

Neural Correlates of Event Related Distractions During A Driving Task Using MEG

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ABSTRACT

Performance of a secondary task, such as a cell phone conversation, may change attention to an automobile driving task. In this study, MEG imaging was applied to an automobile driving simulation paradigm to identify the cortical regions engaged in the primary driving task. Subjects viewed a driving video and responded (foot pedal) to red light stimuli (events) presented either centrally or peripherally in the driving scene. Cortical activation was imaged from MEG data averaged on the foot pedal response. MEG temporal resolution enabled the determination of sequential cortical activations. Orbital frontal gyrus activation was observed throughout the interval. Red light onset evoked occipital cortex activity that was followed by activation in the superior frontal gyrus and anterior cingulate gyrus. Peaks of motor and pre-motor cortex activation were detected during eye fixation movements (light on), and motor activity in the precentral gyrus preceding foot and leg activation of the pedal response pad. This action turned off the light and produced a visual evoked response in the occipital cortex. Occipital activation occurred when the light was turned off with the pedal response. These were brief intervals and correlated with known locations for visual and specific motor cortex locations. Frontal activation was dominant throughout this driving task with prominent peaks associated with the red light onset and the pedal push. Our findings suggest driving tasks recruit neural systems known to be involved in visual-motor multimodal processing and integration. The use of event-related MEG in investigating neural processing during simulated driving tasks is quite promising.

KEYWORDS: Driving, Attention, MEG, MR-FOCUSS

INTRODUCTION

An essential issue for human factors research is to examine and evaluate the design of human-machine interfaces for the safe and efficient operation of complex equipment under multi-tasking conditions [Russo, 2004]. Multi-tasking is required for both primary driving (steering, braking, navigation) and secondary tasks (e.g. a cell phone conversation). Very little is currently known about how the brain functions at the neuronal level during driving tasks with or without distractions from non-driving related in-vehicle devices. This has proven to be a difficult question to answer with indirect measurement techniques. For example, self-reports of attending to the road require that drivers be aware of being distracted – and yet drivers may be unaware that they are missing things on the road [Rensink, 1997]. Measurements of eye movement behavior cannot account for drivers who look right at something and do not see it [Underwood, 2003]. Response time measurements are purely behavioral, and do not elucidate underlying neural mechanisms [Zheng, 2002]. MEG studies of driving performance have not been attempted until now. To determine exactly how and why the performance of secondary tasks such as answering a cell-phone and conversing using a hands-free telematics system can affect primary driving requires knowledge of neural pathways involved in these tasks. Design of a telematics or navigation system to reduce driver distraction, or improve situation awareness probably cannot be accomplished if the fundamental nature of driver distraction is not known. The scientific goal of this study was to determine the neural basis of mental attention shifts that underlie driver errors (i.e., driver distraction). Hopefully, this will provide insights on brain mechanisms that can be used to develop telematics or navigation systems with less impact on driving awareness.

METHODS

Our 148 channel whole head Neuromagnetometer (WH2500 Magnes, 4D Neuroimaging), was used to measure magnetic fields in five individuals, between 30 and 55 years of age (4 females) all of whom possessed a current driver's license. Measurements were taken inside a magnetically shielded room located in the Neuromagnetism Laboratory at Henry Ford Hospital (HFH).

Details of the MEG study: Each subject signed an informed consent form approved by the HFH Internal Review Board. Subjects were prepped for the MEG study with magnetic dipole coils fixed to the subject's head [Bowyer, 2003]. These coils were activated before and after tests to generate signals for calculating the location of the subject's head with respect to the neuromagnetometer detector array. The subject then lay comfortably on the bed inside the magnetically shielded room with the neuromagnetometer array surrounding the subject's head in close proximity to the skull surface. A mirror system was used to enable the subject to view projected driving video. Two red LEDs were affixed to the viewing screen, one in the lower central region, and the second one on the left side of the screen (Fig 1). The subject was asked to avoid excessive eye blinks and body movements during data collection. Data collection runs lasted approximately 4 minutes. Each subject was monitored by video camera and two-way audio speaker system during the time he/she was in the shielded room. The MEG data were band-pass filtered 0.1 to 100 Hz, and digitally sampled at 508.63 Hz.

MEG TEST: While in a supine position each subject attended to surrounding vehicle activity, traffic signals, signs and city scenery in a driving video projected directly in front of him/her. At random intervals either the central or peripheral red light stimulus was turned on and the subject was required to detect the light and push a foot pedal with his/her right foot. Subsequent pedal activation turned the light off and produced a click sound. For the duration of time between turning the light on, to pedal push, a trigger high code was recorded simultaneously with the MEG data. A different code was used for central and peripheral lights. There were 40 red light stimuli during each study. The test was repeated three times to obtain a total of 120 pedal activation events.

MRI Scan: To correlate MEG areas of cortical activity with specific anatomical structures, each subject's MRI was co-registered into each subject's head digitization points collected at the beginning of the MEG study [Bowyer, 2003]. The techniques for co-registration of MEG and MRI are well established and used in all HFH clinical MEG studies. This allows precise correspondence between anatomical structures and MEG areas of cortical



activation. The MRI scan was performed on a 3-Tesla GE whole body MRI scanner. This volumetric scan was a 3D inversion recovery spoiled gradient echo sequence with TE:4.5ms, TI:300ms, and TR:10.4 ms, the imaging matrix was 256x256x200.

Data Analysis: MEG data was analyzed using MR-FOCUSS [Moran 2001, Bowyer 2004] for imaging MEG data to a cortical model of the subject's brain created from the MRI image sequence. For each of the three runs, the 40 windows of MEG data centered on the pedal push response were averaged. Next, the three runs for each subject were averaged and imaged using MR-FOCUSS. For these subjects, the sequence of image activity included extended source activation in the frontal cortex and focal activation events in other brain regions. The imaging results were combined into a single five-subject average by rescaling x,y,z coordinates of imaged activity for each subject to a common MRI head model.

RESULTS

Cortical activation between -500 and 500 ms of pedal activation was imaged by MR-FOCUSS. In Fig. 2, the average MEG data for all five subjects is displayed. The high frequency component in these data has a frequency of 28 Hz and was primarily imaged in the right motor and premotor cortex. In some subjects this component was more prominent than others. During the entire epoch the orbital frontal gyrus activation was active with peaks associated with light onset and pedal activation. In Fig. 3, average brain activation for one subject is shown. Red light on (t=-580ms) evoked occipital cortex activity (Fig. 4a), followed by activation in the superior frontal gyrus and anterior cingulate gyrus (t=-470ms) (Fig. 4b). Motor activity (t=-270ms) in the precentral gyrus (Fig. 4c), corresponding to foot and leg control was followed by foot pedal response pad (t=0). This action turned off the light and produced a visual evoked response (t=95ms) in the occipital cortex and a bilateral auditory response (t=111ms) in auditory cortex. MEG temporal resolution enabled the determination of sequential cortical activations. Occipital activation was seen with light on, and light off. Motor cortex activation was detected during eyeball movement (light on), and foot movement. These were brief intervals and correlated well with known locations for visual and specific motor cortex locations. Frontal-parietal networks were dominant during the driving task.

DISCUSSION

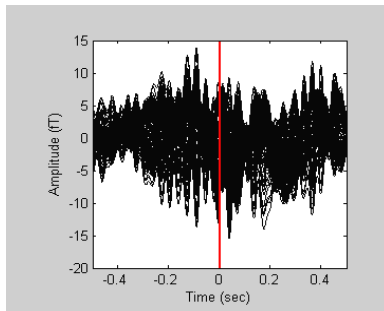


Fig. 2 148 channels of averaged MEG data from all five subjects average on pedal response.

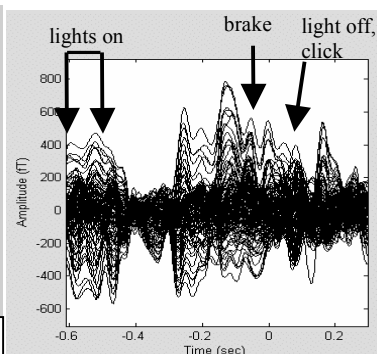


Fig. 3 MEG graph of all 148 MEG channels with significant events marked from one subject.

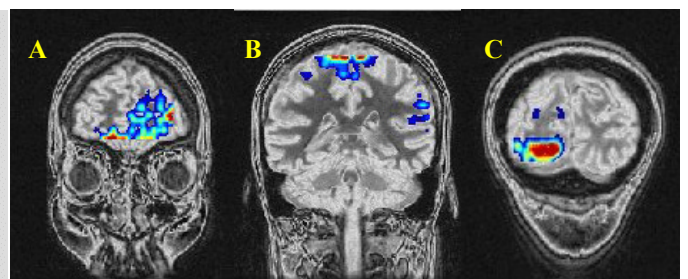


Figure 4 MR- FOCUSS localizations of activity in A) the frontal lobe (t= -300ms), followed by B) activity in the motor cortex (t= -180ms), followed by C) visual cortex activation (t= 80ms) corresponding to light off from subject in fig. 3.

Our findings suggest driving tasks recruit neural systems known to be involved in visual-motor multimodal processing and integration. The use of event-related MEG in investigating neural processing during simulated driving tasks is quite promising. Further studies of MEG involving simulated cell phone conversations may reveal the cortical network involved in driver distraction during telemetric distractions.

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