MEG Applications for Detecting Dyslexia with Real & Nonsense Word Reading

Susan M. Bowyer [1,2,3], Margaret Greenwald [2], John E. Moran [1], Norman Tepley [1,3], Renee Lajiness O'Neill [1,4],

[1] Henry Ford Hospital, Detroit, MI, USA; [2] Wayne State University, Detroit, MI, USA; [3] Oakland University, Rochester, MI, USA; [4] Eastern Michigan University, Ypsilanti, MI, USA

drsusan@umich.edu

Abstract

Introduction: Dyslexia subtypes include: 1) "dyseidetic" reflecting poor whole-word reading of irregular words via a lexical route, and 2) "dysphonetic" reflecting poor grapheme-to-phoneme translation of nonsense words via a sublexical route. A recent MEG study of reading supports the existence of dual lexical and sublexical routes in fluent readers (Wilson et al. 2007). The current study expands this work by exploring the utility of MEG for examining the timing and sources of brain activation underlying clinical dyslexia subtypes.

Methods: MEG data from 16 subjects (8 female, 8 male, aged 8-43): 7 subjects with dyslexic (5 dyseidetic and 2 dysphonetic); 9 normal readers were analyzed with MR-FOCUSS (current density). MEG collected cortical brain activity while each subject read aloud.

Results: Normal readers read all stimuli without difficulties, whereas the dyslexic subjects had difficulty reading nonsense words. Inferior frontal areas are more active in both groups during nonsense words compared to real words consistent with an anterior system involved in word analysis (decoding) (Shaywitz & Shaywitz, 2005). Normal readers activate areas in the left angular and supramarginal gyri in both real and nonsense words, whereas dyslexic subjects rely more on cortical areas in the visual cortex during both tasks suggesting a greater reliance on automatic word recognition (Shaywitz et al., 2007), but poor assembly of phonology.

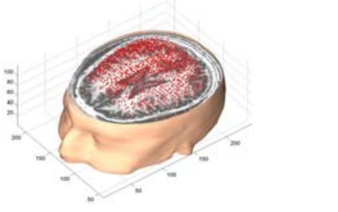
Conclusions: Language is a bilateral cortical process and detailed neural network mapping of locations, latencies, and strengths of neuronal interactions involved in language comprehension is needed. This study provided insight into the temporal processing of reading in dyslexia. Accurate models of these neuronal networks may prove useful in mapping the effects of future dyslexia treatments.

Methods

- 7 Subject diagnosed with dyslexia
- 9 Normal Readers
- The study population included 8 men and 8 women.
- Age range was 8-43 years old (mean age 24 $\pm$ 8 years)
- Writing hand was right in all but one control subject.
- A 148-channel MEG system: Magnetometers (4D Neuroimaging Magnes WH2500) recorded evoked brain activity while each subject read real and nonsense words out loud.
- Visual presentations of four printed letters representing a real word (i.e. "heat") or a non-word (i.e. "ateb").
- Sixty of these black and white printed letter strings were randomly shown for a 300 ms period every 3 seconds. Data from 0.2 seconds prior to stimulus onset until 0.8 seconds after onset of the word was used for analysis.
- Data were sampled at 508Hz, 0.01-100Hz.
- Data were bandpass filtered 1-30 Hz.
- MEG data were analyzed with MR-FOCUSS [Moran, 2005], a current distribution analysis technique capable of imaging simultaneous activity in multiple cortical structures and correlating with specific anatomical structures on volumetric MRI. Analysis performed using MEG-TOOLS.
- Available freeware at: **www.megimaging.com**

Cortical Model

- Created from volumetric MRI
- Approximately 4,000 cortical points
- 3 dipoles at each point that represent x, y, z
- Distribution matches gray matter



Introduction

The terms "dyseidetic" and "dysphonetic" have been used to characterize children with difficulties primarily in reading via a lexical "whole word" route in contrast to those with a primary difficulty in reading via a sublexical route of grapheme to phoneme translation, respectively [Coltheart, 1999]. In the acquired dyslexia literature, lesion studies of stroke patients have distinguished neuroanatomical differences underlying surface dyslexia (in which reading is impaired for whole-word non-phonologic spellings such as 'light' or 'yacht') versus phonological dyslexia and also deep dyslexia (in both of which reading via sublexical "sounding out" of graphemes to phonemes is impaired). Clinical symptoms of dyslexia initially supported a dual-route cognitive theory to distinguish lexical and sublexical processes in reading. It is not clear to what extent phonological (sublexical) processing may influence lexical reading. Research on the developmental acquisition of language suggests that visual word recognition requires phonological processing [Rastle, 1999]. Several studies have revealed that phonological coding is necessary for reading nonsense words [Rack, 1992; Gough, 1991]. MEG has been used effectively to investigate written word processing in dyslexic individuals [Bowyer, 2002] and normal controls [Bowyer, 2004]. These studies show that there is a detectable difference in evoked responses during picture-naming and written word comprehension between individuals with dyslexia and control subjects. Another recent MEG study using current density mapping during visual reading supports the existence of dual-mechanisms underlying reading [Wilson, 2007]. The current study expands this work by exploring the utility of MEG for examining the timing and sources of brain activation underlying clinical symptoms of dysphonetic versus dyseidetic dyslexia during an reading out loud of real and nonsense words. MEG is an excellent method for examining potential patterns of feedback from higher order language processes such as semantic memory to reading subprocesses activated earlier in the time course of reading, such as visual and phonological information. MEG has the potential to provide a window into the interactive activation among reading subprocesses described in current connectionist theories of reading and dyslexia [Plaut, 1996], by showing activation and re-activation of brain regions in contiguous or parallel cortical regions at discrete time points during reading. MEG can track the very rapid changes in language processes and language activation occurring within a few milliseconds to "elucidate the orchestration of these areas" during highly complex language tasks such as reading.

Results

Normal Reader

A. Real word B. Nonsense word

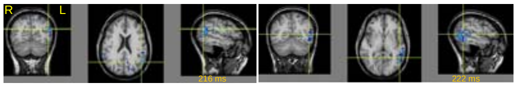


Figure 1. MR-FOCUSS imaging in a right handed, 46 year old normal reader. Angular gyrus on the left side is active in both tasks.

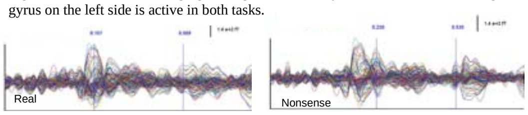


Figure 2. Evoked MEG wave forms. A) Control subject reading real words out loud. B) reading nonsense words out loud. N100m, P200m and Peak at 509ms represents activation in Broca's area. During the nonsense word this activation is delayed.

Reader with Dysphonetic Dyslexia

A. Real word B. Nonsense word

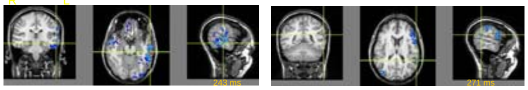


Figure 3. MR-FOCUSS imaging in right handed, 40 year old subject with Dysphonetic dyslexia. Superior temporal gyrus on the left side is active in the real word task but AG is active in the nonsense words. Not shown: Inferior frontal gyrus is more active in the Right IFG during the nonsense word task.

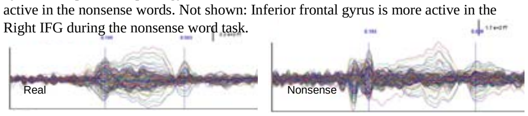


Figure 4. Evoked MEG wave forms. A) Reading real words out loud. B) reading nonsense words out loud. N100m, P200m and Peak at 503ms represents activation in Broca's area. During the nonsense word this activation is delayed.

Reader with Dyseidetic Dyslexia

A. Real word B. Nonsense word

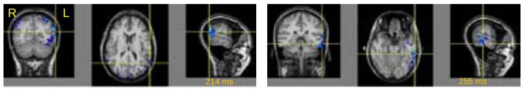


Figure 5. MR-FOCUSS imaging in right handed, 43 year old subject with Dyseidetic dyslexia. AG is active during real word reading but Superior and inferior temporal gyrus on the left side is active in the nonsense word reading task. This is opposite from the dysphonetic subject. Not shown: Inferior frontal gyrus is more active in the Right IFG during the real word task again opposite to the subjects with Dysphonetic dyslexia.

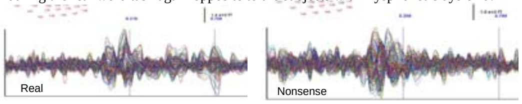


Figure 6. Evoked MEG wave forms. A) Reading real words out loud. B) reading nonsense words out loud. N100m, P200m and Peak at 704ms represents activation in Broca's area. During the nonsense word this activation is delayed.

Results

- Fusiform gyrus - Early processing (100-200ms) is similar between real and nonsense words for both groups. Activations of the fusiform gyrus and visual association areas are evident for both stimulus types for both subject groups using MR-FOCUSS.
- Supramarginal gyrus (SMG), Superior Temporal gyrus (STG), Angular gyrus (AG) - Secondary activations were seen (200-300ms) in the left AG for normal readers during both real and nonsense words (no IFG activation seen) (Figure 1). For most subjects with Dysphonetic dyslexia activation was seen in the left STG in the real word task but AG is active in the nonsense words (Figure 3). Not shown: Inferior frontal gyrus is more active in the Right IFG during the nonsense word task. For most subjects with Dyseidetic dyslexia the AG was active during real word reading but STG and ITG on the left side were active in the nonsense word reading task. This is **opposite** from the dysphonetic subject (Figure 5). Not shown: Inferior frontal gyrus is more active in the Right IFG during the real word task again **opposite** to the subjects with Dysphonetic dyslexia.
- Inferior Temporal gyrus (ITG) - Mid latency processing (300-400 ms) was seen in frontal and left temporal regions in normal readers during real word reading and only the right temporal for subjects with dyslexia. Nonsense words activated right temporal regions but no frontal areas in both Normal readers and subjects with Dyslexia.
- Inferior frontal gyrus (IFG) - Later processing (400-700ms) activity in the IFG was delayed by 100 ms in dyslexic subjects during nonsense word reading compared to real word processing. A delay was also seen in normal readers though not as long.

Conclusions

- Language is a bilateral cortical process and complete understanding requires intensive analysis to provide step-by-step neural network mapping of the locations, latencies, and strengths of neuronal interactions involved in language comprehension.
- Compensated adults use bilateral STG, AG and SMG similar to what was found by Shaywitz et al., [2007] in which older compared with younger dyslexic readers demonstrate increased activation in left inferior frontal and bilateral posterior occipitotemporal regions.
- The benefits of MEG neuroimaging include a better understanding of how language processes occur, and validating neuronal network models of language cognition.
- This study provides further evidence that differences in distinctive neuronal activation in subjects with learning disorders can be detected. MEG may emerge as an imaging modality, useful in the early definition and intervention for learning disabilities.
- Moreover, these studies may further the basic science of validating neuronal network models of attention, decision-making and control of motor function. Accurate models of these neuronal networks may prove useful for the development of future drugs or other treatments.

References and Acknowledgment

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