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Research Report

Conversation effects on neural mechanisms underlying reaction time to visual events while viewing a driving scene using MEG

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A B S T R A C T

Magnetoencephalography (MEG) imaging examined the neural mechanisms that modulate reaction times to visual events while viewing a driving video, with and without a conversation. Twenty-four subjects ages 18–65 were monitored by whole-head MEG. The primary tasks were to monitor a driving video and to depress a foot pedal in response to a small red light presented to the left or below the driving scene at unpredictable times. The behavioral reaction time (RT) to the lights was recorded. The secondary task was a hands-free conversation. The subject pressed a button to answer a ring tone, and then covertly answered pre-recorded non-emotional questions such as "What is your birth date?" RTs for the conversation task (1043 ms, SE=65 ms) were slightly longer than for the primary task (baseline no conversation (944 ms, SE=48 ms)). During the primary task RTs were inversely related to the amount of brain activity detected by MEG in the right superior parietal lobe (Brodmann's Area 7). Brain activity was seen in the 200 to 300 ms range after the onset of the red light and in the visual cortex (BA 19) about 85 ms after the red light. Conversation reduced the strengths of these regression relationships and increased mean RT. Conversation may contribute to increased reaction times by (1) damping brain activation in specific regions during specific time windows, or (2) reducing facilitation from attention inputs into those areas or (3) increasing temporal variability of the neural response to visual events. These laboratory findings should not be interpreted as indicative of real-world driving, without on-road validation, and comparison to other in-vehicle tasks.

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1. Introduction

Behavioral analysis methods have been established and validated for measuring and predicting on-road driver performance, while performing secondary tasks in a vehicle (Underwood et al., 2003; Young, 2001; Angell et al., 2002a; Strayer and Johnston, 2001; Rensink et al., 1997). It is relatively easy to use video recordings to determine whether a driver's hands are on the wheel and eyes are on the road during secondary tasks. Studies using both a central and peripheral light in on-road and laboratory studies demonstrate that simple light detection tasks, when used with appropriate parameters and conditions, can provide a highly sensitive measure for workload variations induced by traffic, the actual road environment, driving experience, and/or human–vehicle interface complexity (Angell et al., 2002a; Young and Angell, 2003). Performance of secondary tasks such as answering a cell-phone or conversing using a hands-free phone system may affect driving performance (Patten et al., 2004). However, these laboratory simulations of driving and secondary tasks are not perfectly predictive of on-road performance. Further, behavioral analysis alone does not directly provide information on how a driver's brain activity is altered by the secondary task while driving.

Fortunately, the development of high resolution brain imaging machines and imaging techniques [Magnetoencephalography (MEG) and Functional Magnetic Resonance Imaging (fMRI)] has made it possible to study the neural pathways and brain dynamics involved in the simultaneous performance of multiple tasks. These imaging techniques can be used to study how the brain alters its performance of a driving task when required to simultaneously attend to a secondary task (Stutts et al., 2003, 2001). Non-invasive fMRI imaging has been used to determine brain activity during a driving task (Graydon et al., 2004; Calhoun et al., 2002). Simulated driving in the fMRI scan found activation of occipital, parietal and sensorimotor cortex as well as cerebellum activation (Walter et al., 2001) during primary driving. Another fMRI study involving a virtual simulation and a retrospective verbal report found premotor, parietal and cerebellar regions were active (Spiers and Maguire, 2007). During driving simulations of avoiding and swerving, fMRI detected occipital, parietal, premotor and insular region activations (Spiers and Maguire, 2007). On the other hand, reduced activation was found in bilateral parietal and superior extrastriate secondary visual areas when engaging simultaneously speech comprehension and lane tracking tasks (Just et al., 2008). fMRI imaging is very useful for determining which brain regions are significantly involved in task-related behavior. However, fMRI imaging provides no information about the complex time sequence of transient activations and interactions between active regions of the brain. Typically, these activities occur in less than half a second and can be measured using EEG (Electroencephalography) or MEG. Evoked responses of the brain have been measured with EEG in a dynamic virtual-reality driving environment (Lin et al., 2007). Event related potentials (ERP) were able to differentiate brain region dynamics in relationship to traffic light simulations. Though cortical source localizations were not performed in this analysis, a signal space network was constructed.

MEG is a technique for non-invasively measuring the magnetic fields arising from electrical activity within the human brain (Hamalainen and Hari, 2002). Changes in neural activity are measured with millisecond resolution and imaged with a spatial resolution of approximately 5 mm. Calculated localization of the cortically active results are displayed on a subject's standard anatomical MRI. Thus, MEG provides spatial resolution of cortical brain activity similar to fMRI and significantly better temporal resolution of the sequence of brain activity. In addition, MEG does not utilize electromagnetic radiation and does not involve any risks to the study participants.

In this study we used MEG imaging, with a validated on-road driving protocol for predicting event detection and response timing (Angell et al., 2002b; Young et al., 2005), to determine the neural mechanisms that underlie event detection while viewing a driving scene (Fig. 1) during conversation and no-conversation conditions.

Fig. 1 – Video display of the driving scene with small red dot stimulus in the lower central viewing area and in the left peripheral area.