Modeling Driver Physiological State Using EEG under Auditory Real-time Travel Information Provision

Shubham Agrawal[1], Irina Benedyk[1], Srinivas Peeta[2]

[1]Purdue University, West Lafayette, IN; [2]Georgia Tech, Atlanta, GA

CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

Background & Motivation

- Plethora of real-time information (RTI) sources
  - Multiple modalities and sources
- Some well-designed, others not so much

Cognitive load

- Limited cognitive resources
- Driving is a cognition-heavy task
- Sharing of cognitive resources for information perception/processing
- Distraction can have negative safety implications

Cognitive benefits

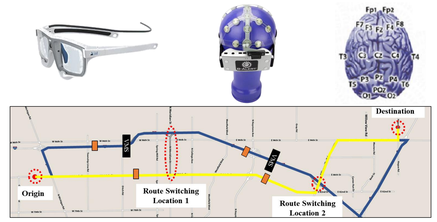
- Informed travel decision
- Reduced travel uncertainty
- Improved situational awareness through alerts and warnings
- Reduced drowsiness

Dichotomous impacts of real-time information on drivers

Past Literature

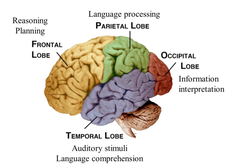
- ✓ Evaluate driver distraction and fatigue
- ✓ Interactions with in-vehicle information systems
- ✓ Assessment of advanced driver-assistance systems
- ✓ Route choice behavior under RTI provision
- ✓ Cognitive impacts of RTI characteristics using survey-based methods
- ✗ **Cognitive assessment of RTI characteristics using objective measures**
- ✗ Data collection under realistic travel environment

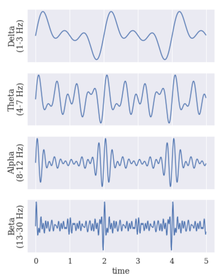
Aim



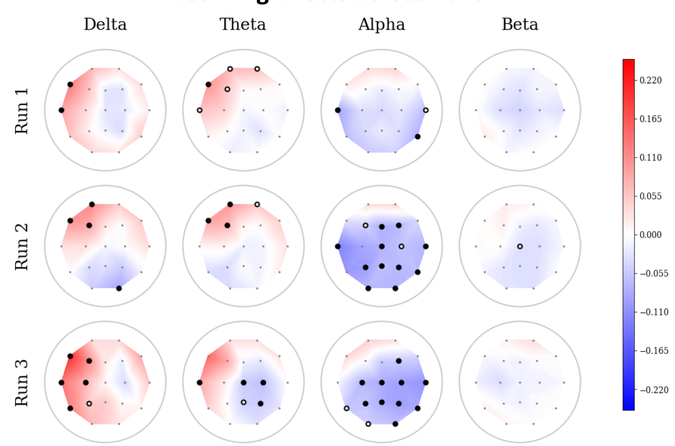
Driving Simulator Experiments

- ✓ Real-world network-level roadmap
- ✓ Dynamic traffic using microscopic traffic simulator integration
- ✓ Public infrastructure and personal device
- ✓ Biosensor data: EEG, ECG and eye tracker
- ✓ Point-based reward system to encourage realistic driving





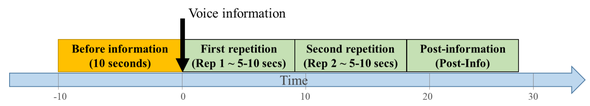
Learning Effects across Runs



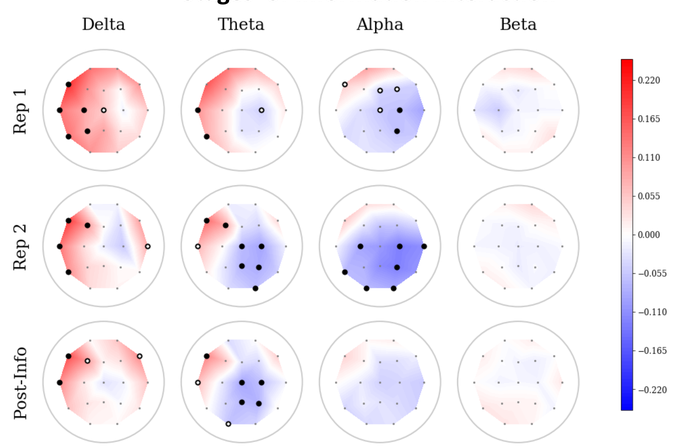
Legend: Statistically significance levels ● 95% ○ 90%

Methodology

- Linear regression / ANCOVA
  - 95 right-handed participants who completed all 3 runs
- Dependent variable: Average band power of EEG electrode
- Independent variable: Average band power of EEG electrode
  - Across runs (learning effects)
  - Across stages of information (perception and processing)
  - Across information characteristics (content and amount)
- Covariate: Average band power of EEG electrode before information

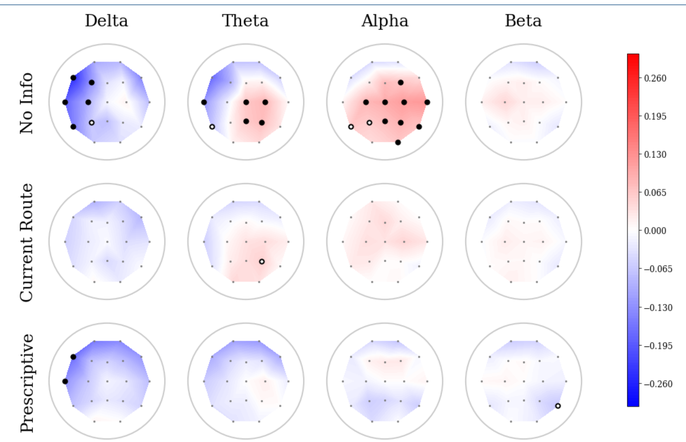


Stages of Information Interaction



Results & Discussion

- Learning effects – increasing familiarity (simulator, road network, and RTI) over runs
  - ▲ Increasing Delta in Left Anterior - internal processing and memory retrieval
  - ▼ Decreasing Theta in Posterior – more alert (expecting RTI?)
  - ▲ Increasing Alpha in Posterior – conscious effort to process information
- Stages of information interactions – perception to processing
  - ▼ Decreasing Delta in Left hemisphere – initial contextualization of RTI
  - ▼ Decreasing Theta in Posterior - more alert (more focused upon receiving RTI)
  - ► Increase and decrease in Alpha – possible indicator of decision-making
- Information characteristics – referenced to Current and Alterative Information
  - No information - ▼ Delta in Left Anterior, ▲ Theta and ▲ Alpha in Posterior
  - Prescriptive information - ▼ Delta in Left Anterior – travel time vs. route suggestion



Information Characteristics

Conclusions & Future Research

- Evaluated driver cognition under real-time information …
  - in a realistic driving simulation environment
  - using objective and measurable physiological measures (EEG)
- Most findings are in agreement with neuroscience literature
  - Statistically significant differences in brain activity pattern can be observed for driver familiarity, elapsed time, information characteristics
  - Need more focused experiments to substantiate some effects

Future Work

- Include ECG and eye tracker – mimic driver monitoring system
- Route choice behavior using physiological indicators

Poster presented on March 5, 2019 at the 105th Purdue Road School Transportation Conference and Expo, Purdue University, West Lafayette.

This work was supported as part of the Center for Connected and Automated Transportation (CCAT) Region V University Transportation Center funded by the U.S. Department of Transportation, Award #69A3551747105.