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Comparison Between Speech and Non-Speech Stimulus in Dyslexia: A MMN Study

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Abstract

Objective: dyslexia is a neurological problem, therefore, auditory mismatch negativity was investigated in dyslexic children. Methods: 52 children with dyslexia (30 male, 22 female) and 52 controls were studied using speech and tonal stimuli. Intensity was used at 65 dB nH. The study focused on latency, amplitude and topographic distribution of MMN in both groups. Results: at the present study with speech stimulus, larger latency and smaller amplitude were found in dyslexic children when compared with controls. Topographic distribution showed larger MMN in right hemisphere than left side in dyslexic children. With tone stimulus we found no differences between two groups. Conclusions: these results provide evidence for MMN and its function in central auditory processing. The MMN using speech can be used to concentrate on the relationship between central auditory processing and learning deficits in children with dyslexia.

Keywords

MMN, Dyslexia, Auditory System

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1. Introduction

Event-related potentials (ERPs) are voltage associated with physical or mental events, recorded from the human scalp. It can provide important results about information processing in the human brain, and about neurological or psychiatric disorders. These data extracted from the electroencephalogram (EEG) by signal averaging and filtering. These waveforms contain components that can be exogenous potentials, eliciting by the physical characteristics of the event in the external world, and the endogenous potentials. Because of the temporal resolution of the ERPs on the milliseconds, ERPs can have accurate information during the processing activities. We must concentrate on each peak, includes typical latencies, cortical distributions, and possible brain sources of observed activity.

These electrophysiological recording techniques are generally noninvasive and relatively inexpensive. In contrast, the ERP approach permits investigators to link recorded signals with stimulus events more directly by focusing on the change in electrophysiological signal that occurs immediately following the stimulus event (Callaway et al. 1975; Rockstroh et al. 1982). The smaller size of the ERPs relative to other brain waves can make it difficult to be extracted and recognized. In order to recording these components, researchers used repeated presentations of the evoking stimuli to average out potentially unrelated events. ERP waveforms are typically described in terms of positive and negative peaks. The ERPs are reflected as post-synaptic (dendrite) potentials of a fairly extensive set of neurons activity. Characteristics of ERP: peak latency, amplitude, cognitive functional significance, scalp distributions, and

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component brain sources are the index for assessment of brain functions. The mismatch negativity (MMN) has many applications in auditory evoked potentials or auditory event related potentials.

The MMN is a negative deflection; reflecting pre-attention mechanism in the auditory system, occur in the frontal area of human brain (Naatanen 1990). It is elicited by two different stimuli (deviant/ standard): in this technique we can present many kinds of stimuli, such as tone, word, nonword. It is very important which kind of task is useful for better evaluation. For example when our survey is about speech processing, useable task must be the speech stimulus. In a general form of MMN design, a group of standard pure tones such as 2000 Hz are presented on 70%-90% and deviant tones such as 2100 Hz on 10%-30% of trails. At this situation, subjects are educated to ignore the tasks, and perform some other auditory tasks or watching the silent movie. It seems to reflect an automatic perceptual evaluate of memory process. Amplitude of MMN is an important factor in evaluating developmental disorder. This parameter has also been studied in the context of stimulus filtering and passive attention (Naatanen 1992). Moreover, the MMN occurs about 200 ms after stimulus and 200-250 presentation of the deviant stimulus in order to record suitable MMN components (McGee et al. 1997). The most common variables in MMN are the amplitude (in μV), the latency in ms and the area under the curve (in μV).

MMN deficits have been used in many kinds of neurological disorder and in a number of studies. The MMN enabled one to understand central auditory processing disorder in dyslexia (Kujala and Naatanen 2006). Naatanen and Winkler (1999) suggested that amplitude and latency reflect the physical difference between two deviant and standard stimuli. Schulte-Koerne et al. (1998) used MMN in order to evaluate auditory dysfunction in dyslexic children, and found that a consonant change in a syllable (/ba/ vs. /da/) was abnormally made by dyslexic children.

Learning disability is a term which is used for complex learning problem, caused by mental disorder. The most common type of learning disability is dyslexia. Other forms of learning disability are dyscalculia, dysgraphia, and short term memory dysfunction. Prevalence of LD is five to ten percent at school ages. Dyslexia may be defined as a specific learning disability that is neurological in origin and characterized by a difficulty with accurate reading fluency and poor decoding and spelling, resulting from a deficit in the phonological component of language.

According to the finding of Vellutino et al. (2004) and their suggestion, dyslexia is a neurological disorder and is thought to affect 5 to 10% of school children. Many other researchers have also reported same rates of dyslexia: see Demonet et al. (2004) who mentioned that dyslexia is a neurological disorder affecting literacy skills in approximately 5%–10% of school-aged children. Dyslexia is a prevalent problem characterized by difficulties in reading, writing and spelling despite having normal or above moderate intelligence. Until now, despite many researches, the exact origin of dyslexia is unknown.

Reading is a complex skill, and for it, coordination of auditory system, visual, phonetic and lexical codes are required (Adams 1990). Neuro-imaging and electrophysiologic studies have demonstrated that reading involves an extensive network of regions in the cerebral cortex (Demb, Poldrack and Gabrieli 1999; Fiez and Petersen 1998). Neurobiological studies of dyslexia have attempted to find the role of these different cortical portions ,but there are many aspects of this issue that remain unknown about function bases of reading skill and reading disorders.

Some studies in animal models have recently showed that the brainstem structures are very important for perception and signal processing in noisy environments in auditory system (Luo et al. 2008). Processing in subcortical structures involves an interaction between sensory and cognitive systems. Also these structures have a special role by feed forward and feedback of these pathways (Tzounopoulos and Kraus 2009). The connection between cortex and subcortical system from the basis for such interaction related top-down control (Winer 2005). In human study, the neural response of auditory system to complex stimuli can be measured from lower levels of the nervous system such as brainstem to the auditory cortex (Johnson et al. 2008; Hornickel et al. 2009; Tzounopoulos and Kraus 2009).

For better evaluation and intervention of this area we need a team of specialists such as audiologists, speech therapists, neurophysiologists, neuropathologists, and educational scientists.

During the past years many researchers have concentrated on different scientific theoretical and practical areas of assessment of dyslexic children. The idea that dyslexia may behave a brain abnormality is not so new. Scottish ophthalmologist James Hinshelwood and Morgan both emphasized on certain neurological syndrome of "visual word blindness" (Hinshelwood 1895; Morgan 1896). Jules Dejerine reported that damage of the left inferior parieto-occipital region results in reading and writing impairment (Dejerine 1891). These early researchers reasoned that reading and writing defect could be due to same parietal region which was damaged (Hinshelwood 1917). These hypotheses were confirmed by Drake (1968), who described the brain of a dyslexic boy who died because of brain hemorrhage due to a vascular malformation. Pathological findings showed a series of brain malformations in the cortical gyri of the left inferior parietal region. Another line of neurological defect has followed by Orton as the 'founding father' of the lateralization theory of dyslexia (Orton 1925, 1937). This idea proposed by Orton and then by Geschwind, is that the lateralization of language to the left hemisphere is delayed in dyslexia, so this area of brain is not able to develop enough in order to read.for learning to read. This theory was confirmed by some dichotic tests (Obrzut 1988; Harel and Nachson 1997) and other researches as the brain asymmetry (for example, Geschwind and Behan 1982; Geschwind and Galaburda 1985, 1987).

Many studies demonstrated that dyslexic children have processing disorder. One more important finding about this problem which some researcher concentrate on is Correlation between brainstem and cortical auditory processes (Brad Wible and Nina Kraus 2005).

According to findings of many researchers (Nina Kraus 1996, Mody 1998, Rarner 1995, Schulte-Koerne 1999), phonological problems, are the main factor in dyslexia. At the present study we have used MMN with tonal and speech stimuli for evaluation of dyslexic children.

2. Methods

2.1. Subjects

Subjects were 52 children (30 male 22 female) aged between 8-10(mean; 8.33), diagnosed as dyslexia and 53 controls who matched the others. 24 children have been referred by speech therapists and the other dyslexia has been referred by institutes of special education. All subjects had normal IQ or above moderate values tested by an expert psychologist. Our inclusion criteria were normal hearing thresholds, normal Tympanometry and reflex, and also normal vision or near normal with glasses.

2.2. Stimuli and Recording

Sharma et al. (2006) studied different speech stimuli for MMN measurement. They found different results for different speech stimuli (Standard/deviant). In their studies, the best effect was found for /da/ as standard and /ga/ as deviant. Benai et al. found the same result. So at the present study for speech stimuli we used these two as standard and deviant stimulus. For standard tone was arranged a sinusoidal 1320 and 1650 Hz tone. The duration of the standard tone was 100ms including 10 ms rise/fall times. Also, MMN components to speech stimulus were collected according to widely used procedures by Naatanen & Picton (1987) and Kraus et al. (1995). An EB NEURO device was used to collect all physiological data. The MMN responses to speech and tones tasks were elicited. The test stimuli were presented to each ear through TDH 39 earphones at an intensity of 60 dB nHL. Recordings were made with silver–silver chloride electrodes, impedance less than 3k. Responses were recorded with electrodes placed at the F3, Fz, F4, C3, Cz, C4, Pt3, Pz, Pt4, T3, and T4 loci on the scalp, and on the left and right mastoids. Reference electrode was placed on the forehead. The MMN were recorded by averaging EEG epochs for each deviant and standard stimulus (da/ga). The analysis period began 100 ms before and terminated 500 ms after stimulus onset. The MMN were digitally filtered with a bandpass of 1-20 Hz. The amplitude and latency were determinate at Fz at 100-250 ms, amplitude value were detected with 50 ms window centred at the individual peaks. The analysis included factors group for control and dyslexic, stimulus (deviance, standard), frontocentral location (Fz, Cz) and laterality (F3-C3, Fz-Cz, F4-C4). We used SSPS 21 for data analysis.

3. Results

Dyslexia has been directly associated to poor auditory processing (Tallal et al. 1993; Nittrouer 2012). Some studies have revealed poor MMN amplitudes to speech stimuli (Ahmmed et al. 2008; Baker et al. 2005; Bradlow et al. 1999; Datta et al. 2010; Davids et al. 2011; Koelsch et al. 2012). MMN amplitude as an index to reflect the phonetic categories, which may be the result of poor auditory processing (e.g. Shafer et al. 2005; Datta et al. 2010). Amplitude, latency, and topographic distribution are three important parameters of the MMN. At the present study we extracted and analyzed these parameters. For data analysis we used SSPS 21. According to our findings, dyslexic children in speech stimulus had significant difference, in both latency and amplitude. In dyslexic children latency was larger in comparison with control group. Other significant result was about lower amplitude in dyslexia than controls. Topographic findings in control group showed largest MMN in left hemisphere than right hemisphere, but in dyslexic children we found largest MMN in right hemisphere than left hemisphere.

But in tone stimulus we did not find significant differences between dyslexic children and controls in amplitude. Latency was a bit longer than control group, but this was not significant.

4. Discussion

Dyslexia is a complex neurological learning disability. This problem can happen in many part of brain. So many researchers were interested to investigate at this area. Study about reading, spelling, writing, education, memory, hearing, vision, genetics, phonology, brain structure, skills, creativity, and sensory integration, dyslexic children showed unusual differences in that object (Angela Fawcett and Nicolson 2002). In this way, researchers suggested some theories, such as: phonological theory, cerebellar theory, genetics theory, auditory processing disorder theory, vision theory, and sensory integration theory. According to most researches, auditory processing disorder is a common problem in dyslexia. One of the most popular techniques for evaluation of central auditory dysfunction is MMN. This is a window to the brain and central auditory processing and the different form of auditory memory (Naatanen et al. 1978). MMN is generated automatically to any change in auditory stimulation. According to findings of Naatanen et al. (1978), Giard et al. (1990), Rinne et al. (2000), MMN gets from two intracranial processes: (1) a bilateral supratemporal process and (2) a predominantly right-hemispheric frontal process. Studies showed that using speech sound, one can explore the sound memory-specific speech and permanent language traces (Naatanen et al. 1997; Sharma 1999).

Our finding confirmed the neurological bases of dyslexia and asymmetry of two hemispheres. T. Kujala et al. (2006) reported several differences in the scalp topography of dyslexic children. For example, the amplitude deceased over the left hemisphere in dyslexic group. These finding certify those of previous surveys about left hemisphere (Galaburda 1999; Renvall and Hari, 2003; Temple et al. 2003) and parietal (Hari et al. 2001) deficits in dyslexia. The left side malfunction of the brain is well substantiated in dyslexia, and suggests an impairment of the language system (Shaywitz et al. 1998; Temple et al. 2003),

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