Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts

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Project Vehicle Partners:
General Motors and Google
Are we there yet? Are we there yet? Are there yet?
Overview of Three Experiments

**Experiment 1 – L2**
- Alert Type (within subject):
  - Cautionary
  - Staged
  - Imminent
- Alert Modality (within):
  - Unimodal
  - Multimodal
- 25 participants
- One 90-min session

**Experiment 2 – L2**
- Driving Session (within)
- Event Type (within):
  - Alert
  - No Alert
  - No Lane Drift
- Prompt Condition (between subjects):
  - 2-s
  - 7-s
  - No prompt
- 56 participants
- Three 60-min sessions

**Experiment 3 – L3**
- Driving Session (within)
- Alert Type (within):
  - Staged
  - Imminent – External Threat
  - Imminent – No External Threat
- 25 participants
- Three 30-min sessions

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Experiment 1
(L2 ADS)

2009 Chevy Malibu

Experiment 2
(L2 ADS)

2010 Cadillac SRX

Experiment 3
(L3 ADS)

2012 Lexus RX450h

GM

Google
Experiment 2

• 56 participants; mean age = 41 yrs.
• Investigated L2 attention prompt effectiveness
• Drivers experienced 2-s, 7-s, or no prompts
  – Prompts progression
    • Stage 1: Visual
    • Stage 2: Visual + haptic
    • Stage 3: Visual + haptic + auditory
Experiment 2

- Three 1-hour driving sessions
- Asus Nexus 7 tablet computer was provided to participants
- In-vehicle experimenter gave a series of navigation, email, and web-browsing tasks
- 30 tasks in each category, potential of 90 tasks in all
Driving-related Glance Time (Attention to Roadway)

- No Prompts
- 7-second
- 2-second

Percentage

Before  After
Time to React to Unexpected Lane Drift

- No Alert: 4 seconds
- Visual + Haptic Alert: 1 second
Time to Regain Control

[Graph showing comparison of 2-second, 7-second, and No Prompts conditions with time in seconds on the y-axis and conditions on the x-axis.]
Experiment 3

- 25 participants; mean age = 38.8 yrs.
- Investigated L3 Take-Over Request Effectiveness
- Drivers received one alert per 30-minute session
  - Staged
  - Imminent – No External Threat
  - Imminent – External Threat (i.e., box on road)
Experiment 3

- Three 30-min driving sessions
- Participants were allowed to perform tasks and access Internet on Asus Nexus 7 tablet and use their personal smartphone as they wished
- Tablet was pre-loaded with movies, games
- Tasks to be done only when L3 automation was activated
Time to Regain Control (Staged Alert)

Phase 1 – Informational Message
Phase 2 – Cautionary Alert
Phase 3 – Cautionary Alert
Phase 4 – Imminent Alert
Phase 4 Ends
Key Takeaways

• Take Over Request
  – Most effective hand-off strategies were those that incorporated nonvisual components
    • Effective countermeasures to primary task reversals when drivers performed non-driving tasks

• Regain Control
  – L2 mean of 1.3 s (S.E. = 0.1 s)
    • Imminent visual and haptic alert
  – L3 mean of 2.3 s (S.E. = 0.2 s)
    • Imminent visual plus auditory alert

• Trust
  – High trust in automation for both levels of automation but calibrated
    • Trust was reduced after events where something occurred unannounced
Vehicle Automation Theories

• Primary Task Reversal

• Alert Annoyance Habituation
Primary Task Reversal

• Full-priority shift from driving-related task to non-driving tasks
  – Non-driving tasks becomes primary task demoting controlling the vehicle to secondary task
  – Readiness to respond to driving-related prompts and alerts can be delayed because operators feel obliged to complete non-driving task first
Alert Annoyance Habituation

• Operators can weigh non-driving task as more urgent if the TOR alert’s urgency is low
• Operators can weigh the non-driving task as less urgent if the TOR alert urgency is high
• Need HMIs that balance conspicuity, urgency, and annoyance
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Questions

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