Mixed-Function Automation Naturalistic in Naturalistic Settings

Sheldon Russell
Jon Atwood
Vikki Fitchett
Tammy Trimble
Myra Blanco
Paul Rau (NHTSA)

VirginiaTech
Transportation Institute

Objective

- Investigate driver interaction with market-ready mixed-function automation (MFA) through a naturalistic driving study (NDS)
  - Evaluate how drivers operate vehicles equipped with MFA
    - Lateral and longitudinal automation
  - Monitor internal vehicle data relevant to targeted functions

2017 Audi Q7

- Driver Assistance Package
  - Adaptive cruise control*
  - Active lane assist*
  - Congestion assist*
  - Lane departure warning
  - Side assist
  - Audi pre-sense

2015 Infiniti Q50

- Dynamic Driver Assistance
  - Intelligent Cruise Control w/ Distance Control Assist*
  - Active Lane Control*
  - Lane Departure Warning & Prevention*
  - Blind Spot Warning & Prevention

2016 Mercedes-Benz E350

- Driver Assistance Package
  - –DISTRONIC PLUS with steering assist*
  - –PRE-SAFE brake with pedestrian recognition
  - –BAS PLUS with cross-traffic assist
  - –Active blind spot assist
  - –Active lane keeping assist

2015 Tesla Model S

- Autopilot Tech Package
  - Traffic-Aware Cruise Control
  - Autosteer
  - Auto Lane Change

2016 Volvo XC90

- Convenience Package
  - Adaptive cruise control
  - Lane keeping aid
  - Pilot Assist

Data Acquisition

- Vehicles equipped with VTTI's NextGen Data Acquisition System (DAS)
- Accelerometers
  - Peaks indicate SCEs
- Vehicle variables
  - Speed
  - Lane position
  - Headway
  - GPS
- Incident button

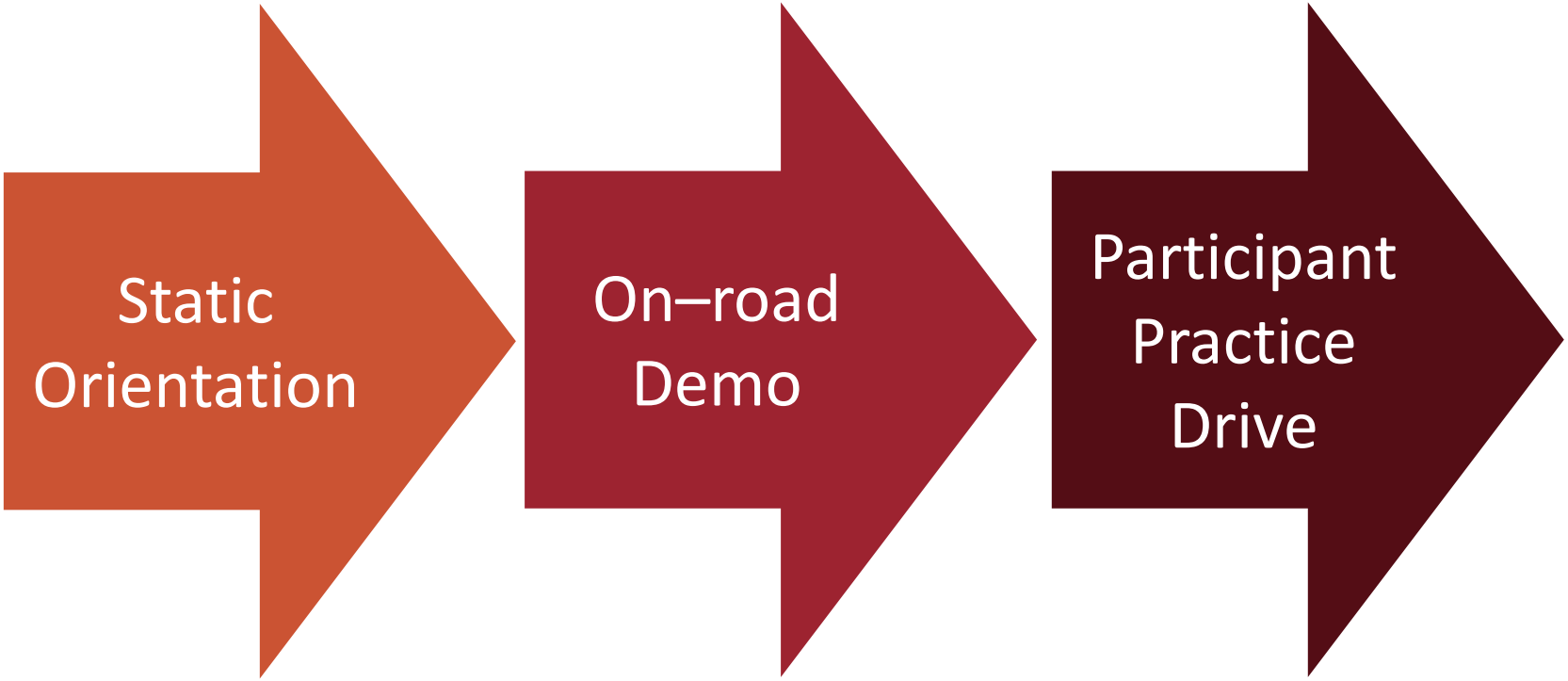
DAS Video Views

- Forward view
- Driver face
- Over the shoulder (OTS)
- Foot well (pedals)
- Rear view
- Instrument cluster (HMI)

Recruitment

- Recruit 120 drivers from the Northern Virginia/Washington, DC region
  - Equal number of males and females ages 25-39 years old and 40-54 years old
  - Screening for 1,200 miles per month
    - Incentive to drive at least 1,200 miles during participation
    - Targeting ~15,000 mi per year for each vehicle
    - FHWA (2015) national average is 13,476 per year

Training


Static Orientation
On–road Demo
Participant Practice Drive

Participant Timeline

Week 1	• Participants begin driving study vehicle
Questionnaire	• Subjective Experience & Trust
Week 2	
Questionnaire	• Subjective Experience & Trust
Week 3	
Questionnaire	• Subjective Experience & Trust
Week 4	
Questionnaire & Debrief	• Post-drive questionnaire • Payment
Vehicle Prep	• Vehicle Inspection, cleaning & prep • Data Ingestion

Data Sampling

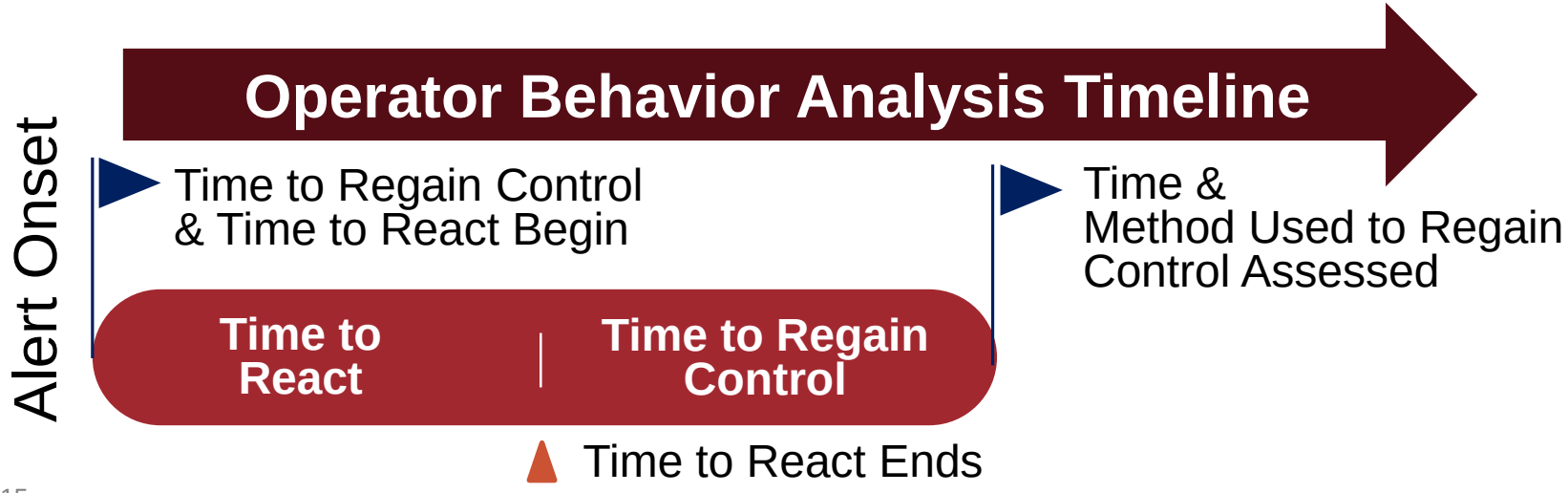
Epoch Type	Total Number of Epochs	Estimated Total per Driver	Estimated Frequency per Week per Driver
2 Functions Active	1,440	12	3
1 Function Active	1,440	12	3
0 Functions Active	1,440	12	3
MFA Alerts	1,440	12	3
All SCEs	All	All	All

Data Reduction Variables

- Driver variables
  - Non-driving task engagement, drowsiness/impairment, etc.
  - Visual behavior
- Vehicle variables
  - Speed, lane position, headway, etc.
- Environmental variables
  - Roadway markings, roadway type, traffic density, relation to junction, weather conditions, lighting conditions, etc.

Question Reduction

- Full question reduction will be performed on all epochs
- Similar to SHRP2 data dictionary
  - Captures driver variables, vehicle variables, and environmental variables



Research Question Focus Areas

1. Driver Performance
2. Driver Engagement
3. System Performance
4. Driver-System Interaction

Other Topics of Interest

- Integrated into focus areas as appropriate
  - Driver interface design
  - Unintended or Improper use
    - Misuse and/or abuse
  - Unintended consequences
  - Safety and security
  - System failures
  - Licensing and training

Safety Critical Event

Questions?

Sheldon Russell, Ph.D.
srussell@vtti.vt.edu

Focus Area 1
Driver Performance

- **RQ 1.1:** How do drivers respond to MFA alerts?
- **RQ 1.2:** How do drivers change their behavior over time?
- **RQ 1.3:** Does using MFA for long durations change any driving performance measures?

Individual Tests
RQ 1.1 Response to MFA

- How quickly did participants react to the MFA alert?
- How quickly did participants regain control after the MFA alert?
- What was the first response to the MFA alert?
- Were the reaction and regain control times in response to the MFA alert different across different scenario characteristics (e.g., LOS, weather)?
- Was the manner of first response to the MFA alert different across different scenario characteristics?

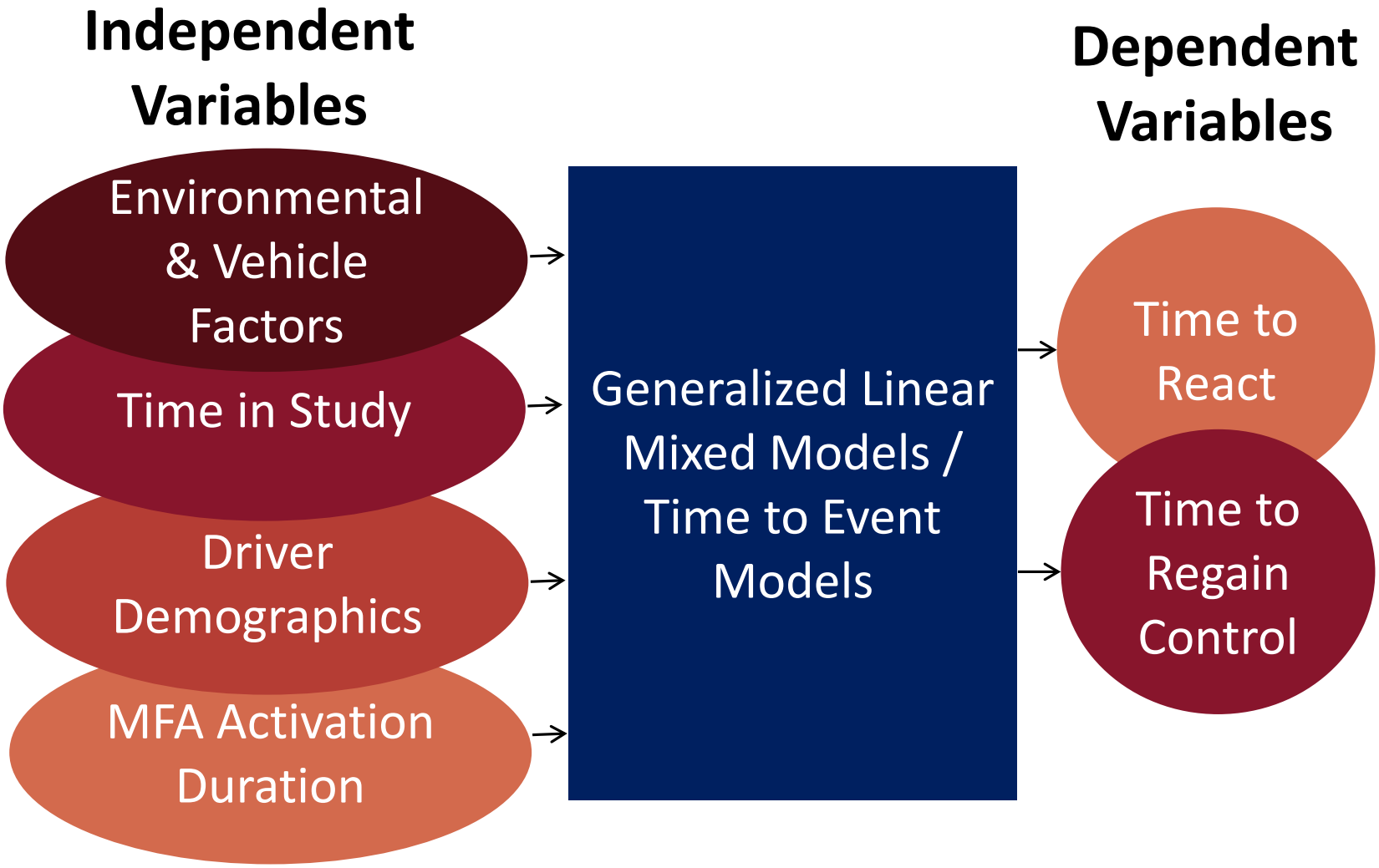
Individual Tests
RQ 1.2 Performance Over Time

- Did participants' time to react or time to regain control after an MFA alert change significantly over time?
- Did the probability of performing a non-driving task during MFA activation change significantly over time?

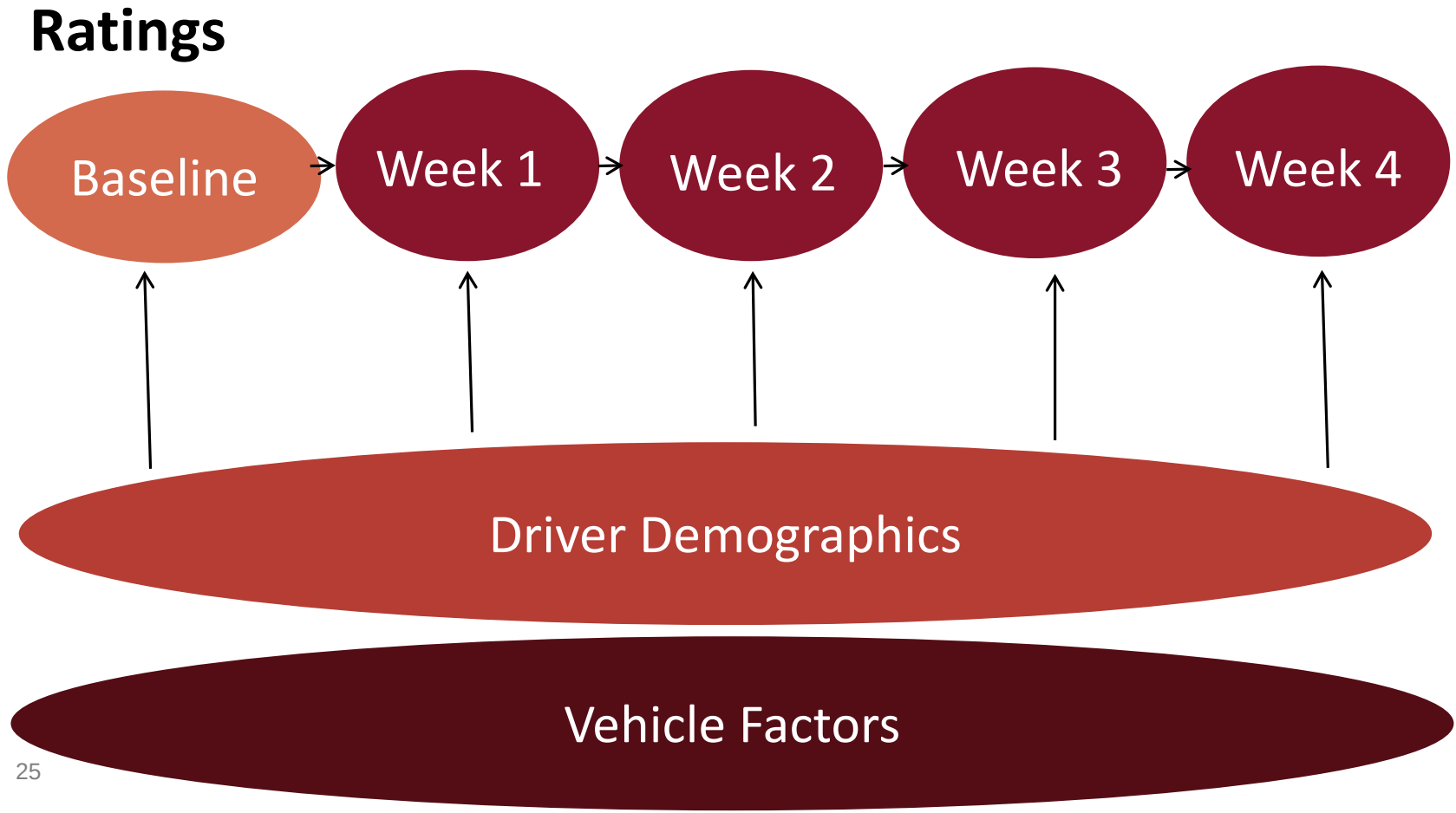
Individual Tests
RQ 1.3 Long Durations of MFA

- Does time to react after an MFA alert depend upon how long the MFA was active before the alert occurred?
- Does time to regain control after an MFA alert depend upon how long the MFA was active before the alert occurred?

Analysis Approach
Driver Performance



Analysis Approach
Subjective Data



Focus Area 2
Driver Engagement

- **RQ 2.1:** If available, how do drivers respond to system prompts?
  - Prompt vs. Alert
- **RQ 2.2:** Are there specific aspects of the MFA features that drivers find more useful than others?

Prompt vs. Alert

- Prompt – keep drivers engaged in the driving task (e.g., hand[s] on wheel)
  - System remains controlling lateral and longitudinal vehicle path
- Alert – notify driver to start controlling lateral and/or longitudinal vehicle path

Focus Area 3
System Performance

- **RQ 3.1:** How does the combined lateral and longitudinal control system operate?
- **RQ 3.2:** Are there environmental factors that reduce the availability of the MFA features?

Focus Area 4
Driver-System Interaction

- **RQ 4.1:** What driver behaviors are observed when the MFA is active?
- **RQ 4.2:** Do drivers report that the MFA functions as they would expect?
- **RQ 4.3:** Do drivers report different expectations across various types of roadways, driving conditions, speeds, etc.?

Crash Severity Levels

- **Level 1:** crashes that include airbag deployment, injury, rollover, high Delta-V crashes or towing. High Delta-V is defined as a change in speed of the subject vehicle in any direction during impact greater than 20 mph (excluding curb strikes) or acceleration on any axis greater than ± 2g (excluding curb strikes)

- **Level 2:** crashes that do not meet the requirements for a Level 1 crash. Includes sufficient property damage that one would anticipate that it is reported to authorities (minimum of $1,500 worth of damage, as estimated from video). Also includes crashes that reach an acceleration on any axis greater than ± 1.3 g (excluding curb strikes). Most large animal strikes and sign strikes are considered Level 2

Crash Severity Levels

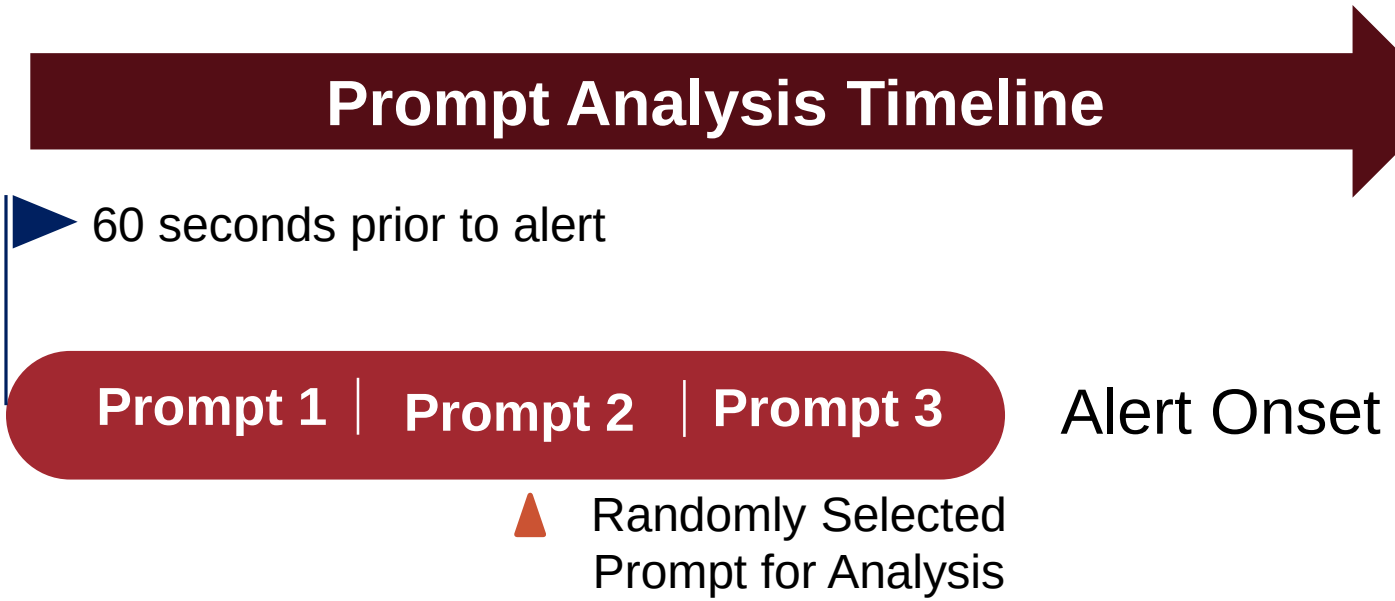
- **Level 3:** crashes involving physical conflict with another object (but with minimal damage) that do not meet the requirements for a Level 1 or Level 2 crash. Includes most road departures (unless criteria for a more severe crash are met), small animal strikes, all curb and tires strikes potentially in conflict with oncoming traffic, and other curb strikes with an increased risk element (e.g., would have resulted in worse had curb not been there, usually related to some kind of driver behavior or state, for example hitting a guardrail at low speeds)

- **Level 4:** tire strike only with little/no risk element (e.g., clipping a curb during a tight turn). The distinction between Level 3 and Level 4 crashes is that Level 3 crashes would have resulted in a worse crash had the curb not been there while Level 4 crashes would not have due to the limited risk involved with the curb strike

Individual Tests
RQ 2.1

- How many prompts did drivers receive in the 60 seconds prior to an MFA alert?
- How quickly did participants respond to a prompt?
- What was the manner of response to the prompt?

Diagram of Prompt Analysis



Individual Tests
RQ 2.2

- Which aspects of the MFA did participants rate as useful or annoying?
- Which aspects of the MFA did participants rate as easy or difficult to understand?

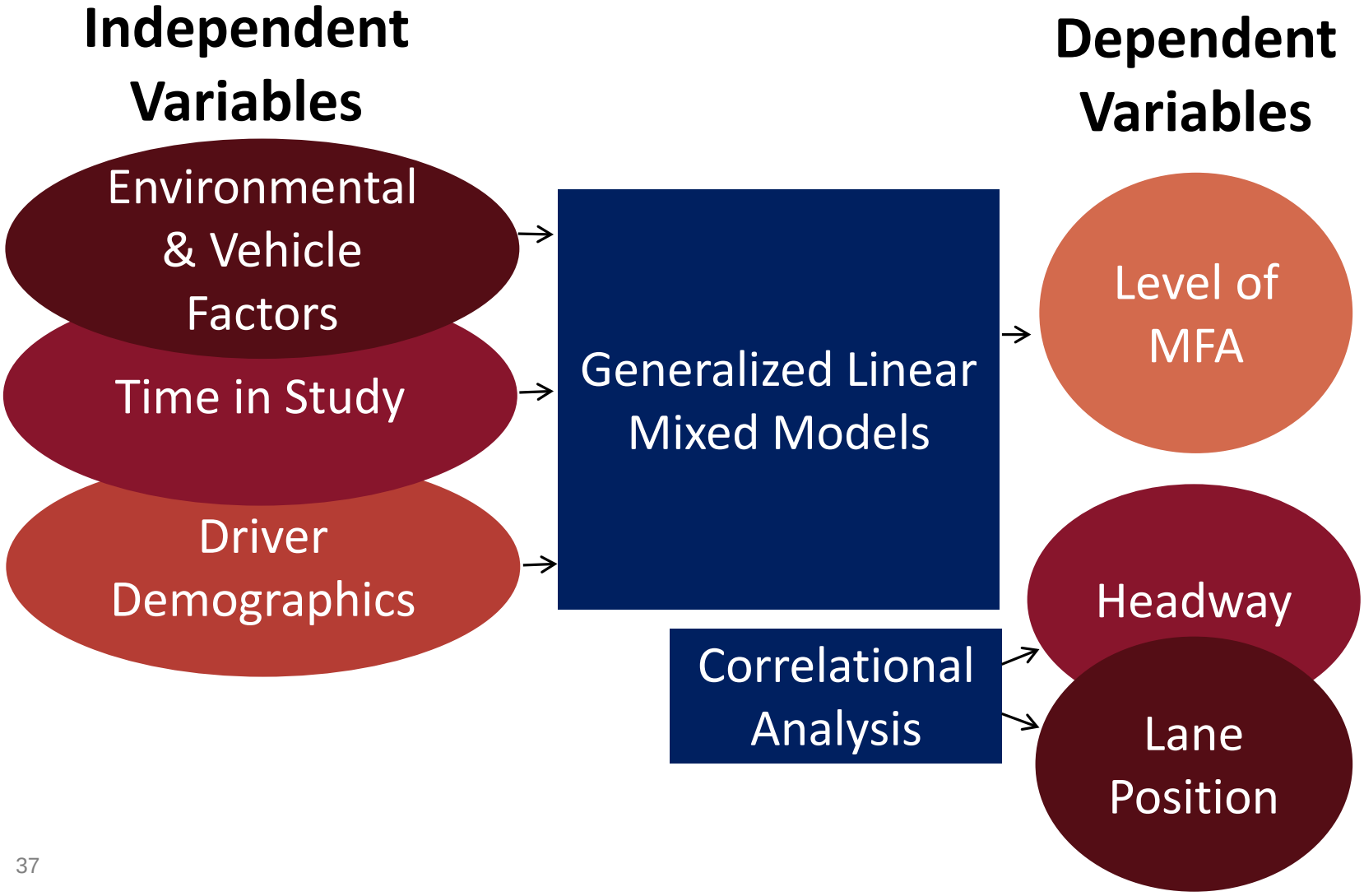
Individual Tests
RQ 3.1

- What were the mean and standard deviation of headway and lane position?
- What is the relationship between the mean headway and mean lane position?

Individual Tests
RQ 3.2

- Are roadway scenarios in which MFA is active different from roadway scenarios in which MFA is available but is not active or is only partially active?

Analysis Approach
System Performance



Individual Tests
RQ 4.1

- How likely were participants to perform a non-driving task during MFA activation?
- What types of non-driving tasks did participants perform during MFA activation?
- Were participants more likely to perform a non-driving task during MFA activation compared to partial activation and no activation?

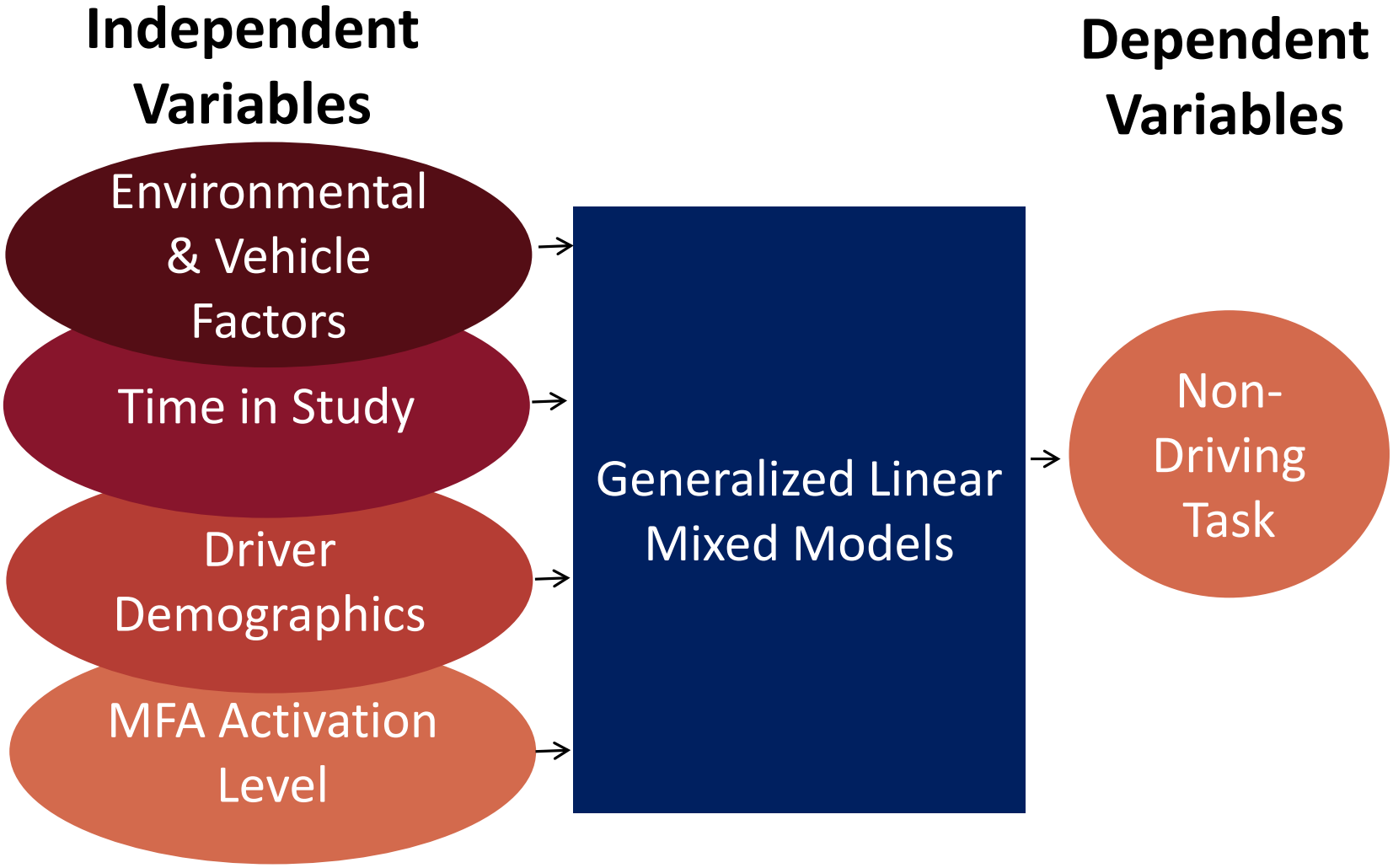
Individual Tests
RQ 4.2

- Do participants rate the MFA functioning as close to expectations, above expectations, or below expectations?
- How do drivers rate their level of trust in the MFA?

Individual Tests
RQ 4.3

- Do drivers rate expectations for MFA high or lower in different types of driving environments?
- Do their ratings change over their week in the study?

Analysis Approach
Driver-system Interaction



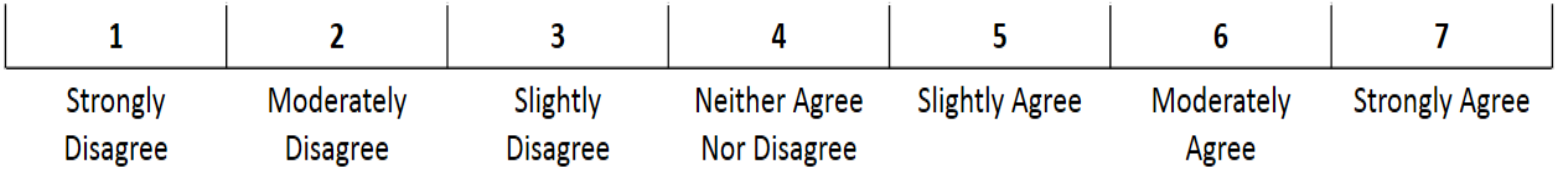
Pre/Post Questionnaire

- I can rely on the automated system to function properly while I am doing something else
- The automated system provided alerts when needed
- The automated system gave false alerts

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree

Pre/Post Questionnaire

- The automated system is dependable
- I am familiar with the automated system
- I felt safe using the automated system
- I trust the automated system



Weekly Check-in Interview

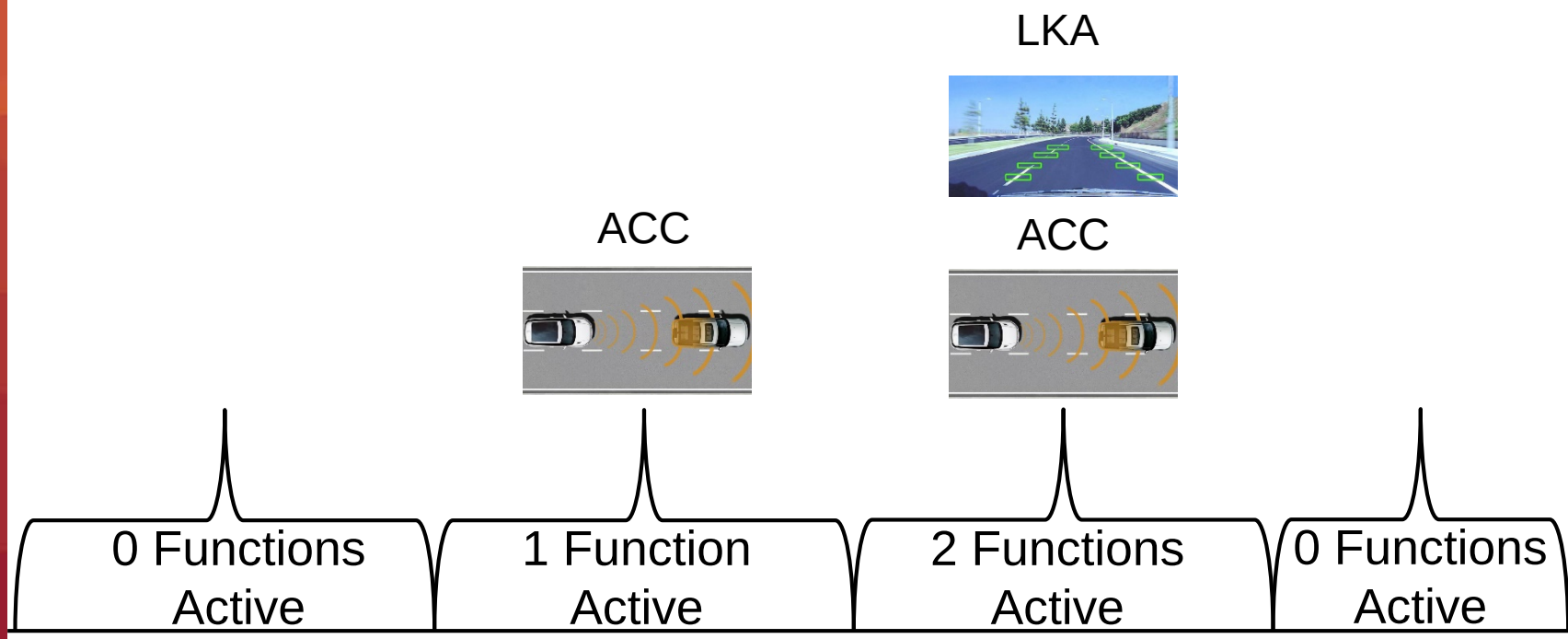
- Overall, what are your thoughts on the automated system?
- Can you describe how comfortable you were with using the Adaptive Cruise Control?
- Can you describe how comfortable you were with using lane keep assist?

Weekly Check-in Interview

- Were there driving conditions that changed how you used the automated systems?
- What were your thoughts when the automated systems provided you with alerts?
- When the automated system provided a message, what were your first thoughts and actions?

Weekly Check-in Interview

- If you were talking to a design team, what concerns would you have about an automated system such as you experienced?
- Please rate your overall level of trust in the automated systems (uses 1-7 scale)
- Is there anything else regarding your experience with the study vehicle that you would like to share?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