MEG Fields of Subjects with Dyslexia During Word and Shape Recognition Tasks

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1 Introduction

Dyslexia, a poorly understood group of learning disorders, is the inability to read, despite having adequate intelligence and the ability to see and recognize letters [1]. Significant differences have been reported between auditory evoked responses of dyslexic individuals, obtained using the conventional Electroencephalography (EEG) and those of control subjects (normal readers matched in intelligence and age) [2].

Auditory evoked potentials have been investigated in children using EEG during dichotic listening tasks [3], and revealed normal readers had larger amplitude N100 responses in the left hemisphere than the dyslexic group. MEG has been used to investigate the visual processing in dyslexic individuals [4]. That study was performed on 6 dyslexics and 8 non-dyslexics, and found a lack of cortical responses in left inferior temporal-occipital region of the brain, an area that was active in non-dyslexics during the corresponding time interval. MEG has also been used on ten normal subjects (5-females, 5-males) to determine the time courses of word and context comprehension [5]. The measured responses to sentences that ended with the correct word, wrong word and a non-word were monitored with whole head MEG. The results from that study show that at 350 msec after onset of a word there is a large response if the context of the sentence is not understood and no response if the sentence is understood. The authors concluded that impaired perception of visual word form maybe the underlying cause of dyslexia. These three studies show that there is a detectable difference in reading/auditory responses, word comprehension of individuals This study measured responses to visual presentations of a written word /shape and the simultaneous presentation of the auditory correct word/shape, wrong word/shape, or a non-word with whole head MEG. The results from this study show that mean cortical responses between 250-600 msec after onset of word/shape are more active in normal readers for the wrong word/shape or non-word/shape than for individuals with dyslexia. The individuals with dyslexia had cortical responses during the matching word/shape presentation.

2 Methods

Cortical magnetic fields were monitored with 148 channel (4D Neuroimaging WH2500) Neuromagnetometer from four subjects diagnosed with dyslexia and four normal readers, inside a magnetically shielded room, located in the Neuromagnetism Laboratory at Henry Ford Hospital. Dyslexic and normal readers were identified by standard tests.

Auditory Evoked Cortical Magnetic Fields (AECMFs) were recorded using 1000Hz tone bursts lasting 500 milliseconds (ms) presented at an intensity of 40 dB above the subject’s hearing threshold [6]. The auditory stimulus was presented 200 times. Visual Evoked Cortical Magnetic Fields (VECMFs) were measured during the presentation of an alternating square-checker board pattern for 2 minutes.

Word comprehension was studied by measuring the subject’s MEG field responses to visual presentations of a printed word (i.e. “airplane”) and the simultaneous auditory presentations either of the name of the object (i.e. “airplane”) or another object (i.e. “boat”) or a pseudo word (i.e. “habgla”). Approximately 100 (5-9 letter) concrete words were randomly shown for a 300 msec period every 3 seconds. During each presentation at time=100msec, an auditory word was presented. The subject was asked to determine whether the visual
presentation matched the auditory presentation, if it did not match, or if it was not a word. These decisions were not recorded.

Shape comprehension was studied by measuring the subject’s MEG field responses to visual presentations of shapes (i.e. “square”) and the simultaneous auditory presentations either of the same shape (i.e. “square”) or another shape (i.e. “triangle”) or a pseudo word (i.e. “habgla”). Approximately 26 shapes were randomly shown for a 300 ms period every 3 seconds. During each presentation at time=100 ms, an auditory word was presented. The subject was asked to determine whether the visual presentation matched the auditory presentation, did not match, or was a pseudo word. Again, decisions were not recorded. Between each set of visual/auditory stimulation a tone was presented, to let the subject know when the next presentation would start. The subject’s response to the tone was also recorded. To keep the subject alert he/she was asked to push the trigger button every time the word ‘yellow’ or a yellow circle was presented.

With time to place a subject in the room and ensure his/her comfort, the whole study lasted approximately two hours.

2.2 Data analysis

All data were collected on a Sun Ultra 60 workstation, digitized at 290.64 samples per second, band passed at 0.01-100 Hz. The MEG data were stored on optical disks.

Equivalent current dipole source analysis was used to determine latency, location and amplitude of the AECMF and VECMF response arising from the cortex. Dipole fits were made based on the magnetic field distributions that were measured by the neuromagnetometer.

The AECMFs were band pass filtered (3-70 Hz), digitized (250Hz), and 200 Epochs were averaged. Each epoch contained one cycle of the black and white pattern flash. The major peak latencies corresponding to the n75m, the p100m, and the n145m were identified and the single equivalent dipole for each peak was calculated.

Two Dimensional Inverse Imaging (2DII), a computer modeling technique involving multiple source analysis [7], was applied to MEG data during word and shape comprehension tasks. 2DII was used to determine the areas of cortical activation from these tasks. The results were displayed onto a pseudo MRI scan that was morphed into the digitized points collected during data acquisition of each individual’s head shape.

The Word comprehension was studied by averaging the subject’s measured MEG field responses to visual presentation of a printed word (i.e. “airplane”) and simultaneous auditory presentation of the correct name of the word (i.e. “airplane”). The second set was an average of the visual presentation of a printed word (i.e. “airplane”) to a simultaneous auditory presentation of the wrong word (i.e. “boat”). A third set was the response to the visual presentation a printed word (i.e. “airplane”) to a simultaneous auditory presentation of a pseudo word (i.e. “habgla”). Each set contained 25 responses to determine the averaged evoked response. This data was filtered 1-50 Hz with a notch at 60.

Shape comprehension was studied by averaging the subject’s measured MEG field responses to visual presentation of a shape (i.e. “square”) and simultaneous auditory presentation of the correct name of the shape (i.e. “square”). The second set was an average of the visual presentation the shape (i.e. “square”) to a simultaneous auditory presentation of the wrong shape (i.e. “circle”). A third set was the response to the visual presentation of a shape (i.e. “square”) to a simultaneous auditory presentation of a pseudo word (i.e. “habgla”). Each set contained 8 responses to determine the averaged evoked response. This data was filtered 1-50 Hz with a notch at 60.
Attention responses were recorded by means of occasional presentation of a yellow circle, at which time the subject was asked to press a trigger button. This data were averaged (approximately 10 trails) and filtered 1-50 Hz with a notch at 60.

3 Results

The responses of dyslexic individuals during the word and shape comprehension tasks was different from normal readers. For the word comprehension task, (the simultaneous presentation of the visual printed word and the correct auditory word), the amplitude of the MEG data (300 – 400ms) was significantly lower for the dyslexic group. In addition, compared to the non-dyslexic group, a smaller area of cortical activation was observed in 2DII cortical activation images, (Fig. 1 a & e). However, 2DII cortical activation was found in the left language hemisphere in the dyslexic group during auditory presentation of the matching word compared to the wrong or pseudo words (Fig. 1a,b & c) where no significant response or activation was found. For the non-dyslexic subjects the opposite was found. The 2DII cortical imaging results demonstrated more cortical activation in the left language hemisphere during the auditory presentation of the wrong word or a pseudo word (Fig.1 e, f & g) in the non-dyslexic group. The attention responses, (yellow circle), were similar in cortical activation areas in both groups (Fig1 d & h).

For the shape comprehension task, (simultaneous presentation of the visual shape (i.e. “square”) and the correct auditory word (i.e. “square”)), both the amplitude of the MEG data, (300 – 400 msec), and the area of 2DII cortical activation in the dyslexic group was smaller than the non-dyslexic group, (Fig. 2 a & d). During the auditory presentation of the wrong word (i.e. “diamond”) or a pseudo word (i.e. “habgla”) the dyslexic subjects had a smaller area of activation than for the correct shape (Fig.2 a, b & c). The non-dyslexic group had larger areas of cortical activation than for the same word (Fig. 2 d, e & f).

Both, dyslexic and non-dyslexic individuals had identifiable n100m Auditory Evoked Cortical Magnetic Fields (AECMFs) responses. Visual Evoked Cortical Magnetic Fields (VECMFs) responses at n75m, p100m, and n145m were identifiable in both groups.

![Figure 1 Word comprehension 2DII localization results from a subject with Dyslexia during the visual presentation of a word and the auditory presentation of the word. a) same word, b) wrong word, c) a pseudo word and d) attention response (yellow). e,f,g,h are same presentation but in non-dyslexic individuals.](image)
4 Discussion

This study demonstrates differences in the location of the Magnetoencephalography (MEG) signals during word comprehension tasks between learning-disabled and non-learning-disabled individuals. Non-dyslexic individuals had significant cortical activity in the left language regions of the brain during the time interval 200-600 ms. Dyslexic individuals showed little or no activation in this area during the same time interval. During shape comprehension tasks the dyslexic individuals displayed more cortical activation in the left language hemisphere than during the word comprehension tasks. Non-dyslexic individuals again had more cortical activation in the left language areas during the correct shape compared to the wrong shape or the pseudo shape.

This study supports the hypothesis that the neuronal activations in dyslexic subjects are not the same as in non-dyslexic individuals.

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References