Effects of Conversation Complexity of Cell Phone Conversations on Driving: ERP Lab and On-Road Driving Studies

Sean Seaman\textsuperscript{1,2,3}, Li Hsieh\textsuperscript{1,2}, Richard Young\textsuperscript{2,4}

\textsuperscript{1}Wayne State University, Communication Sciences and Disorders,  
\textsuperscript{2}Wayne State University, Institute of Cognitive and Applied Neuroscience,  
\textsuperscript{3}Wayne State University, Psychology,  
\textsuperscript{4}Wayne State University, School of Medicine, Psychiatry and Behavioral Neurosciences

How does the complexity of a conversation affect driving performance? Previous work (Hsieh et al., 2008; Bowyer et al., 2008) has revealed that small, reliable effects of conversation on driving performance can be observed using simulators, but data concerning the kind of conversation – and the specific effects on driving performance it may have – has been lacking. We addressed this research gap in a series of studies designed to measure driving performance while engaged in a secondary conversation task. In the first study, we looked at simulator responses to visual events during a live conversation task. The cognitive complexity of the conversation was manipulated to reflect two naturalistic levels of speech complexity. In addition to measuring behavioral measures of driving performance, such as reaction times to visual stimuli and lane maintenance, we also measured ERPs and subjective workload estimates. In the second study, we took the task on-road to evaluate the effects of live speech, and its varying levels of complexity, in a real-world driving task. Here, we also measured driving performance (in terms of visual event reaction times and lane maintenance), ERPs, and subjective workload estimates. These studies reveal a pattern of the subtle ways in which different conversation demands can interact with the network of cognitive processes that underlie proficient driving performance.
Effects of Conversation Complexity of Cell Phone Conversations on Driving: ERP Lab and On-Road Driving Studies

Authors: Sean Seaman, M.A., Richard Young, Ph.D., Linda Angell, Ph.D., John Sullivan, Ph.D., Susan Bowyer, Ph.D., John Moran, Ph.D., and Li Hsieh, Ph.D.

Affiliations:
1 Department of Communication Sciences and Disorders, Wayne State University
2 Department of Psychology, Wayne State University
3 Human Factors Division, University of Michigan Transportation Institute
4 Department of Neurology, Henry Ford Hospital
5 Department of Psychiatry and Behavioral Neurosciences, School of Medicine, Wayne State University

Introduction

- Driving and cellular phone studies provide an applied testing platform for cognitive multi-tasking theory.
- Most of these studies, however, do not correlate lab performance to real-world driving through explicit on-road testing.
- Moreover, as the tendency to employ neuroscience methodology to understand multitasking becomes more prevalent, the disconnect between lab and real world driving increases.
- This study is an attempt to bridge that by using naturalistic cellular phone conversations in conjunction with a driving or driving-like task on the road and in the lab, respectively.
- In addition to emphasizing ecological validity in the primary task, we also pushed the complexity of the secondary task by utilizing realistic conversation scenarios of varying cognitive complexity.
Two Factors in Current Study: Speech Duration and Primary Task Demand

<table>
<thead>
<tr>
<th>Speech Complexity</th>
<th>Low (Lab)</th>
<th>High (Car)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>- -</td>
<td>- +</td>
</tr>
<tr>
<td>High</td>
<td>+ -</td>
<td>+ +</td>
</tr>
</tbody>
</table>

Objectives of Current Study

- To investigate the conversation effect on simulated driving and real driving by using natural speech.
- To manipulate complexity content of the secondary speech task.
- To develop a sensitive and reliable simulated driving protocol which provides an economical and efficient way to test new products or new concepts for automotive design and evaluation of driving safety.
Working Hypotheses

• Speech may have minimal or no impact on driving performance in terms of miss rates.
• Speech may cause a slight delay in reaction times, between 50 and 150 msec.
• The content of speech may enhance or degrade perceptual processing of event detection stimuli in either the lab, car, or both settings.
• The complexity of the primary driving task may affect task performance in conjunction with a secondary task.

Current Study – Lab Design

• Participants performed simulated hands-free phone conversations during simulated driving.
• Four different calls were received (each lasting 1 minute) in each 9 minute block.
• Each run contained 2 conversations containing simple stimuli and 2 conversations containing complex stimuli.
• Example simple question: “Tell me about the best teacher you ever had.”
• Example complex question: “Can you help me write a pamphlet for college students on steps they can take to improve their time management?”
• Complex questions were designed to elicit real-time problem-solving processes.
Car Adaptation

- Lab data was contrasted with on-road data.
- On-road data was collected at the University of Michigan Transportation Research Institute.
- Red and green LEDs were positioned in the center of the driver’s field of vision and to the left. Responses to the LEDs were made using a foot pedal near the driver’s left foot. Calls were answered using a hand button.

Schema of Experiment

Driving Only Baseline Condition

Examples of Conversation and Driving Condition

- Total duration: 9 min
- 1 min Conversation period
- 1 min Driving period

Audio/Manual Task Condition

- Total duration: 9 min
- 1 min Conversation period
- 1 min Driving period
- 1 min Audio/Manual Task

Ring/Goodbye period

Conversation period

No Conversation period
Behavioral results – RTs by site and speech task

Total length of one session: 9:00
Number of target events: 80
Number of non-target events: 40

Behavioral results – red light misses by site and speech task
Behavioral results – green light responses by site and speech task

-0.50% 0.00% 0.50%

Baseline Simple Complex Answer Simple Complex Answer

Covert Speech Overt Speech

Behavioral Results

• Both types of conversations are associated with significantly longer RTs than no conversation periods or baseline runs.
• Complex and simple conversations had equivalent mean RTs.
• Patterns across lab and car were similar, as well as across overt and covert speech.
• Car testing was associated with more red light misses during both sets of overt speech.
• Lab testing was associated with a tendency to make more green light errors in the complex condition only.
• We interpreted this result to be an indicator of an interaction between visual task demand and cognitive/speech demand.
• In cases when visual demand is high, subjects are more likely to miss events – both targets and non-targets. When visual demand is low, cognitive complexity affects the ability of subjects to inhibit responses to detected stimuli.
EEG Testing

- Preliminary data is from three subjects tested across road and lab conditions.
- Data was recorded using a 64-channel Waveguard cap in our lab and on the road at the University of Michigan Transportation Research Institute.
- Data was band pass filtered at 1-30Hz, corrected for artifacts, averaged with artifacts removed, and corrected for baseline differences.

ERPs to left non-targets in lab

No conversation
Simple
Complex
ERPs to center non-targets in lab

ERPs to left non-targets in car
ERPs to center non-targets in car

ERPs to center non-targets: Lab vs. Road @ P300

Lab

Car

Simple

No Conversation

Complex

Simple

No Conversation

Complex
ERPs to left non-targets: Lab vs. Road @ P300

Conclusions

- Small reaction time (RT) effects were observed in all contrasts between speech and no speech.
- In all comparisons, simple RTs were statistically similar to complex RTs.
- Car testing was associated with more red light misses during both types of overt speech, and lab testing was associated with a tendency to make more green light errors in the complex condition only, which suggests that visual complexity may affect response sensitivity while speech affects bias.
- ERPs show topographic distinctions around P300 for the cognitive complexity condition, primarily to center non-target stimuli in the lab across frontal electrodes.

Acknowledgements:

- Funded by State of Michigan Technology Tri-Corridor Grant to Prof. Li Hsieh, PI.