination can be studied using auditory-evoked potentials known as mismatch negativity (MMN). MMN is elicited by deviants interspersed between repeated standard sounds. The deviation can be in different sound qualities such as frequency, intensity, duration, and sound location, or even in more complex stimuli like phonemes and abstract feature rules. The MMN response begins approximately 100 ms after the onset of the deviant stimulus (Mäntysalo and Näätänen, 1987) and its amplitude is approximately −3 μV (Licht and Horsley, 1998); the latency and the amplitude of the MMN peak are, however, affected by the properties of the stimulus. The MMN generators have been localized to the supra-temporal auditory cortex and frontal cortex (Giard et al., 1990; Gomot et al., 2000; Opitz et al., 2002; for a review see Alho, 1995). (For a more thorough introduction to MMN characteristics see Bishop, 2007; Näätänen, 1992).

MMN generation is considered to be based on an automatic process that compares the incoming stimulus to the memory trace of the preceding regular auditory stimuli (Näätänen, 1992). MMN does not seem to be dependent on attention and can be recorded while the participant is concentrating, for example, on a video (Jacobsen and Schröger, 2003; Pettigrew et al., 2004), a book (Sussman et al., 2003; Tervaniemi et al., 1999), or video game (Woods et al., 1992). In addition, MMN has even been recorded in sleeping participants (Campbell et al., 1991; Martynova et al., 2003; Nashida et al., 2000; Sallinen et al., 1994). However, some studies have proposed that attention affects MMN parameters (Szymanski et al., 1999; Woldorff et al., 1991). MMNs to changes in intensity appear to be particularly sensitive to attention (Näätänen et al., 1993). Often studies that have found MMN to be affected by attention have applied dichotic listening where the participant has been attending to the stimuli delivered to one ear while ignoring the stimuli delivered to the other ear. According to Sussman et al. (2003), the results on dichotic listening might be explained by the competition hypothesis. This suggests that selective attention per se does not affect MMN; instead top–down processes can modulate data that reach the change detection process when there is competition for the same processing capacities. Sabri et al. (2006) also found attention to have an effect on MMN when they compared the frequency MMN and the MMN responses elicited in an easy versus difficult task. However, in this study some support for the competition hypothesis was also found since the distractor task was a duration discrimination task where the participants had to react to changes in the auditory stimuli. It seems possible that focusing the attention can slightly enhance auditory discrimination when small deviations are applied (Muller et al., 2002; Muller-Gass et al., 2006; Woods et al., 1992), although the elicitation of MMN does not rely on attention.

1.3. Auditory discrimination and language skills

Accurate auditory discrimination is crucial for the development of language skills. It has been suggested that reading problems might result from a temporal processing deficit in low-level auditory processing as this could distort speech perception and thus hamper the formation of phoneme representations (Farmer and Klein, 1995; Tallal, 1980; Tallal et al., 1991; Tallal and Benasich, 2002). Such inaccurate phoneme representations might in turn hinder acquisition of grapheme–phoneme correspondences. The results of behavioral studies have given rise to different conclusions regarding the generality of the possible auditory problem in participants with reading disorder. According to Tallal (1980, 1984), the temporal processing deficit is specific to the auditory modality and affects the perception of all kinds of rapidly changing auditory stimuli. Some studies have shown temporal processing deficits in visual processing similar to those noted in the auditory modality (Facoetti et al., 2003; Farmer and Klein, 1993, 1995). In contrast, some studies have failed to find deficits in the auditory processing of tones, whereas problems have appeared when speech stimuli have been used (Bradley and Bryant, 1991; Brady et al., 1983; Mody et al., 1997). MMN studies have provided evidence for both views. Studies have found diminished MMNs in participants with reading disorder when MMNs have been elicited by changes in tone frequency (Baldeweg et al., 1999; Kujala et al., 2003, 2006), duration (Corbera et al., 2006) and complex tone patterns (Kujala et al., 2000). Also children at familial risk for dyslexia have shown diminished mismatch responses to changes in tone frequency (Maurer et al., 2003), duration (Leppänen et al., 1999, 2002) and phonemes (van Leeuwen et al., 2006). Interestingly, the study by Schulte-Körne et al. (1998) found MMNs to be attenuated only in response to deviations in speech sounds.

1.4. Comorbidity of attention deficit and reading disorder

Attention problems[2] often co-occur with reading disorder (RD), and recent studies have suggested that they may even arise from shared genetic influences (Stevenson et al., 2005; Willcutt et al., 2000). In a Finnish sample of RD participants as many as 20% also showed attention problems (Lyytinen et al., 1998). The prevalence of concurrent attention deficits (AD) has been found to be approximately the same in studies of RD participants from other language groups (Gilger et al., 1992; Schaywitz et al., 1995). Two competing hypotheses have been put forward regarding the deficits experienced by the comorbid group. According to the phenocopy hypothesis, presented by Pennington et al. (1993), RD participants with comorbid Attention Deficit Hyperactivity Disorder (ADHD) show similar cognitive deficits to those found in the pure RD group while they do not experience the cognitive deficits typically found in the ADHD group. Recent studies have provided evidence in support of the common etiology hypothesis, which proposes that the comorbid group shows cognitive deficits associated with both AD and RD. In the studies by Willcutt et al. (2001, 2005) children with RD have shown significant deficits, especially in phonological awareness, and ADHD children the most pronounced problems in response inhibition, while the comorbid group showed great impairments in all of the aforementioned measures. Similarly, Purvis and Tannock (2000) found both phonological deficits and problems in inhibition in the comorbid group. However, Bental and Tirosh (2007) found that in addition to the attention and reading impairments typically shown by the participants with ADHD or RD those in the comorbid group experienced unique problems in rapid naming and more severe problems in working memory than either the pure ADHD or RD groups. Thus participants in the comorbid group may significantly differ in their cognitive functions from those with pure forms of AD and RD.

[1] Dyslexia refers to a specific neurobiological learning disability that is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities (Lyon et al., 2003). In this study the term reading disorder (RD) is applied, since the participants were referred to the study with a diagnosis of RD. When referring to other studies the terms applied by the authors are used.

[2] In this article the term attention deficit (AD) is used as a general term when discussing attention problems. Various terms and diagnostic procedures have been used in other studies and thus it is to be acknowledged that there are differences in the subject groups of the studies reviewed here. Terms used by the authors are applied when referring to other studies.