

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

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ABSTRACT

We used MEG to explore the neural correlates of language processing in a simulated driving environment. Functional MRI and MEG studies require subjects to remain still and not move their mouths, unlike real on-road driving conditions. MEG was used to identify the cortical regions engaged in language processing during hands-free overt (out loud) 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 out loud (Task 2) or silently (Task 3). MEG data were collected for 8 minutes for each task. 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. 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.

KEYWORDS: MEG, Driving, Overt Speech, Covert Speech

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 out loud (overtly). Numerous covert language studies have been performed in the MEG [1-3], fMRI [4, 5], and PET [6, 7] 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.

METHODS

Sixteen subjects (5 males and 11 females; 34 ± 11 years old) with valid USA driver's license were scanned with MEG while performing a simulated driving scenario. Data was collected while the subjects lay on the bed in the magnetically shielded room. Subjects watched a video of a driving scene 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. 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 such as "What is your birth date?", "What is your address?" Presentation software was used to display the computer-generated driving scene image, red light stimuli and the prerecorded questions. MEG data were collected at 508Hz, band passed from 0.1-100 Hz for 8minutes. Subjects keep their eyes open and fixated on the driving scene in front of them.

Independent component analysis (ICA) technique was used to remove heart artifact from the MEG data. Then singular valued decomposition (SVD) of MEG data was used to eliminate the noise components [8]. Data was frequency filtered 1-50Hz. After artifact was removed

from the MEG data by the previous 2 methods we applied the MR-FOCUSS-ICA [9] technique to localize brain activity. The ICA part of this technique obtains signals from distinct cortical sources and MR-FOCUSS [10] images the cortical activation corresponding to these ICA signals. Coherence imaging analysis was then performed on the MR-FOCUSS-ICA imaged brain activity to identify cortical sources that interacted strongly within each frequency band. To calculate coherence, a temporal sequence of cortical source FFT spectra was created from short data segments (256 time points each) that overlap by 25 %. For each frequency of the FFT spectra, the cross-spectral matrix of active brain sources was calculated then normalized. Finally, for each active cortical site, the average coherence with all other sources was calculated for each frequency. In addition, for each cortical site the connectivity was also calculated. The connectivity spectrum of an active site with other active sites was calculated by creating a histogram of the number of sources that are coherent with the target site for each of 20 levels of coherence between 0.05 and 1 for each FFT frequency component. Coherence images were generated for each consecutive 7.5 seconds of the 8 minutes of MEG data. These were averaged to obtain coherence magnitude and location of strongly interacting cortical sources. The variance across this set of images is a measure of the stability of the cortical network activity and allows changes in coherence across time to be assessed for statistical significance. Coherence between cortical sites is a consequence of both direct and indirect connectivity within normal cortical networks. MEG coherence imaging is particularly effective for observing cortical sites involved in persistent network activity that dominates the duration of these 8 minute studies.

Cortical areas involved in language included 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] and Broca's area [inferior frontal gyrus (IFG) BA 44, 45, and may include middle frontal gyrus (MFG) BA 46 and 9].

RESULTS

MEG data from fifteen 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 all 15 subjects. Figure 1 shows the MEG coherence imaging for one subject during Task 1 (no speech).

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 (fig 2). During the covert speech condition in Task 3 Wernicke's area was found to be active while watching a driving scene (fig 3).

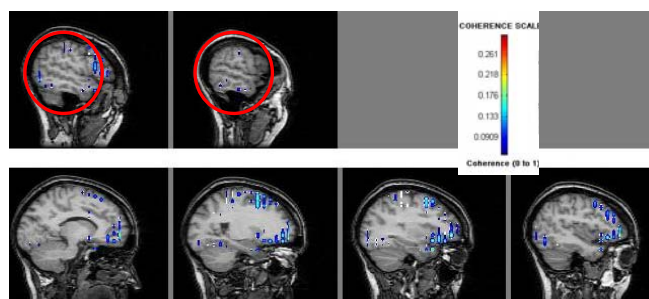


Fig 1. MEG coherence imaging for one subject during the no speech condition (Task1) is displayed on the subject's MRI. High coherence was not seen in the Left or Right (not shown) Wernicke's area. This implies a network for language processing was not active in this condition.

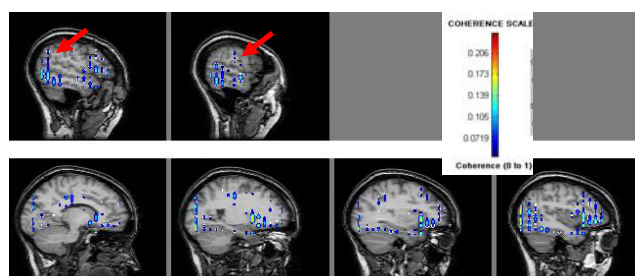


Fig 2. MEG Coherence images of task 2, speaking OVERTLY while watching a driving scene. This is the same subject as in fig 1. MRI shows localization of coherent brain activity in the Left STG and AG. This implies a network for language processing was active in this condition.

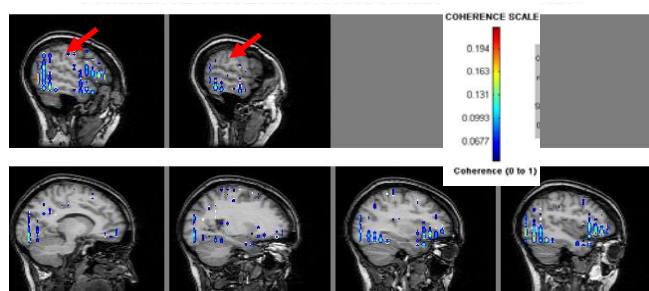


Fig 3. MEG Coherence images during task 3, speaking COVERTLY while watching a driving scene. This is the same subject as in figs 1 & 2. MRI shows localization of coherent brain activity in the Left STG and AG, similar to fig 2. This implies that the same network for language processing is active in both overt and covert conditions.

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 areas were seen across all 3 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 is active in all 3 conditions with different degrees of intensity. The No speech condition (Task 1) has a small area at a low level of coherent activity detected. Task 2 has the highest level of coherent activity detected compared to the Task 1 and 3.

DISCUSSION

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. We determined 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). These results show that speaking silently is similar to speaking out loud as detected by noninvasive MEG using coherence imaging.

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 task.

Several studies have shown that Verbal auditory feedback is very important in speech production to assure correct and proper speech output [11]. 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 [12]. 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.

CONCLUSION

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 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.

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