OUTLINE

• Past
  • Drivers’ Response to Real-Time Traffic Information

• Present
  • Introductory Information, Trust, and Takeover

• Future
  • Road Design and User Attitudes Toward L4 AVs
DRIVING SIMULATOR
DRIVERS’ PSYCHOPHYSIOLOGICAL RESPONSE TO REAL-TIME TRAFFIC INFORMATION

Shubham Agrawal, Irina Benedyk, & Srinivas Peeta
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
DRIVING SIMULATOR EXPERIMENTS

- Real-world network-level road map with responsive traffic conditions

- Data collection
  - Individual characteristics
  - Micro-level driving performance (e.g. vehicle speed)
  - Physiological data (EEG, ECG and eye tracker)
  - 95 out of 125 participants with valid data for all three experiment runs
MODELING THE IMPACTS OF REAL-TIME AUDITORY INFORMATION ON DRIVER PHYSIOLOGICAL STATE USING EEG
**EEG DATA**

- **B-Alert EEG**
  - 256 Hz recording of 20 unipolar channels referenced to linked mastoids
  - Artifact identification and data decontamination using signal analysis
  - Power Spectral Density (PSD) computed using fast Fourier transform (FFT) algorithm for frequencies 1 – 40 Hz

- **EEG frequency bands**

<table>
<thead>
<tr>
<th>Band name</th>
<th>Frequency bandwidth</th>
<th>Associated state</th>
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<tbody>
<tr>
<td>Gamma</td>
<td>30 – 40 Hz</td>
<td>High-level information processing</td>
</tr>
<tr>
<td>Beta</td>
<td>13 – 30 Hz</td>
<td>Focused attention, mental processing</td>
</tr>
<tr>
<td>Alpha</td>
<td>8 – 12 Hz</td>
<td>Conscious but relaxed</td>
</tr>
<tr>
<td>Theta</td>
<td>4 – 7 Hz</td>
<td>Drowsiness</td>
</tr>
<tr>
<td>Delta</td>
<td>1 – 3 Hz</td>
<td>Sleeping OR Internal processing during mental tasks</td>
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RESULT ANALYSIS - LEARNING EFFECTS

• Regression model
  • **Dependent variable**: Average PSD of a frequency band for each EEG electrode during information provision
  • **Independent variable**: Information indicator (1 for real-time auditory information provided; 0 otherwise)
  • **Covariate**: Average PSD of a frequency band in specific region of brain during information provision
RESULT ANALYSIS - LEARNING EFFECTS

- As experiment proceeds, driver familiarity with simulator, road network and real-time information increases

- Prominent Delta/Theta in Left Anterior
  - Internal processing and memory retrieval increases with familiarity

- Alpha activity in Posterior brain increases and then decreases
  - Three phases of interaction with information: Inexperience – Acquaintance – Familiarization

Regression coefficients for absolute PSDs in “Information” scenario with respect to “No information” scenario
ANALYSIS ONGOING

• Analyze the impacts of real-time information on other physiological data collected using ECG and eye tracker

• Modeling route choice behavior under real-time information using psychophysiological analysis
INTRODUCTORY INFORMATION, TRUST, & TAKEOVER

Dustin J. Souders, Shubham Agrawal, Irina Benedyk, Yujie Li, & Srinivas Peeta
MOTIVATION

HOW THE SMASH HAPPENED

1. May 7: Joshua Brown (below), had engaged autopilot mode in his Model S Tesla while he drove on the highway.

2. A white articulated truck pulls across the dual carriageway in front of the Tesla.

3. The Tesla's radars and cameras did not distinguish the truck from the sky, tearing the roof off as it went under the trailer. The truck driver claims the Tesla driver was watching a Harry Potter film on the Tesla's infotainment screen.

LONG RANGE RADAR:
Looking ahead of the car, monitoring the presence of other vehicles. It can 'see' through rain or fog.

IMAGE RECOGNITION CAMERAS:
These also look ahead of the car, identifying things such as traffic signs, lane markings and pedestrians.

360 DEGREE ULTRASONIC SONAR:
This all-round sensor detects everything from cars to children or pets in your blind spot.
INTRODUCTORY MATERIALS & TRUST IN AV (KÖRBER, BASELER, & BENGLER, 2018)

- Trust promoted group more likely to…
  - Spend less time monitoring the road, more time engaged in NDRT
  - Perform riskier takeover maneuvers
    - Longer take-over time (1154 ms)
    - Lower minimum TTC (933 ms)
  - Crash in obligatory take-over situation
    - 6 of 20 compared to 0 of 20 in trust lowered group
AV CONDITION FRAMES

• Both groups learn about:
  • SAE Levels of Automation
  • How the ADS functions

• 2 Frame Conditions:
  • Level 3 Reminder
  • Future Benefits

• Double-blind Between-subjects Design
AUTOMATED DRIVING SYSTEM

• Can perform longitudinal and lateral control on highway
  • Set speed of 65 mph

• Can pass slower moving vehicles

• Warnings
  • 1 chime = Uncertainty
  • 3 chimes = Take-over request
NON-DRIVING RELATED TASK
PROCEDURE

PRE-EXPERIMENT SCREENING MEASURES
- Motion Sickness Screen
- Weschler Logical Memory Scale
- Demographics & Driving Patterns
- Automation Complacency Potential Scale

INFORMED CONSENT

SIMULATOR PRACTICE RUN

INFORMATIONAL VIDEO
- Pre-Drive System Acceptance Scale (1)
- Self-driving Car Acceptance Scale (1)

EQUIP BIOSENSORS & EYE TRACKER

NDRT & ADS FAMILIARIZATION (SCENARIO 0)
- Trust in Automation Scale (1)

SCENARIO 1
- NASA-TLX (2)
- TiA (2)

SCENARIO 2
- NASA-TLX (2)
- TiA Scale (3)

SCENARIO 3
- NASA-TLX (3)
- TiA Scale (4)

POST-SCENARIO MEASURES
- NASA-TLX (3)
- TiA Scale (4)
- Post-Drive SAS (2)
- SCAS (2)
- Simulator Sickness Questionnaire

DEBRIEF,
- Remove EEG/ECG & Eye-Tracker,
- Compensation
MAIN TASK

• 3 Scenarios
  • ~10 minutes each
  • I-65 to Chicago
    • 2 lanes
  • Medium level of traffic
    • 6 vehicles spawning 500 m in front of or behind subject vehicle
MAIN TASK - SCENARIO 1

• Close automatic pass of slower-moving (50 mph) truck
  • Single chime before ADS changes lanes to pass
    • Headway distance of ~35 meters
  • Participant would likely grab steering wheel and turn if less trusting
MAIN TASK- SCENARIO 2

- Broken down vehicle occluded by lead vehicle
  - Obligatory Take-over Event
  - Single chime @ 7 TTC when lead vehicle shifts lanes
  - Triple chime take-over request @ 4 TTC
MAIN TASK - SCENARIO 3

• Longitudinal control late to account for slower-moving truck (50 mph)
  • Single chime before ~35 m away
  • Longitudinal control safely re-engages without need for intervention
  • Likely participant response would be hitting the brake
OBJECTIVE MEASURES
EYE-TRACKING

- Measure of System Trust/Task Engagement
  - Percentage of Time on Area of Interest (AOI)
  - Glance Frequency
  - Mean Glance Duration
NDRT/ROAD GLANCE CYCLE
EEG-ECG
TAKEOVER PERFORMANCE

• Takeover Time
• Minimum TTC
• Lateral Acceleration
• Maximum Brake Position
• Collision Occurrence
SUBJECTIVE MEASURES
SUBJECTIVE MEASURES

Trust in Automation Scale (Körber, 2015)
- Competence/Reliability
- Understanding/Predictability
- Familiarity
- Propensity to Trust
- Trust in Automation

Self-driving Car Acceptance Scale (Nees, 2016)
- Perceived Reliability/Trust
- Cost
- Appropriateness of the Automation/Compatibility
- Enjoyment of Driving
- Perceived Usefulness of the Automation
- Perceived Ease of Use of the Automation
- Experience with Automation
- Intention to Use Automation
SUBJECTIVE MEASURES CONT’D

- System Acceptance Scale (Van der laan, Heino, & De Waard, 1997)
  - Provides Usefulness and Satisfaction Scores before and after system usage
- NASA Task-Load Index (Hart & Staveland, 1988)
  - Subjective Workload Measure
- Simulator Sickness Questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993)
CONTRIBUTION

• Assess the effects of different frames of introductory information on…
  • Visual monitoring of L3 automation
  • Take-over performance
  • Subjective trust in automation
  • AV acceptance attitudes

• Provide guidance on how L3 system capabilities and limitations should be presented to the user to promote their safe usage
ROAD DESIGN & USER
ATTITUDES TOWARD
L4 AVS

Yuntao Guo, Dustin J. Souders, Irina V. Benedyk, Shubham Agrawal, Yujie Li, Samuel Labi, Srinivas Peeta
STUDY OBJECTIVES

• How AV perceptions are affected by:
  • Being a Human driver vs. AV user in the same design
  • Differences between roadway designs
  • Providing travel time/cost and emission comparisons (GHV vs. EAV or GAV)
  • Users’ environmental concerns, technology adoption, and perceptions of AV & EV
ORIGINAL DESIGN

• Typical 3-lane one-way street
  • Street parking on both sides
DESIGN 1

• ½ of Parking replaced by AV Pick-up/Drop-off
• Dedicated lane for AV
DESIGN 2

- Parking Removed, AV Pick-up/Drop-off instead
- Dedicated AV, Bus, & Bike Lanes
BETWEEN-RUN ASSESSMENTS

• Perceptions of:
  • AV speed
  • AV advantage
  • AV comfort/satisfaction

• Willingness to:
  • Use or Buy an AV
  • Buy EAV vs. GAV
  • Pay for EAV vs. GAV
DEVELOPING SCENARIOS NOW!
QUESTIONS?

Thank you to my Nextrans colleagues and CCAT Funding!

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FUNCTIONAL AREAS OF HUMAN BRAIN

- Language processing
- Reasoning
- Planning
- Auditory stimuli
- Language comprehension
- Information interpretation
COMPLACENCY-POTENTIAL RATING SCALE  (SINGH, MOLLOY, & PARASURAMAN, 1993)

• 4 Factors:
  • Confidence
  • Reliance
  • Trust
  • Safety

1. I think that automated devices used in medicine, such as CT scans and ultrasound, provide very reliable medical diagnosis.
2. Automated devices in medicine save time and money in the
1. ATMs provide a safeguard against the inappropriate use of an individual's bank account by dishonest people.
2. Automated devices used in aviation and banking have made
1. Manually sorting through card catalogues is more reliable than computer-aided searches for finding items in a library.
2. I would rather purchase an item using a computer than have to deal with a sales representative on the phone because my
1. I feel safer depositing my money at an ATM than with a human teller.
2. I have to tape an important TV program for a class assignment. To ensure that the correct program is recorded, I would use the automatic programming facility on my VCR rather than manual taping.
SYSTEM ACCEPTANCE SCALE
(VAN DER LAAN, HEINO, & DE WAARD, 1997)

- Given Pre- and Post-Interaction with Technology
  
- Usefulness & Satisfaction Scores calculated

- Difference scores calculated to gauge effect of experience
NASA TASK-LOAD INDEX
(HART & STAVELAND, 1988)

• Subjective workload measure
  • 1-21 point scale
  • Use to check/validate EEG readings
SELF-DRIVING CAR ACCEPTANCE SCALE
(NEES, 2016)

- Motivated by theories of technology and automation acceptance, specifically designed for self-driving cars
- 7-point Likert Scale
- 8 subdimensions
  - Perceived Reliability/Trust
  - Cost
  - Appropriateness of Automation/Compatibility
  - Enjoyment of the To-be-automated Task
  - Perceived Usefulness of Automation
  - Perceived Ease of Use of Automation
  - Experience with Automation
  - Intention to Use Automation

- Self-driving cars will be safe.
  - I would trust a self-driving car to get me to my destination.
  - People will need to watch self-driving cars closely to be sure the computers don’t make mistakes. (reverse scored)
- I would be willing to pay more for a self-driving car compared to what I pay for a traditional car.
  - The benefits of a self-driving car would outweigh the amount of money it would cost.
  - The cost of a self-driving car would be the most important thing I would consider before purchasing it.
- I do not think that computers should be driving cars. (reverse scored)
  - It is important for a human to be able to take back control from a self-driving car. (reverse scored)
  - There are some driving scenarios that will be too difficult for a self-driving car to handle. (reverse scored)
- I enjoy driving a car.
  - I prefer to be the driver rather than the passenger while in the car. (reverse scored)
  - I enjoy cruising and going for joy rides.
  - A self-driving car would allow me to be more productive.
  - A self-driving car would allow me to be more safe while in the car.
  - Self-driving cars will reduce traffic problems.
- A self-driving car will be easy to use.
  - Self-driving cars will be hard to use.
  - It will be a lot of work to figure out how to use a self-driving car. (reverse scored)
  - It would take me a long time to figure out how to use a self-driving car. (reverse scored)
- It is important for me to use technology to make tasks easier.
  - I have bad experiences when I try to use new technology instead of doing things “the old-fashioned way”. (reverse scored)
  - There are tasks in my life that have been made easier by computers doing the work for me.
TRUST IN AUTOMATION SCALE  (KÖRBER, 2015)

• 6 Sub-scales:
  • Competence/Reliability  Cronbach’s α = .92
    The system is capable of interpreting situations correctly.
    The system works reliably.
  • Understanding/Predictability  Cronbach’s α = .81
    A system malfunction is likely.*
    The system is capable of takinguser complicated tasks
    The system might make sporadic errors.*
  • Familiarity  Cronbach’s α = .83
    I am confident about the system’s capabilities.
    I should be careful about unfamiliar automated systems.*
  • Intention of Developers  Cronbach’s α = .78
    I rather trust a system than I mistrust it.
    I trust the system.
    I can rely on the system.
  • Propensity to Trust  Cronbach’s α = .75
  • Trust in Automation
    rally work well.
SIMULATOR SICKNESS QUESTIONNAIRE
(KENNEDY, LANE, BERBAUM, & LILIENTHAL, 1993)

• Lists possible symptoms of SS
• Asks P to gauge how much they feel each one
• Score is sum of responses
  • None = 0
  • Severe = 3

Instructions: Circle how much each symptom below is affecting you right now.

1. General discomfort
   None     Slight   Moderate   Severe
2. Fatigue
   None     Slight   Moderate   Severe
3. Headache
   None     Slight   Moderate   Severe
4. Eye strain
   None     Slight   Moderate   Severe
5. Difficulty focusing
   None     Slight   Moderate   Severe
6. Salivation increasing
   None     Slight   Moderate   Severe
7. Sweating
   None     Slight   Moderate   Severe
8. Nausea
   None     Slight   Moderate   Severe
9. Difficulty concentrating
   None     Slight   Moderate   Severe
10. «Fullness of the Head»
    None     Slight   Moderate   Severe
11. Blurred vision
    None     Slight   Moderate   Severe
12. Dizziness with eyes open
    None     Slight   Moderate   Severe
13. Dizziness with eyes closed
    None     Slight   Moderate   Severe
14. *Vertigo
    None     Slight   Moderate   Severe
15. **Stomach awareness
    None     Slight   Moderate   Severe
16. Burping
    None     Slight   Moderate   Severe
TRUST & AUTOMATION

• Hoff & Bashir (2015) Framework
Pre-experiment online survey

Schedule experiment

Consent form

Baseline questionnaire (B)

Introduction + Practice + ECG + Eye Tracker

Drive 1

Phase I

Phase II

Before coming to the lab

After coming to the lab

Human-driver in original design
REFERENCES


