This fMRI study investigated the role of emotion in multitasking using a multi-modal task designed to assess the effect of emotional speech on visual event detection during simulated driving. Ten participants were asked to respond to visual stimuli in a go/no go design while covertly answering spoken questions. Behavioral results showed longer visual reaction times during a concurrent speech task than with no speech; however this effect was moderated by presenting speech questions in an angry voice. fMRI analysis indicated increased activations (t > 3.2; p < 0.0014) associated with both neutral and angry speech tasks, compared to no speech, in the bilateral temporal lobes, the left inferior frontal gyrus, and the left middle frontal gyrus; and decreased activations in the right inferior parietal lobe and the right cuneus. Direct comparisons between angry and neutral speech tasks showed increased activations (t > 2.8; p < 0.0051) in the right prefrontal gyrus, the right middle frontal gyrus (BA10), the right insular, the right superior temporal gyrus, the right paracentral lobule (BA5), the right claustrum, and the right inferior parietal lobe (BA40). Decreased activations were found in the left frontal operculum, the left lingual gyrus (BA18), and the left parahippocamal gyrus (BA28). These results suggest that speech compared to no speech causes slightly longer behavioral reaction times and increased brain activation in language areas. Moreover, an angry emotional tone improves behavioral reaction time performance compared to a neutral tone, while eliciting the right frontoparietal networks and dampening the left frontal activity.
NEURAL BASIS OF EMOTIONAL MODULATION OF SIMULATED DRIVING PERFORMANCE: AN fMRI MULTITASKING STUDY

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Overview – Driving as a Research Platform

• Driving is commonly referred to as a single task
• But driving is really complex multitasking
  – It involves sensory, motor, and higher-level cognitive components
  – These play out over different levels of functional hierarchy, on different timescales, and often concurrently (Michon, 1989; Groeger, 2000).
Overview: Multitasking & Language

- Multitasking experiments give language researchers a unique platform for viewing language use in one of its most natural forms – in a multisensory processing environment.
- By seeing how the brain allocates resources for conversation while engaged in a driving task, we can find what the shared anatomy and networks are for language, executive functions, and general perceptual processing.

Introduction

- Many investigations into human performance involve the use of driving simulators
- What is often lacking is a validation of these simulators using on-road data
- Behavioral validation studies for predicting event detection on the road from lab data have recently had excellent results (Young et al., 2009)
  - Correlations of more than 0.9 for brake reaction times to visual events.
- Validation is especially important given:
  1. The cognitive complexity of a real-world driving task and
  2. The public policy implications of driver performance research.
- This study is the first we know of to apply a neuroscience measure (fMRI) to a validated driving paradigm.
Previous Cognitive Neuroscience Studies of Conversation Effect on Driving

- Project undertaken with Wayne State University, Univ. of Michigan, and Henry Ford Hospital to improve these predictions and understand underlying neural mechanisms.
- Bowyer et al. (2009) for MEG measures of event detection while driving
- Hsieh et al. (2009) for fMRI measures

Right Superior Parietal Region activation appeared ~240 ms after red light that precedes a brake response, 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).

Decreased correlation with reaction times in the right superior parietal region (Red Arrows) during conversation condition (E) compared to no conversation (D).

- Bowyer et al. (2009)
Previous fMRI Findings: Red Light Responses

Driving with Long Conversation Minus Driving Only (No Conversation)

Goals

1. To evaluate conversation and emotional effects on visual event detection in a multitasking scenario (*Enhanced Static Load Task* (ESLT), Young et al., 2009) in both the lab and MRI scanner.

2. To investigate fMRI brain activations and compare the behavioral performance between behavioral lab and fMRI sites.

3. To identify brain activation patterns mediating emotional changes during driving while engaged in cellular conversations.
Methods

• A battery of behavioral measures estimated the effects of a simulated cellular phone conversation on driving performance.
• Collected fMRI data using a 3T GE MRI at Henry Ford Hospital.
• Ten participants were engaged in simulated driving and responded to visual target events using light stimuli positioned around the driver’s field of view in the lab and the fMRI scanner.
• In both environments, participants’ reaction times to visual events were assessed, and functional MRI signals were recorded to the visual events.
• While in the fMRI scanner or in the lab, participants covertly answered questions from an experimenter in a hands-free cellular phone conversation.

Experiment

• Neutral vs. angry conversations.
• Compared with no conversation baseline.
• Also did manual task of answering a phone ring.
• 10 participants performed hands-free phone conversations during simulated driving in the lab.
• 10 participants performed hands-free phone conversation in the fMRI scanner.
• Four different calls were received (each lasting 1 minute) in each 9 minute block.
  – Each participant completed 3 runs (4 conversations each), and a baseline run (without any conversation).
In this fMRI study, ten participants were asked to respond to visual stimuli in a target/non-target design while covertly answering spoken questions. This is essentially a Go/No Go task – participants are asked to respond to red circle stimuli, and not to respond to green circle stimuli. The same driving paradigm was also conducted in the behavioral lab (below) and in the fMRI scanner.

Before imaging these results in fMRI, we assessed the influence of one imaging restraint – the need for covert speech. Multitasks of driving and conversations were replicated using covert speech – asking participants to respond without substantially moving their articulators.
Overt vs. Covert - RT

RT (msec) as a function of block, speech-type

<table>
<thead>
<tr>
<th>Speech-type</th>
<th>Covert</th>
<th>Overt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversation</td>
<td>900</td>
<td>800</td>
</tr>
<tr>
<td>No Conversation</td>
<td>800</td>
<td>700</td>
</tr>
<tr>
<td>Ring</td>
<td>700</td>
<td>600</td>
</tr>
</tbody>
</table>

fMRI Adaptation of ESLT

- Due to the restraints of the scanner, the visual angle from the center light to the left light was reduced from 20 degrees to 12 degrees.
- Participants steered using a handheld controller with two buttons, and responded to red targets using a foot pedal.
Conversation Effect on Simulated Driving in the Lab and fMRI:
Behavioral Performance (RTs)

- Significant Conv. RT Effect in both sites: \( F(9,2) = 5.24, p < .01 \)
- <4% Error Rates in both the Lab and fMRI (fMRI<Lab).

Cross-Validation from Lab to Road

- Behavioral results showed longer visual reaction times during a concurrent speech task than with no speech (blue bars)
- However, this effect was moderated by presenting speech questions in an angry voice (yellow bars)
- Same effects in lab and road
fMRI Findings (1)

• fMRI analysis indicated increased activations ($t > 3.2; \ p < 0.0014$) associated with both neutral and angry speech tasks, compared to no speech, in the bilateral temporal lobes, the left inferior frontal gyrus, and the left middle frontal gyrus; and decreased activations in the right inferior parietal lobe and the right cuneus.

fMRI Findings (2)

• Direct comparisons between angry and neutral speech tasks showed increased activations ($t > 2.8; \ p < 0.0051$) in the right prefrontal gyrus, the right middle frontal gyrus (BA10), the right insular, the right superior temporal gyrus, the right paracentral lobule (BA5), the right claustrum, and the right inferior parietal lobe (BA40). Decreased activations were found in the left frontal operculum, the left lingual gyrus (BA18), and the left parahippocampal gyrus (BA28).
Conclusions

1. Hands-free cellular phone conversations caused significant but small reaction time (RT) effects for visual event detection for simulated driving in the lab and MRI scanner. ANOVAs shown statistical significance of conversation effects on RT in both settings.
2. Consistently high accuracy for visual event detection was found regardless of emotionality of speech content during cellular phone conversations in the lab and MRI scanner.
3. Angry conversations may increase the alertness for event detection.
4. These fMRI results suggest that speech compared to no speech causes slightly longer behavioral reaction times and increased brain activation in language areas.
5. Moreover, an angry emotional tone improves behavioral reaction time performance compared to a neutral tone, while eliciting the right frontoparietal networks and dampening the left frontal activity.
6. In conclusion, this fMRI study suggests that a top-down emotional and attentional processing mediated by the frontal-parietal network.

References