Imaging of Brain Activities Related to Reaction Times in a Driving Simulation

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

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

rezaf@rad.hfh.edu

Abstract

MEG imaging has the required millisecond temporal resolution needed to determine how the brain multi-tasks. Hence, it is well suited for studies of brain activity during simulated driving, which includes the performance of more than one task. In our primary studies, we acquired MEG data during a simulated study of driving where a driving scene was viewed. The primary driving task was to respond to a small red light by pressing a foot pedal. The reaction times to execute the pedal were recorded and subsequently related to changes in MEG data and imaged brain activities. MEG data were processed based on the synchronization of a red light presentation. For MEG data synchronized to the red light presentation, the amplitude of brain activity in the right parietal cortex reached its peak nearly 230 ms after light onset. In addition, brain activity was found to be inversely related to reaction time.

In our current study, we are using conversations involving emotional (angry vs. neutral voice) interactions. In addition, a lane tracking task was added to the study. Subsequently, we image differences in brain activity that are associated with different combinations of conversation contents and reaction time performance.

Here, we describe the methods we have developed to extract MEG signals related to driving task performance and subsequently image the signals and quantify differences in brain activity related to language and driving interaction. This study contributes to the understanding of neural mechanisms that underlie brain processing of information in multi-tasking environments.

Method

- 16 Right-hand subjects with valid USA driver's license were scanned with MEG while performing a simulated driving scenario.
- 148 channels MEG: Magnetometers (4-D Neuroimaging Magnes WH2500)
- Data were 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 [1]. We termed this condition "No-Conversation". Other conditions involved performing the same detection task while listening to an emotional (angry or neutral) conversation presented as a simulated cell phone conversation and responding using covert (silent) speech. 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 in his/her mind. Presentation software was used to display the computer-generated driving scene image, red light stimuli and the prerecorded questions.
- Data were sampled at 508Hz, 0.01-100Hz and digitally filtered, 3-30Hz. Subsequently, bad channels were removed from the analysis.
- Artifact removal techniques were also applied to refine the data.
- Data in a similar condition were averaged. Each condition was also divided into two groups based on the reaction time (short and long reaction time). Fig. 1 shows a typical averaged data (after applying all the above pre-processing modules) in the angry conversation while the red light comes on the center position of the screen and when the subject had a short reaction time. We show each of the possible condition by $\mathbf{C_i}$.

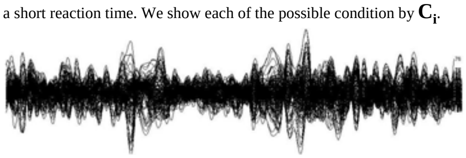

Fig. 1. A typical averaged 148-MEG data in angry conversation while the red light comes on the center position of the screen and when the subject had a short reaction time.

- Using partial least squares method [5], and the combination of all possible conditions, a signal space (SP) including the principle components of the data were provided.

$$\begin{bmatrix} C_1 \\ C_2 \\ . \\ . \\ . \\ C_n \end{bmatrix} = \begin{bmatrix} \textit{MEG Signal} \\ \textit{Space} \end{bmatrix} \bullet \begin{bmatrix} \textit{Singular} \\ \textit{Values} \end{bmatrix} \bullet \begin{bmatrix} \textit{Conversation} \\ \textit{Driving Task} \\ \textit{Space} \end{bmatrix} \quad (1)$$

- We then cleaned the MEG data by projecting it on the SP and removing the least significant components. Fig. 2 displays the result.

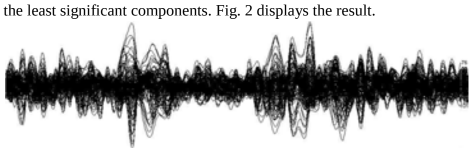

Fig. 2. Cleaning the data by removing the least significant components.

Introduction

Among different functional imaging techniques, MEG has sufficient temporal resolution for determining the sequence of brain activity associated with language processing (1-4). In this research, we employ the MEG to study brain activity in a driving simulation scenario with a simultaneous conversation task designed to evoke emotional (angry and neutral voice) interactions. This work follows our preliminary MEG study of simulated driving performance (reaction time to light on stimulus) which used a relatively undemanding conversation task. In the current analysis, we will use a partial least squares method [5] to extract signals related to all the different driving task/conversation conditions as well as long versus short reaction times. This analysis will be applied to each subject separately. These individual imaging results will be combined by applying a transform that maps the location of activity to MNI coordinates. The final group averaged results will quantify differences in brain activity between types of conversation tasks and between driving plus conversation and the baseline (driving task only) condition. Further, within each driving/conversation (or driving only) condition the change of brain activity associated with reaction time will be determined. In our preliminary study [1], we found that changes in brain activity relating to reaction time were linearly related to a single component of MEG data arising primarily from the parietal and occipital cortex. Furthermore, our preliminary study showed, that in the parietal and occipital cortex, the amplitude of brain activity was inversely related to reaction time and adversely affected by the inclusion of the conversation.

Method (Continued)

- We applied the MR-FOCUSS-ICA [4] technique to localize brain activity. The ICA part of this technique obtains signals from distinct cortical sources and MR-FOCUSS images [6] the cortical activation corresponding to these ICA signals. Figs. 3 and 4 shows the brain activity modulations corresponding to the Angry-conversation and No-conversation conditions, respectively.

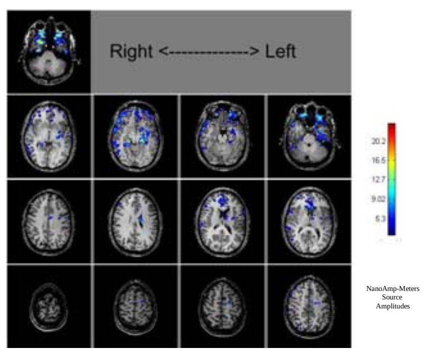

Fig. 3. Brain activity modulations associated with MEG data obtained in angry-conversation while the red light came on and the subject had short reaction times.

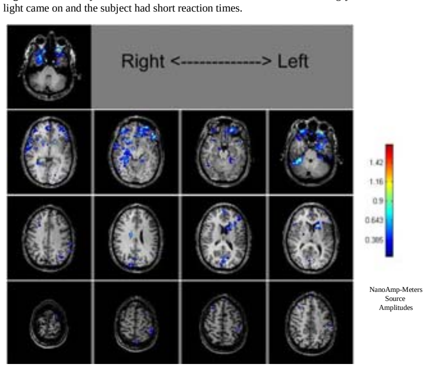

Fig. 4. Brain activity modulations associated with MEG data obtained in No-conversation while the red light came on and the subject had short reaction times.

- Finally, the difference in brain activity modulations related to different conversation contents were calculated. Here, we present the result of applying this technique to a typical subject to compare No-conversation versus Angry- conversation and also show the difference in brain activity with short and long reaction time.
- MEG-Tools is a freeware package available at: www.megimaging.com

Results

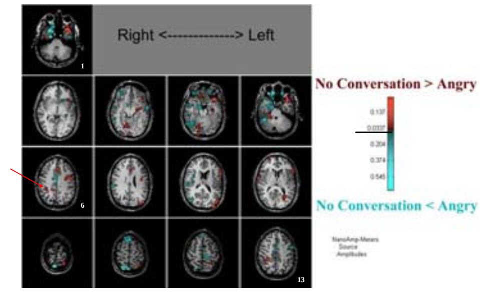

Fig. 5. For this pilot subject**,** during the No-conversation brain activity modulations are statistically significant relative to the noise, for the Angry-conversation in the right parietal cortex, seen as red area in Slice 6 (Arrow).

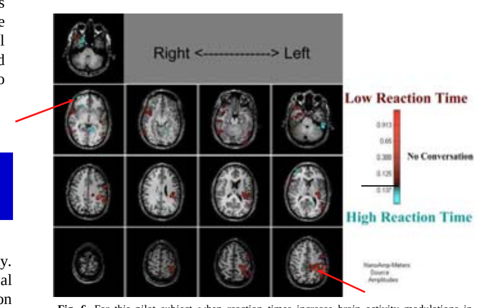

Fig. 6. For this pilot subject**,** when reaction times increase brain activity modulations in the left parietal areas is reduced and frontal activity increases. Note the location changes of red to blue regions.

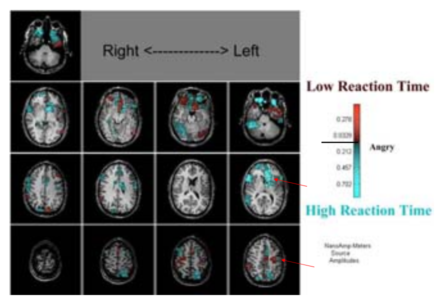

Fig. 7. For this pilot subject**,** when reaction times increase brain activity modulation reduces activity in the parietal areas and increase the activity in the frontal. This is more strongly seen during the angry conversation in this figure than in Fig. 6.

Conclusions

- We have described the methods that were developed for evaluating changes in brain activity (detected by MEG) based on recorded reaction times.
- This technique depicts brain activation modulation shifts as reaction times increase.
- As in our previous study [1], the right superior parietal region is more actively modulated in the no conversation condition.
- This single pilot study shows promise for these methods in identifying some neural effects of emotional content of conversations.
- These studies contribute to our understanding of the neural mechanisms that underlie brain activity in multi-tasking environments.

References and Acknowledgment

[1] Bowyer SM**,** Moran JE, Hsieh L, Manhoran A, Young RA, Malladi K , Yu Y-J, Chiang YR, Hersberger R, Genik II RJ, and Tepley N, MEG Localization of Cortex Involved in attentional Processes during a Driving Task with Conversation. In: International Congress Series: New Frontiers in Biomagnetism: Proceedings of the 15th International Conference on Biomagnetism, Vancouver, BC Canada, August 21-25, 2006. D. Cheyne, B. Ross, G. Stroink and H. Weinberg (Editors). 1300 pp. 401-404.

[2] Young, R. A., Aryal, B., Muresan, M., Ding, X., Oja, S., Simpson, S. Validation of the static load paradigm for prediction 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, Marine.

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

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

[5] McIntosh, A.R., et al., Partial least squares analysis of neuroimaging data: applications and advances. Neruoimage, 2004 23:supp1:S250-63.

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

Research supported by State of Michigan MTTC Grant and NIH/NINDS Grant RO1-NS30914.