Evaluating the Impacts of Driver Cognitive and Physiological State on Decision-Making Behavior under Real-Time Travel Information

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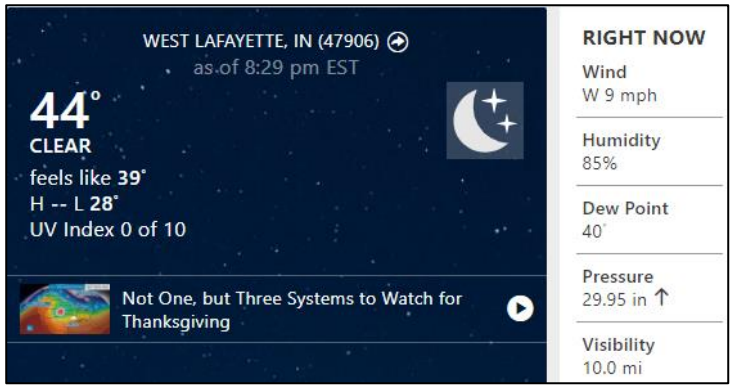
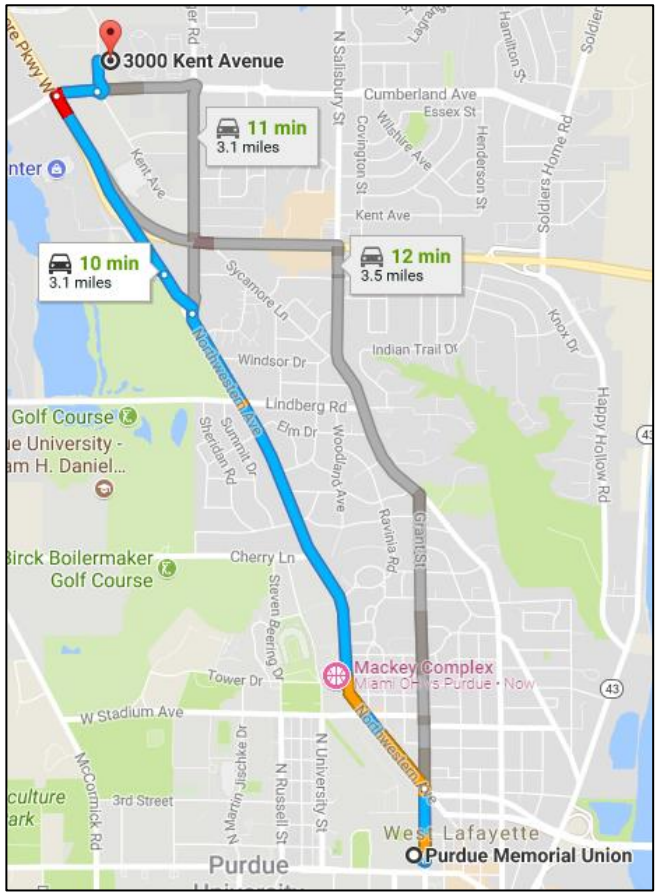
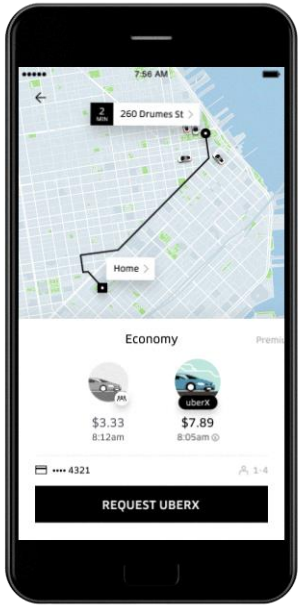
Age of Information

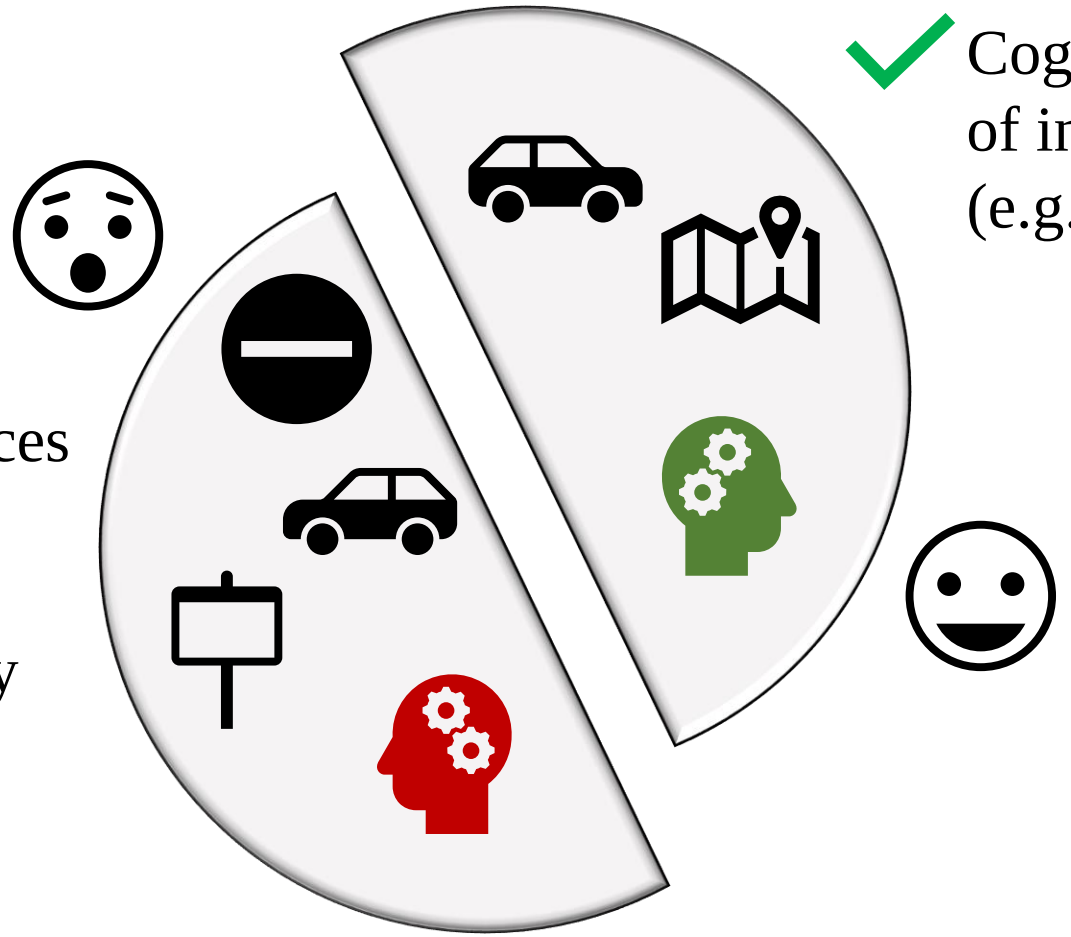






Motivation

- Dichotomous impacts of real-time information on drivers



✓ Cognitive benefits in terms of informed travel decision (e.g. route choice)

✗ Sharing of cognitive resources between information perception/processing and multitasking driving activity

Motivation

- Impacts of real-time information characteristics on driver physiological and psychological factors
  - Strategize “when, what and how” of real-time information delivery
- Advances in in-vehicle driver monitoring systems
  - Real-time tracking of driver physiological data
  - Unobtrusive and continuous estimation of driver cognition using physiological factors
    - As opposed to survey based methods

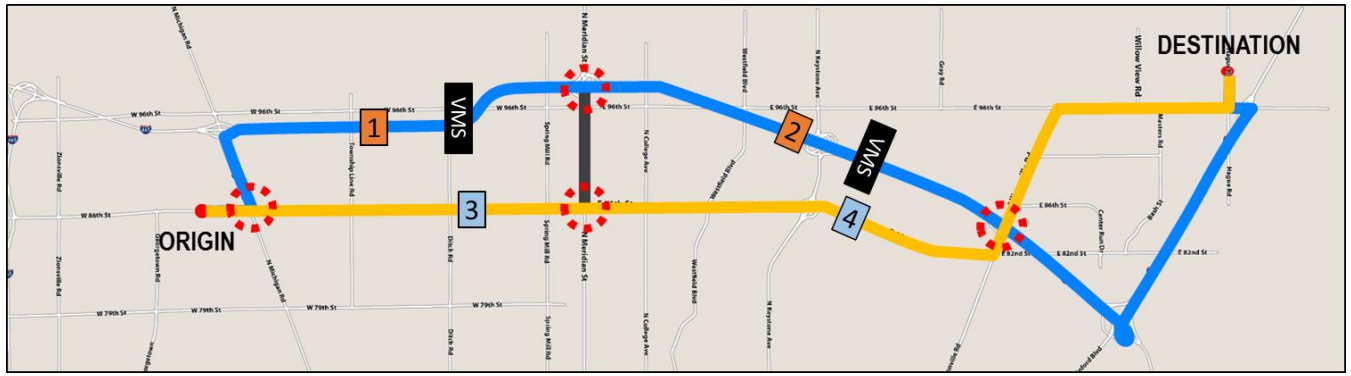
Source: https://www.digitaltrends.com

Research Questions

- Are there differences in certain physiological and psychological factors across population subgroups under real-time information provision?
- How do real-time information characteristics and travel conditions affect these differences?
- How does driver physiological and psychological state under real-time information provision affect decision-making process?
- Can the impacts of real-time information on driver physiological and psychological state be reliably predicted in real-time?
  - How should the information be designed to improve tangible and intangible benefits?

Driving Simulator Experiments

- Real-world network-level road map (Northern Indianapolis)
- Real-time travel information consistent with ambient traffic conditions
- Reward system to provide a sense of urgency and penalize rash driving
- Three experiment runs for each participant with varying information characteristics
  - Content: descriptive (travel time) and prescriptive (alternative route suggestion)
  - Amount: current route and alternative route
  - Source: voice-only, VMS-only or both

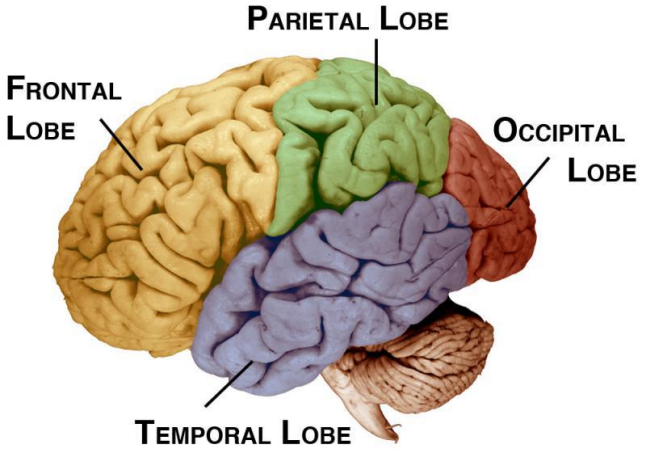


Data Collection

- Individual characteristics
  - Sociodemographic data
  - Attitude towards and experience with real-time information
- Information characteristics
- Physiological data using EEG, ECG and eye tracker
- Micro-level driving performance
- Post-run survey on experience and satisfaction with real-time information

Brain Anatomy and EEG Sensor Locations

- Temporal lobe (T3, T4, T5, T6)
  - Auditory stimuli, visual memories, language comprehension
- Parietal lobe (P3, Pz, P4, POz)
  - Tactile sensory information, language processing
- Occipital lobe (POz, O1, O2)
  - Visual stimuli, information interpretation
- Frontal lobe (Fp1, Fp2, F7, F3, Fz, F4, F8)
  - Reasoning, motor skills, short-term memory, planning
- Central sulcus (C3, Cz, C4)
  - Body movements



B-Alert EEG System Preliminaries

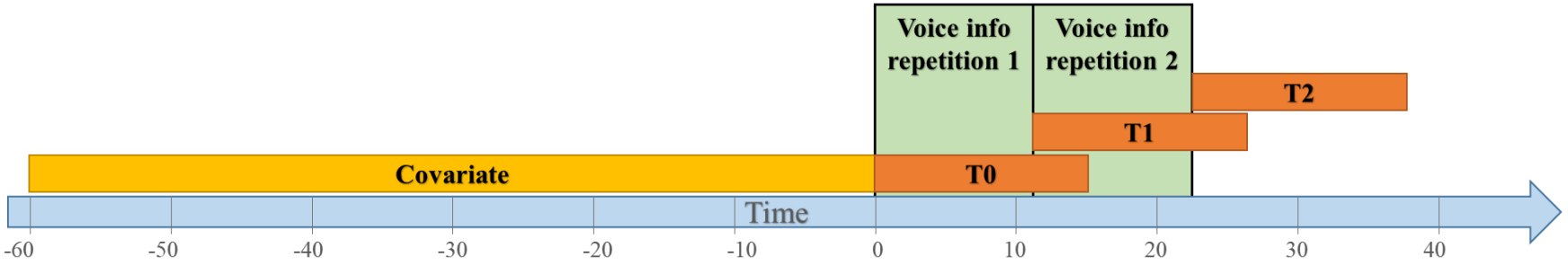
- 256 Hz recording of 20 unipolar channels referenced to linked mastoids
- Power spectral densities (PSDs) are computed using fast Fourier transform (FFT) algorithm
  - 5 EEG frequency bands: Delta (slowest), Theta, Alpha, Beta, Gamma (fastest)
- Artifact identification and data decontamination using signal analysis
  - Also filters out frequencies above 40Hz as artifacts
- Uses proprietary method to compute two psychological classifiers
  - Mental workload classifier (low workload and high workload)
  - Task engagement classifier (sleep onset, relaxed wakefulness, low engagement and high engagement)

Data preliminaries

- 125 participants completed at least one experiment run
- 110 completed three runs and has valid data
- 101 right-handed participants
  - Dexterity affects activity in brain lobes
- Data selected for analysis
  - 76 participants that received voice information at the first location of run 1

Data Analysis

- ANCOVA (analysis of covariance) to analyze systematic differences between voice information and driver physiological state
  - Dependent variable
    - 15-second average of PSD values with three different starting points (T0, T1 and T2)
  - Covariate
    - 60-second average of PSD values before the beginning of information



  - Independent variables
    - Sociodemographic data, and attitudes towards and experience with real-time information
    - Information characteristics
    - Survey indicators for experience with received real-time information

Analysis Results

- The Gamma wave activity in Occipital and Parietal lobes is higher for drivers who receive prescriptive information compared to descriptive information
  - Providing “congestion ahead” and suggesting to take alternate route invokes higher-level processing compared to providing travel times on current and alternative routes

Start time	Brain lobe	EEG band	Independent variable		
			Description	Coefficient	p value
T0	Parietal	Gamma	Receives prescriptive information	0.085	0.031
T0	Occipital	Gamma	Receives prescriptive information	0.077	0.04
T1	Parietal	Gamma	Receives prescriptive information	0.089	0.03
T1	Occipital	Gamma	Receives prescriptive information	0.078	0.048

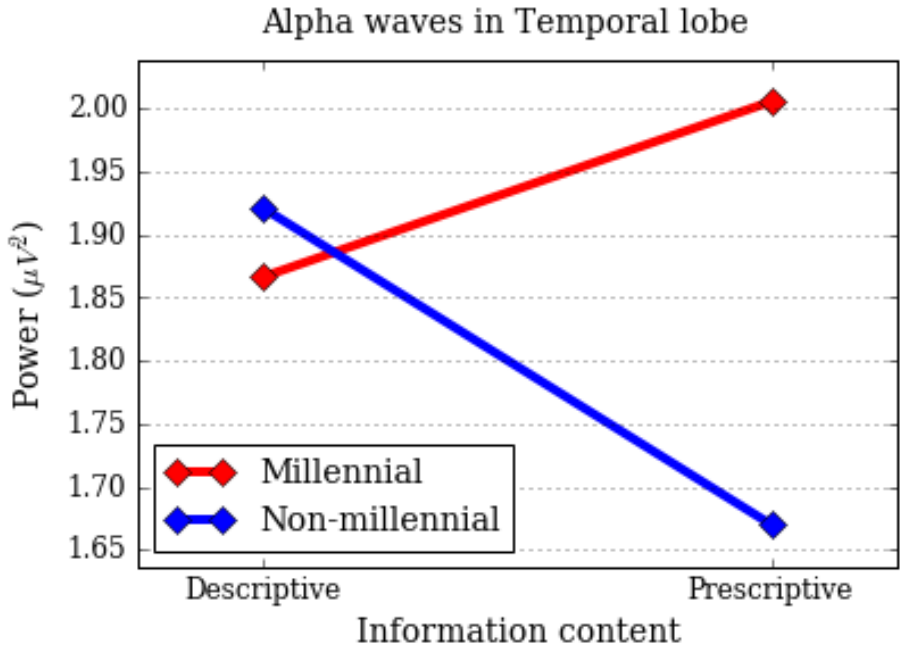
Analysis Results

- Driver age and information content have significant interaction effects in Alpha band in Temporal lobe

Start time	Brain lobe	EEG band	Independent variable 1			Independent variable 2			Interaction	
			Description	Coefficient	p value	Description	Coefficient	p value	Coefficient	p value
T1	Temporal	Alpha	Non-millennial	-0.166	0.023	Receives prescriptive information	0.072	0.015	-0.253	0.004

Analysis Results

- The Alpha wave activity in Temporal lobe is higher for millennials who receive prescriptive information compared to descriptive information; while it is lower for non-millennials who receive prescriptive information compared to descriptive information
  - Millennials have a higher trust in information systems and hence, are more comfortable in following prescriptive information from information systems compared to non-millennials



Ongoing work

- Analyze patterns to identify beginning and duration of different stages of interaction with information (i.e. perception, processing, decision-making)
  - Multivariate analysis of PSDs across different brain lobes
- Analyze ECG patterns and eye tracking data
- Integrate relevant physiological and psychological factors in route choice behavior models

Summary

- Contributions
  - Analyze changes in physiological factors under real-time information provision that enables the development of integrated in-vehicle driver monitoring and information dissemination systems
  - Evaluate the impacts of real-time information on physiological factors based on driver experience and preferences about receiving real-time information
- Innovations
  - Analyzing the effects of several information characteristics on driver physiological factors under realistic travel conditions using a network-level road map with responsive traffic

Thank you!