Language Processes during Overt and Covert Speech in a Simulated Driving Task

Susan M Bowyer[1,2], Allison Shatz[1], John E Moran[1], Sean Seaman[2], Richard A Young[2], John Sullivan[3], Reza Farjam[1,2], Norman Tepley[1], Li Hsieh[2]

[1] Henry Ford Hospital, Detroit, MI, USA; [2] Wayne State University, Detroit, MI, USA; [3] University of Michigan, Ann Arbor, MI, USA

drsusan@umich.edu

Abstract

- **Objective:** We used MEG to explore the neural correlates of language processing in a simulated driving environment. Since functional MRI and MEG studies require subjects to remain still and not move their mouths, unlike real on-road driving conditions, we explored this constraint.
- **Methods:** MEG was used to identify the cortical regions engaged in language processing during hands-free overt (aloud) and covert (silent) cell phone conversations during simulated driving. Subjects viewed a real-world driving video and responded (foot pedal) to red dot stimuli (visual events) presented either centrally or peripherally on the driving scene, while performing a lane tracking task (arrow on screen) with right fore and middle fingers. We termed this condition, with no-speech, as Task 1. Other conditions involved performing Task 1 while the subject spoke aloud (Task 2) or silently (Task 3). MEG data were collected for 8 minutes for each task.
- **Results:** Coherence analysis compared activations of Broca's and Wernicke's areas in the three conditions. The inferior frontal gyrus (Broca's) and the superior temporal gyrus (Wernicke's) language areas were activated similarly in the overt and covert conditions. These activations were significantly different from the no-speech condition where little or no cortical activation was detectable in these language processing areas.
- **Conclusions:** The use of MEG to investigate neural processing during simulated driving tasks appears quite promising, since the use of covert speech instead of overt speech can provide similar cortical activation patterns, in the movement-sensitive MEG environment. This study hopes to expand automotive safety technology, which may help reduce traffic accidents/crashes by better understanding how the brain processes information in multi-tasking environments, in turn leading to improved designs of in-vehicle technologies. Research support: State of Michigan MTTC Grant and NIH/NINDS Grant RO1-NS30914.

Methods

- 16 Subjects (5 males and 11 females) with valid USA driver's license were scanned with MEG while performing a simulated driving scenario.
- Age range was 21-60 years old (mean age 34±11 years)
- Writing hand was right.
- 148 channels MEG : Magnetometers (4-D Neuroimaging Magnes WH2500)
- Data were sampled at 508Hz, 0.01-100Hz.
- Data were collected while the subjects lay on the bed in the magnetically shielded room. Subjects watched a video of a driving scene (figure 1) and pressed a pedal under their left foot when a red light appeared. Red light stimuli appeared in either the lower central or left peripheral visual field [1]. We termed this condition, with no-speech, as Task 1. Other conditions involved performing the same detection task as in Task 1 while answering questions presented as simulated cell phone conversation with overt speech (Task 2) or covert speech (Task 3). At the start of the conversation subjects pressed a button, placed under his/her right hand, to answer a ring, and then responded to simple pre-recorded questions (see examples listed in Table I). Presentation software was used to display the computer-generated driving scene image, red light stimuli and the prerecorded questions.
- Data was frequency filtered 1-50Hz. We then applied the MR-FOCUSS-ICA [2] technique to localize brain activity. The ICA part of this technique obtains signals from distinct cortical sources and MR-FOCUSS [3] images the cortical activation corresponding to these ICA signals. Coherence imaging [4] analysis was then performed on the MR-FOCUSS-ICA imaged brain activity to identify cortical sources that interacted strongly within each frequency band. Available freeware at: **www.megimaging.com**

Visual and Auditory Stimuli

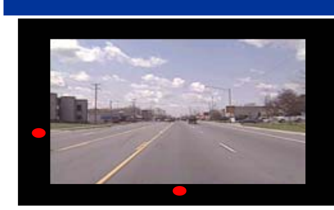

Figure 1. Driving Scene video with red event lights in the lower central viewing area and in the left peripheral area.

Table 1 Conversation example

Simulated cell phone call:	(Ring).
Driving subject:	(Manually press a button to answer the call)
Recorded speech:	Hi, could you tell me your birth date?
Driving subject:	(Month/day/year)
Recorder caller:	Could you tell me your home address?
Driving subject:	(street number, street, city, state)
Recorder caller:	Could you tell me your home telephone number?
Driving subject:	(area code) (xxx-xxxx)
Recorder caller:	Thanks, that's all. Bye.
Driving subject:	Bye (and press the same button to hang up the phone).

Introduction

Functional imaging techniques such as fMRI and MEG require subjects to remain still and not move during the data acquisition periods. Neuroimaging studies of language generally require speaking subjects to speak silently to self (covertly) and not move their mouth as opposed to speaking aloud (overtly). Numerous covert language studies have been performed in the MEG [5-7], fMRI [8, 9], and PET [10, 11] scanners. This study was performed to determine if language processing was similarly activated in both overt and covert speech processing while performing an event detection task. Only in this way could we determine if the neural networks are activated similarly in both conditions. A recent study by Just using fMRI showed decreased activation in parietal and superior extrastriate areas and increased activation in temporal and prefrontal language areas during simulated driving [12].

Image Results

Subject #8

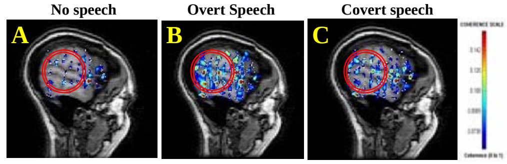

Figure 1: Sagittal slice of the left hemisphere showing red circle around Wernicke's area [supramarginal gyrus (SMG) also known as Brodmann's area (BA) 40; superior temporal (STG) also known as BA 22, 41, 42 and angular gyrus (AG) BA 39]. Areas in red indicate coherent activation of brain cortex. A) No Speech condition. Note cortical activity in Wernicke's areas indicating language comprehension during the B) Overt, and C) Covert Trials.

Subject #16

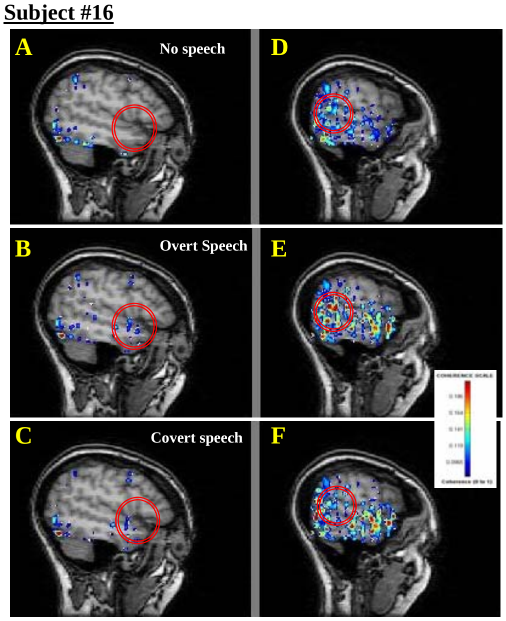

Figure 2: Sagittal slice from left hemisphere showing red circle around Broca's area [inferior frontal gyrus (IFG) BA 44, 45, and may include middle frontal gyrus (MFG) BA 46 and 9]. A) No Speech, B) Overt Speech and C) Covert Speech Trials. Note no cortical activity in Broca's areas during the A) No Speech condition and increased cortical activity in the B) Overt, and C) Covert Trials. Figures E-G display red circles around Wernicke's areas. Note The most coherent activity is seen in the B) Overt Speech condition.

Subject #6

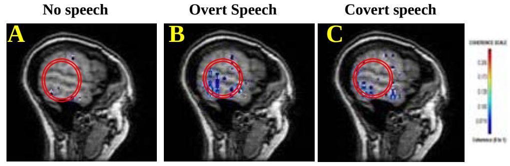

Figure 3: Sagittal slice from left hemisphere showing red circle around Wernicke's area. A) No Speech no coherent brain activity is seen, B) Overt most coherent brain activity is seen, and C) Covert Trials displaying some coherent brain activity.

Results

- MEG data from 15 subjects were used for this analysis. One subject had a metal brace in her mouth and the MEG scan was contaminated with excessive magnetic noise.
- During Task 1, where no speech production occurred, no activity was seen in Wernicke's area for most subjects. The MEG coherence imaging for three subjects during Task 1 (no speech) is shown in the Figures part A and D.
- In contrast, during Task 2 Wernicke's area was found to be highly coherent in all subjects indicating the language processing network was active in this overt speech condition (Figs. B and E).
- During the covert speech condition in Task 3 Wernicke's area was found to be more active than the no speech condition and slightly less active than the overt condition (Figs. C and F).
- In some subjects, the level of coherence was not as high as in the covert condition as in the overt condition. In all 15 subjects similar coherent patterns were seen across both conditions. This implies the same network for language processing is active in this overt and covert condition, which was significantly different from the no speech condition.
- Broca's area was active in all 3 conditions with different degrees of intensity across all subjects. The No Speech condition (Task 1) resulted in a small area of low level of coherent activity detected. In some case no activity was seen. The Overt Speech (Task 2) resulted in a higher level of coherent activity than during the Covert Speech (Task 3).

Conclusions

- These preliminary data show that MEG coherence imaging enables us to detect cortical neuronal activity involved in language processing while performing an event detection task in a simulated driving environment.
- Our findings suggest that cortical brain activity in Wernicke's area was similar in both overt and covert conditions of language processing and that these 2 tasks were significantly different from the no speech condition.
- Neuroimaging the MEG signals arising from speaking out loud activates similar cortical language areas (Wernicke's) as speaking silently to self (with no mouth movement).
- The detection of Broca's area during the no speech condition may imply that subjects are silently directing their movements during Task 1. The brain activity in the motor speech area will need to be evaluated further to determine how the activation during speech and no speech is altered during this driving simulation.
- Several studies have shown that Verbal auditory feedback is very important in speech production to assure correct and proper speech output [13]. A recent fMRI study found that the anterior cingulate cortex, which is often implicated in error-processing and conflict-monitoring, is also engaged in ongoing speech monitoring. Furthermore, in the superior temporal gyrus, they found a reduced response to speaking under normal feedback conditions [14]. This is in contrast to our results where most subjects had similar levels of activation between the overt and covert speech conditions. In a few subjects there was a reduction in coherence during the covert speaking condition compared to the overt speech condition.
- The use of MEG to investigate neural processing during simulated driving tasks appears quite promising, since the use of covert speech instead of overt speech can provide similar cortical activation patterns, in the movement-sensitive MEG environment. This study will help to expand the understanding of how the brain processes information in multi-tasking environments.

References and Acknowledgment

[1] Young, R. A., Aryal, B., Muresan, M., Ding, X., Oja, S., Simpson, S. (2005). Validation of the static load paradigm for predicting on-road driving performance while using advanced in-vehicle information and communication devices. 3rd International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design Rockport, Maine.

[2] Moran, J.E., Drake, C.L., Tepley, N, ICA Methods for MEG Imaging, in Biomag 2004: Proceedings 13th International Conference on Biomagnetism, E. Halgren, Ahlfors, S., Hamalainen, M, Cohen, D., Editor. 2004: Boston. p. 573-574.

[3] Moran, J.E., Bowyer, S., Tepley, N, Multi-Resolution FOCUSS: A source imaging technique applied to MEG data. *Brain Topography, 2005*. **18**: p. 1-17.

[4] Salmelin R and Kujala J Neural representation of language: activation versus long-range connectivity. TRENDS in Cognitive Sciences 2006, 10(11):519-525.

[5] Bowyer, S.M., et al., MEG localization of language-specific cortex utilizing MR-FOCUSS. *Neurology*, 2004. **62**(12): p. 2247-55.

[6] Levelt, W.J., et al., An MEG study of picture naming. *J Cogn Neurosci*, 1998. **10**(5): p. 553-67.

[7] Simos, P.G., et al., Identification of language-specific brain activity using magnetoencephalography. *J Clin Exp Neuropsychol*, 1998. **20**(5): p. 706-22.

[8] Binder, J.R., et al., Human brain language areas identified by functional magnetic resonance imaging. *J Neurosci*, 1997. **17**(1): p. 353-62.

[9] Shaywitz, B.A., et al., Sex differences in the functional organization of the brain for language. *Nature*, 1995. **373**(6515): p. 607-9.

[10] Gross-Glenn, K., et al., Positron emission tomographic studies during serial word-reading by normal and dyslexic adults. *J Clin Exp Neuropsychol*, 1991. **13**(4): p. 531-44.

[11] Petersen, S.E., et al., Positron emission tomographic studies of the cortical anatomy of single-word processing. *Nature*, 1988. **331**(6157): p. 585-9.

[12] Just MA, K. T., Cynkar J. (2008). "A decrease in brain activation associated with driving when listening to someone speak." Brain Research **1205**: 70-80.

[13] Levelt WJM , Roelofs A., Meyer AS, A theory of lexical access in speech production. *Behav Brain Sci* 1999. **22**: p. 1-75.

[14] Christoffels I.K., Formisano E., Schiller N.O., Neural Correlates of Verbal Feedback Processing: An fMRI Study Employing Overt Speech. *Human Brain Mapping*, 2007. **28**: p. 868-879.

Research supported by: NIH NINDS Grant RO1 NS 30914 and Michigan Technology Tri-Corridor (MTTC).