CONVERSATION EFFECTS ON DRIVING: NEURAL MECHANISMS UNDERLYING REACTION TIMES TO VISUAL EVENTS

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ABSTRACT

OBJECTIVES

The purpose of this study was to determine the behavioral and neural correlates of conversation effects on driving using the same visual event detection paradigm in brain imaging, behavioral testing, and closed-road driving experiments.

METHODS

The “load” paradigm (Young et al., 2005b) assessed the effects of conversation on visual event detection during simulated driving in behavioral labs, fMRI and MEG imaging centers, and actual driving on a closed road. Behavioral and imaging data were collected. The primary task was 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 secondary task was to engage in a conversation. The participant pressed a button to answer a ring tone, and then answered simple auditory questions such as “What is your birthdate?” fMRI and MEG data were analyzed to examine the neural substrates of driving with and without conversation. The correlation, reliability and repeatability across experimental settings were analyzed using statistical procedures such as random effect ANOVA and multivariate regression models with repeated measure adjustment.

RESULTS

The behavioral results from all sites demonstrated that conversation had a small but consistent increase in reaction time (about 70-200 ms) with no effect on miss rates compared to the “no conversation” baseline. The random effect ANOVA and adjusted regression models confirmed the conversation effect in all settings, with good reliability and repeatability. The fMRI results showed that conversation activated not only language-specific areas as expected, but also increased activation in fronto-parietal pathways engaged in sensory-motor integration, attention modulation, and decision execution (Young et al., 2005a). Results of MEG imaging showed that in the “no conversation” baseline, behavioral RT was inversely related to changes in MEG brain activity in the right superior parietal lobe: more modulation in brain activity in the 200-300 ms range after light onset resulted in shorter RTs, and less modulation in longer RTs. A similar
relation to RT was also seen in brain activity in the visual cortex in the 85-90 ms interval after red light onset. Conversation again activated language-specific areas in the MEG study, and resulted in less modulation in the right parietal and visual regions (Bowyer et al., 2006). Accordingly, conversation tended to increase mean behavioral RT slightly (no conversation 926 ms; conversation 993 ms). Further experiments are required to determine if the reduction in modulation due to conversation arises from inhibition, interference, or a removal of facilitation from top-down attentional processes.

CONCLUSIONS

Conversation slightly increases visual event reaction times in laboratory and closed-road driving experiments compared to a no-conversation baseline, with little or no effect on miss rates. Common fMRI and MEG imaging findings revealed fronto-parietal and visual-auditory-motor networks associated with sensory-motor integration, decision-making, and attention modulation during a driving-like scenario. Conversation appears to contribute to increased reaction times by reducing brain modulation to visual events in the right superior parietal region and visual cortices. These experimental findings should not be interpreted as if conversation increases the rate of crashes in real-world driving when compared to baseline driving without real-world validation and comparison of reaction time effects from other in-vehicle tasks.

REFERENCES


An important issue is the design of driver-vehicle interfaces that support safe and efficient vehicle operation under multi-tasking conditions, particularly with the addition of secondary in-vehicle tasks (e.g., cell phone conversations).

Some is known about the brain mechanisms underlying primary driving tasks (Calhoun et al., 2002; Spiers and Maquire, 2007; Uchiyama et al., 2003; Walter et al., 2001), but little about secondary tasks -- although it is likely that there is some functional overlap, and perhaps consequent interference between primary and secondary tasks.

It is important to evaluate how much simulated driving studies can produce detectable effects which will be likely to predict crash rates in real-world driving compared to normal baseline driving.

In this study, the same visual event detection paradigm during simulated driving in behavioral lab, fMRI and MEG imaging centers, and closed-road driving (Schreiner et al., 2004) was used to identify the neural systems engaged in the driving task and to compare driving performance in behavioral lab and imaging centers.
Goals

- To determine behavioral and neural correlates of conversation effects on simulated driving using the same visual event detection paradigm in brain imaging and behavioral driving experiments.
- To examine correlations of reaction times and miss rates among behavioral and imaging studies.

Driving Video & Event Detection Paradigm
Wayne State University: 4 Tesla fMRI Driving Study

Henry Ford Hospital: MEG Driving Study

- MEG: A technique for localizing sources of electrical activity within the human brain by non-invasively measuring the magnetic fields arising from such activity.
Methods

- The "load" paradigm (Angell et al., 2002; Young et al., 2005b) assessed the effects of conversation on visual event detection during simulated driving in behavioral labs, fMRI and MEG imaging centers, and actual driving on a closed road (Schreiner et al., 2004). Behavioral and imaging data were collected.
- The primary task was 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 secondary task was to engage in a conversation. The participant pressed a button to answer a ring tone, and then answered simple auditory questions such as “What is your birthdate?”.
- fMRI and MEG data were analyzed to examine the neural substrates of driving with and without conversation.
- The correlation, reliability and repeatability across experimental settings were analyzed using statistical procedures such as random effect ANOVAs and Generalizability (G) theory.

Speech Task Related to Event Detection During Driving

![Diagram showing the sequence of events during long, short, and no conversations during driving.]
• Subjects:
  – Behavioral testing (N=28, 11 males and 17 females)
  – MEG (N=24, 7 males and 17 females)
  – fMRI (N=11, 5 males and 6 females)

• Subject Selection Criteria:
  – Native English speaker
  – 18 to 65 years old
  – Right-handed
  – Normal hearing and normal vision (with correction)
  – With driver’s license
  – No previous neurological or psychological history
  – No metal in the body

• Age groups:
  – Younger (18-24 years old)
  – Middle (25-44 years old)
  – Older (45-65 years old)

• Testing order:
  – Behavioral testing, MEG, and then fMRI (same subjects)

Behavioral Findings

• No statistically significant effect of speech on miss rates.

• Reaction times are slightly longer in Conversation than in No Conversation conditions. These reaction time effect sizes are small (≤ 73 ms).

• However, these lab data should not be interpreted as though the cell phone usage in real world is a driver distraction without on-road investigation.

• Instead, these findings are a reflection of cognitive reactions in a multiple-task environment during a driving-like scenario.
Task Effects on Behavioral RT

- **Static Lab**: (LC, SC > NC); LC effect size = 73 ms, N = 28.
- **fMRI behavioral data**: showed similar tendency as in static lab; LC difference = 42 ms, N = 11.
- **MEG behavioral data**: showed similar tendency as in static lab, LC difference = 73 ms, N = 24.
- Overall, reaction times are slightly longer for Speech conditions than No Conversation condition.

Reliability and Repeatability

- Four-way Random effect ANOVA (subject x site x task x period): Subject, site, and speech period factors are statistically significant.
- G-Theory analysis: The speech effect was 0.52% of the total variance with Generalization Coefficient (GC), $\rho^2 = 75\%$.
  
  => This means that speech effect only accounts for a small portion of the total variance but the detectable effect is reliable and predictable.
Functional MRI Findings

- The neural correlates underlying multitasking are consistent with static lab and MEG results.
- Our imaging results in the fronto-parietal and visuo-auditory-motor pathways are known to be involved in visuo-sensory multimodal processing and integration, as well as decision making and attention modulation under a multiple-task condition.
- Furthermore, the use of fMRI together with MEG in investigating simulated driving tasks revealed the neural pathways responsible for cognitive processing in a driving-like scenario.
- Key new finding: Right Superior Parietal association region is the likely site of effect for event reaction time performance while integrating conversation into a driving-like behavior.

fMRI Data During Long Conversation (LC) Compared to Fixation Baseline
- Visual-Auditory-Motor pathways and Speech-specific areas are activated
Neural mechanisms of Driving with Conversation

### fMRI Data During Conversation (LC, SC) Compared to No Conversation Conditions
- Higher order association cortex for sensory-motor integration and speech-specific areas showed significantly increased activations.

### fMRI Data During Long Conversation (LC) Compared to No Conversation Condition
- Auditory-Motor pathway, higher order association cortex for sensory-motor integration, and speech-specific areas showed significant activations.
Neural mechanisms of Driving with Conversation

MEG Findings

(A) Location of brain regions affected by conversation for one subject. Red arrow indicates right superior parietal region.

(B) MEG Brain activation changes associated with the conversation. Greatest at ~240 ms after the brake stimulus is observed.

(C) Discriminant analysis quantifies the MEG data corresponding to brain activity with and without conversation (x-axis) related to reaction time (y-axis). The red dots correspond to MEG data during no conversation; black dots represent MEG data during conversation.

• Right Parietal Region activation appeared ~240 ms after brake light, averaged across all subjects. Right superior parietal region is an association area where higher functioning and integration of multiple sensory inputs occurs (i.e. visual and motor).

(D) Increased activation in the right parietal region (Red Arrows) during no-conversation condition;

(E) Conversation

(E) Less activation in the same region during conversation.
Conclusions

• Conversation slightly increases visual event reaction times in laboratory driving experiments compared to a no-conversation baseline, with little or no effect on miss rates.

• Common fMRI and MEG imaging findings revealed fronto-parietal and visual-auditory-motor networks associated with sensory-motor integration, decision-making, and attention modulation during a driving-like scenario.

• Conversation appears to contribute to increased reaction times by reducing brain modulation to visual events in the right superior parietal region and visual cortices.

• Combination of behavioral and imaging methodologies provides a powerful tool which allows researchers to investigate broader and more refined aspects concerning driving behaviors and driver attention.

• These experimental findings should not be interpreted as if conversation increases the rate of crashes in real-world driving when compared to baseline driving without real-world validation (Young, 2001; Young and Schreiner, 2007) and comparison of reaction time effects from other in-vehicle tasks.

References


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