MEG Fields from Normal Readers and Individuals with Dyslexia During Language Tasks

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Abstract

MEG data were acquired during three different language processing tasks [picture naming (PN), verb generation (VG), and a matching task] from 8 normal readers and 8 subjects diagnosed with dyslexia. Analysis of the amplitude differences in the evoked responses during the latencies 0-600 ms were analyzed utilizing MR-FOCUSS, a technique that is capable of imaging simultaneous activity in multiple cortical structures. Cortical activation maps during PN and VG displayed activity in the superior temporal gyrus (STG) and planum temporale during 150-350ms after onset of stimuli and the lateral prefrontal cortex (PFC) during 300-600ms after onset of stimuli. Increased bilateral activation was found in the subjects with dyslexia during the latencies 200-350 ms after onset of VG stimuli. Same word matching tasks gave less neuronal activation in superior temporal gyrus (STG) between 200-320 ms compared to the wrong word tasks in all subjects. Subjects with dyslexia had less focal activation in superior temporal gyrus (STG) compared to normal readers in all matching conditions.

1 Introduction

Dyslexia is the inability to read, despite adequate intelligence and the ability to see and recognize letters [1,2]. Numerous studies have been performed to determine the mechanism underlying this learning disorder; for review see Habib [2].

Magnetoencephalography (MEG) has been used in patients to study the cortical processes during language activation [3-6]. Levelt, Praamstra, and Meyer [3] used MEG to define the cortical activation processes in normal subjects during a picture-naming task. Salmelin, Service, Kiesila, Uutela, and Salonen [4] investigated visual processing in dyslexic individuals. They found a lack of cortical responses in left inferior temporal-occipital region of the brains of the dyslexic group; this region was active in non-dyslexic individuals during the corresponding time interval. Papanicolaou et. al. [5], and Krober et. al. [6] both used MEG to localize cortical areas involved in language processing. These studies demonstrate that MEG can be used to detect cortical activation during language comprehension in individuals.

The present study investigated evoked MEG responses to visual presentations of a written word and the simultaneous auditory presentation of a matching word, mismatching word, or a pseudoword. We found cortical activation differences in subjects with dyslexia compared to control. MEG signal arising from activation in both wrong and pseudo matches were stronger than correct word matches in all subjects. We also looked at cortical activation difference PN and VG language tasks. Subjects with Dyslexia showed more cortical activity in the right hemisphere than subjects without learning disorders. Multiple areas of activation can be visualized with a multisource analysis technique developed in our laboratory, MR-FOCUSS [7,8]. This technique can reliably localize and quantify language specific cortical activity.

2 Methods

2.1 Patient studies

MEG recordings of eight individual with dyslexia, (4 men, 4 women) between 8-24 years of age, were acquired during language comprehension tasks. These individuals were identified and tested by the Michigan Dyslexia Institute or the Department of Neuropsychology at Henry Ford Hospital and determined to have a discrepancy between intelligence, determined by standardized tests, and reading ability.

MEG fields also were measured in eight normal control subjects matched in age, gender and handedness to subjects with dyslexia. This group had normal, age appropriate, reading ability. Normal readers were identified by standard word tests that were given and graded. If scores for a particular individual fell below a preset standard, that participant was excluded from the study. No subjects or controls were taking medication and none suffered from a neurological disorder other than dyslexia. All subjects gave written informed consent prior to study. The Institutional Review Board of Henry Ford Hospital approved the protocol.

2.2 Techniques

Studies were performed using a 148-channel Neuromagnetometer (4D Neuroimaging WH2500). All data were collected with a high pass filter of 0.1Hz, a low pass filter of 100 Hz, and a sampling rate of 508.63 Hz. All subjects were continuously monitored by audio speakers and video camera during the MEG study, while inside the magnetically shielded room. Auditory Evoked Cortical Magnetic Fields (AECMFs) and Binocular, Hemi field Visual Evoked Cortical Magnetic Fields (VECMFs) were measured for each subject.

PN was studied by measuring the subject's MEG field response to visual presentations of black and white line drawings [9] while silently naming the object. VG was studied by measuring the subject's MEG field response to visual presentations of black letter printed words (nouns) while silently thinking of a verb that corresponded to the noun presented.

Word comprehension was studied by measuring the subject's MEG field responses to visual presentations of a printed word (e.g. "airplane") and the simultaneous auditory presentations either of the matching name of the object (e.g. "airplane"), or a mismatched name for the object (e.g. "boat"), or a pseudo word (e.g. "habgla"). Approximately 100 (5-9 letter nouns, selected from [10] with concreteness > 4) concrete words were randomly shown for a 300 ms period each with a new presentation every 3 seconds. At 10 ms into each presentation an auditory word was presented. The subject was asked to determined whether the visual and auditory presentations matched, did not match, or if a pseudoword was involved. These decisions were recorded. Between each set of visual/auditory stimulations a tone was presented to alert the subject that the next presentation would start.

MRI scans were performed on each subject using a clinical GE 3.0 Tesla, 1 meter bore whole body magnet. The MRI scan parameters: coronal T1 images, 124 slices, and 256x256 matrix that includes the entire skin surface of the head. Images were converted to volumetric MRI data with isotropic pixel dimensions. This allowed for a precise localization of the anatomical landmarks and cortical activation area arising from auditory, visual, and language processes.

2.3 Data Processing/Analysis

MR-FOCUSS [7,8], a current density imaging technique involving multiple source analysis, was applied to locate possible extended sources. This source model incorporated each subject's MRI co-registered to the MEG data. The MRI was used to constrain the 2DII cortical images to lie within the cortical gray matter. The source localization results were displayed on the MRI scan of each individual's head.

VG responses were averaged; each set contained 60 responses. PN responses were averaged; each set contained 80 responses. Word comprehension was studied by separately averaging the subject's measured MEG field responses to the visual presentation of a written word and the simultaneous auditory presentation of a 1) matching, 2) mismatched, and 3) pseudo word. Each averaged set contained 30 responses to determine the averaged evoked response. These language data sets were filtered 1-50 Hz with a notch filter at 60Hz. Each data set was then individually analyzed by MR-FOCUSS to localize and quantify cortical activation in language specific areas.

3 Results

Auditory evoked (N100m) and Visual evoked (N75m, P100m, N145m) signals were similar in both groups. VG results from MR-FOCUSS showed the left STG area (Wernicke's area) was activated in at 201 ± 39ms after onset of stimulus in the normal controls. Subjects with dyslexia had similar latencies of activation 211 ± 12ms but location of initial activation was in the STG of the right hemisphere. Average amplitude of underlying cortical sources were 491 ± 30pAm. In subjects with dyslexia the underlying cortical activation was weaker ~ 300 ± 90pAm. MR-FOCUSS also localized high amplitude cortical neuronal activity over the left PFC later at 350-450ms during this same task in both normal subjects and subjects with dyslexia.

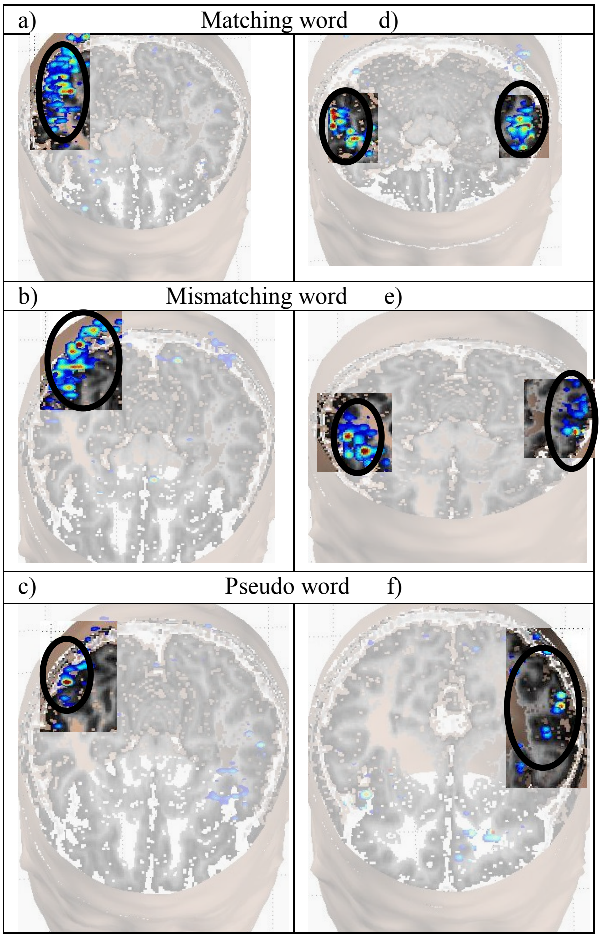

Figure 1 Word comprehension: Real time cortical localization results from a subject with Dyslexia during the visual presentation of a word and the auditory presentation of the a) matching word, b) mismatching word, and c) a pseudo word, d, e, and f, are same presentations but in a normal control individuals. The cortical responses at 230ms are displayed using MR-FOCUSS. Circles enclose most intense cortical activity.

During a silent PN task the left prefrontal cortex (Broca's area) was activated at 308 ± 49 ms in all normal controls. Subjects with dyslexia had similar left prefrontal cortex activation at latencies of 340 ± 35ms. Average amplitudes of underlying cortical sources were 308 ± 40 pAm for normal controls, while for subjects with dyslexia the underlying cortical activations were 300 ± 20 pAm.

MR-FOCUSS analysis of the word comprehension tasks showed the STG area in normal subjects was activated on average earlier than subjects with dyslexia. Overall dyslexic individuals tended to have delayed activation in the STG and PFC area compared to normal readers. Both groups showed delays in activation of STG and PFC areas for the mismatching word compared to the matching word.

Word comprehension data for one individual with dyslexia and his age, gender, and handedness matched control were analyzed by MR-FOCUSS. For both subjects all data sets (matching, mismatching, or pseudo) showed initial maximum activity at 230 ms after onset of stimuli. Figure 1 displays the cortical activation at 230 ms and the amplitude scale for the underlying electrical activity of the neuronal sources in nanoAmp-meters. Maximum amplitudes of neuronal activity were similar in these two fourteen-year-old subjects. The individual with dyslexia had predominantly more neuronal activity in the right hemisphere than the matched control subject. Also the amplitude of the activity at this latency increased for the mismatched word compared to the matching word and increased still more when a pseudo word was presented. The opposite trend was seen in the matched control subject's data.

4 Discussion

This study demonstrates MEG can effectively be used to localize language specific cortical areas utilizing a multi source analysis technique. FMRI and PET techniques image the neurological features of cortical language indirectly, using measurements of blood oxygenation [11], or glucose uptake [12]. Since MEG is a non-invasive, direct measurement of neuronal activation, with ms temporal resolution it provides direct knowledge of cortical processes involved in language function. The multi source analysis, MR-FOCUSS, revealed the extended cortical activation involved in language comprehension not seen using single ECD analysis. This study also provides further evidence that differences in neuronal activation in subjects with learning disorders can be detected.

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