# MIXED-FUNCTION AUTOMATION IN NATURALISTIC SETTINGS

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## ABSTRACT

Vehicles with increasingly advanced automated capabilities are rapidly becoming a reality, and data are needed to understand the operation of the various types of these vehicles currently in use on public roads. This project is investigating real-world driver interaction with market-ready mixed-function automation (MFA) through a naturalistic driving study (NDS). The vehicles being used in this study have the capability to simultaneously activate automated lateral and longitudinal functions, allowing drivers to operate the vehicle with their hands off the steering wheel and feet off the pedals for several seconds, with the caveat that this capability is not explicitly stated or condoned by original equipment manufacturers (OEMs). All systems generate alerts to notify drivers to regain control of the vehicle. This study will observe and evaluate how drivers operate five different commercially available vehicles equipped with MFA. The study will recruit a total of 120 drivers from the Northern Virginia and Washington, DC metro area. Drivers will drive one of the study vehicles instead of their own for a period of four weeks. Study vehicles will be instrumented to capture vehicle data as well as audio and video. The data collected will be sampled and analyzed in order to assess drivers' overall use of the systems and specific types of interactions—such as the sequence of events when regaining control and secondary task engagement. It is anticipated that interactions with the MFA features will be observed in operation in mixed traffic under a variety of roadway types, driving conditions, and speeds. At present, 47 drivers have completed their 4-week participation period, with an estimate of at least 56,400 miles driven. This project will support the identification and/or refinement of human factors best practices to encourage the safe operation of highly automated vehicles.

## INTRODUCTION

Currently, there are several commercially available vehicles that automate lateral and longitudinal vehicle control. Depending on the make of vehicle, different terms are used to name and describe these automated lateral (e.g., steering assist, lane keep assist, lane centering) and longitudinal (e.g., adaptive cruise control, intelligent cruise control, advanced cruise control) systems. For this report, the general terms of automated lateral and automated longitudinal control will be used to refer to their respective automated systems. Technically, combined lateral and longitudinal control fall under Level 2, Partial Driving Automation as defined by the Society of Automotive Engineers (SAE; SAE International, 2016). SAE describes the roles of the driving automated system and the driver during Level 2 (L2) automation in standard J3016:

*Level 2 (Partial Driving Automation):*

*The Driving Automation System (while engaged):*

*Performs part of the dynamic driving task (DDT) by executing both the lateral and longitudinal vehicle motion control subtasks and disengages immediately upon driver request.*

*The Driver (at all times):*

*Performs the remainder of the DDT not performed by the driving automation system, supervises the driving automation system and intervenes as necessary to maintain safe operation of the vehicle, determines whether/when engagement and disengagement of the driving automation system is appropriate, and immediately performs the entire DDT whenever required or desired*

The functionality of commercially available systems with L2 functionality has not been studied in real-world settings. Different implementations of automated functions for lateral and longitudinal control likely have different functional envelopes and/or capabilities. For example, some systems may only operate at highway speeds. As such, it may be premature to identify current market-ready systems as L2. For this study, the term used will be Mixed-Function Automation (MFA), which is meant to specify that both lateral and longitudinal controls are automated in some fashion, and both systems can be enabled simultaneously. Note that MFA does not specify a level of automation, and is not intended to imply a system more advanced than an L2 system; rather, it is used to capture the variability of capabilities inside this category without debating the boundaries of that level.

Previous research has evaluated human factors concepts with automated lateral and longitudinal functions (Blanco et al., 2015) in test track settings. While these test track studies provide valuable insight into potential benefits and drawbacks of MFA technologies, they can be complemented by naturalistic driving studies (NDS). NDSs provide a method for evaluating new vehicle technologies during daily driving situations and without the presence of an experimenter. Previous research has shown that, while there is a brief period of time in which participants behave differently due to the presence of cameras in the vehicle, they appear to adapt to the presence of this instrumentation in less than an hour (Dingus et al., 2006). Earlier NDSs have evaluated new technology for collision avoidance systems in heavy vehicles (Grove et al., 2016), video imaging and camera systems (Wierwille et al., 2011), and studied normal driving performance and behaviors (Klauer et al., 2006; Klauer et al., 2010; Dingus et al., 2015). The current study, Mixed-Function Automation Naturalistic Driving Study (MFA NDS), described herein will generate practical data to support new understanding of MFA technology use by evaluating a subset of currently available advanced MFA technologies as drivers experience them during their daily use.

An NDS is an in situ investigation of driver performance and behavior. By instrumenting vehicles with cameras, sensors, and data recorders, drivers can be continuously recorded over an extended period of time without an experimenter in the vehicle. Under these conditions, participants drive as they normally would, without influence from experimenters. Naturalistic driving research supports the simultaneous investigation of driver, vehicle, and environmental factors pertaining to transportation safety, and can capture true driver motivation to use an MFA system and engage in non-driving tasks. It also enables the identification of edge cases unforeseen by designers via the observation of MFA system operation across a wide range of drivers and various environmental conditions. Finally, it is anticipated that safety-critical events (SCEs) of different severity levels (e.g., crashes and near-crashes) will be observed and their relationship to MFA system use (or lack thereof) can be investigated.

The objective of the MFA NDS project is to investigate, through an NDS, real-world driver interaction with market-ready mixed lateral and longitudinal function automation. The study will 1) observe and evaluate how drivers operate vehicles equipped with MFA driving features intended for operation in mixed traffic under a variety of roadway types, driving conditions, and speeds; and 2) monitor internal vehicle data relevant to the targeted functions. This study will also support the identification and/or refinement of human factors best practices to help encourage the safe operation of vehicles with automated control systems. At present, the study is ongoing, and this paper provides an outline of the research questions, the implemented approach, and a brief summary of the current status of data collection.

## RESEARCH QUESTIONS

Test track studies using vehicles equipped with MFA have left salient research gaps that can be addressed by an NDS. The types, durations, and frequencies of non-driving tasks performed by drivers when MFA systems are activated are not fully understood. For example, do drivers misuse or abuse the MFA features by overly engaging in visual or manual non-driving tasks? Test track research suggests that drivers' response and regain control times change based on the modality of take-over request alerts, a finding that should be evaluated in an NDS. Duration of exposure also needs to be explored, as longer exposures could result in longer response times, which could suggest complacency or an adaptation to the environmental circumstances surrounding the alert. Additionally, results of MFA system evaluations in non-ideal roadway conditions (e.g., heavy traffic, severe weather) have not been made publicly available; thus, the overall performance envelope is not publicly known. Determining whether MFA systems experience performance issues in the real world could help identify rare and unexpected scenarios to be addressed in future designs. Finally, the degree to which drivers understand MFA system operation should be determined in order to guide the development of future human-machine interface (HMI) concepts. Understanding driver trust in the technology before and after using it in real-world situations could greatly inform researchers and system developers as to drivers' willingness to detach from the driving task and attempt to push the system beyond its capabilities.

Focus area 1 of this study investigates Driver Performance. Driver performance will be measured by drivers' responses to take-over alerts (i.e., requests to intervene) generated by the MFA systems. Note that other alerts, such as forward collision warning alerts, are not part of the planned analyses, although they may be investigated in future analyses. This focus area will also investigate performance changes over time. This focus area contains three research questions (RQs):

<u>RQ 1.1</u>: How do drivers respond to MFA alerts? The sequence and timing of driver responses immediately prior to and following an alert until the driver regains full manual control or re-engages the automated features is being investigated. Data collected during alert instances will be sampled and reduced. The sequence and timing of responses observed will be compared to the findings of test track studies, specifically those reported in NHTSA's 2015 *Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts* (Blanco et al., 2015).

<u>RQ 1.2</u>: How do drivers change their behavior over time? For example, drivers could learn to take fewer steps to activate the system, or the transition to taking hands off the steering wheel or moving feet off the pedals could become quicker during the final week (of the 4-week study, see below) compared to the first few engagements. The differences in driver behaviors between the first week of MFA system use and the final week of MFA system use is being investigated.

<u>RQ 1.3</u>: Does using MFA systems for long durations change any driving performance measures or otherwise impact driver behavior? Note that the specific definition of a long duration will be based on the overall usage profile that is observed upon data analysis. Specific samples that occur during longer instances of MFA activation will be compared to samples that occur during shorter duration instances.

Focus area 2 investigates Driver Engagement, which refers to specific behaviors that are observed while the MFA systems are active. This focus area includes two RQs:

<u>RQ 2.1</u>: If available, how do drivers respond to system prompts? Some study vehicles include prompts designed to keep the driver engaged or aware when the MFA systems are active. When these features are present, prompts will be sampled relative to their frequency during the window of time prior to an alert.

<u>RQ 2.2</u>: Are there specific aspects of the MFA features (e.g., alerts, displays) that drivers find more useful than others? Conversely, are there aspects of MFA features that are misleading, annoying, or difficult to understand? These questions are being investigated by asking drivers' opinions about said vehicle features.

Focus area 3 investigates System Performance, and is independent of the user. This focus area is heavily informed by the vehicle characterization effort, but sampled and reduced data will also provide insight into the performance of the system. This focus area includes two RQs:

RQ 3.1: How does the combined lateral and longitudinal control system operate? The system's operation was investigated during the vehicle characterization effort.

RQ 3.2: Are there environmental factors that reduce the availability of the MFA features? For example, the impact of factors such as roadway markings, traffic level of service, and weather on MFA system use are being investigated.

Focus area 4 investigates the Driver-System Interaction and includes three RQs:

RQ 4.1: What driver behaviors are observed when the MFA systems are active? For example, is there a higher prevalence of non-driving tasks performed by drivers when the MFA systems are active compared to times when they are not?

RQ 4.2: Do drivers report that the MFA systems function as they would expect? Furthermore, do they report that they trust the MFA systems? Drivers will be asked about their opinions of the MFA features throughout their participation. Changes in their expectations will be noted, as well as their reported levels of trust.

RQ 4.3: Do drivers report different expectations across various types of roadways, driving conditions, speeds, etc.? That is to say, when asked for their opinions, do drivers recognize the limitations of the MFA systems in various environments?

The RQs in focus areas 1 through 4 are expected to provide a general overview of MFA system use, reliability, and driver interaction. Within the scope of RQs in focus areas 1 through 4 are additional related topics. As such, the results of this study are also expected to inform the following sub questions (SQs):

SQ 5: Driver Interface Design: Were the tested automation concepts consistent with the draft Automated Vehicle-Human Factors Design Principles developed within the *Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts* study? Any data or observations from this study that could help support these design principles will be noted.

SQ 6: Unintended Use: Research questions in focus areas 1 through 4 investigate the limits and intended use of the MFA systems. However, drivers may find and implement means for defeating the automation's monitoring mechanisms or intended use. Any observed occurrence of this type of behavior will be reported and investigated as it relates to other research questions. It is understood that unintended use is defined by the manufacturer; the research team has worked with original equipment manufacturers (OEMs) to define unintended use for each vehicle. The research team also acknowledges that misuse and abuse may be difficult to distinguish except in extreme cases of abuse (e.g., a soda can taped to the steering wheel or a driver moving into the passenger seat).

SQ 7: Unintended Consequences: Any unintended consequences regarding drivers' daily use of the vehicle with automated control systems, such as complacency, indifference, or errors of omission/commission, are being investigated. This may include unintended consequences not captured by other research questions.

SQ 8: Safety and Security: Any specific comments from drivers regarding safety and security will be noted. These include whether or not drivers are satisfied using the vehicle with automated control systems for their daily driving. Based on drivers' self-reports, estimates of participant reliance on the MFA systems is being assessed. Consistently high levels of trust in the MFA systems could be an indication that automation produces a false sense of safety and security, particularly if high trust ratings are associated with improper system use.

SQ 9: System Limitations: RQ 1.1 specifically investigates alerts. A subset of alerts may be the result of unexpected system failures or other design limitations. The timing and sequence of events observed from these types of alerts, including whether they are false alarms, advisory warnings, etc., will be noted. Definitions for valid, false, and advisory alerts will be adapted from previous work (Grove et al., 2016). Also of interest are SCEs, such as unintended lane departures, which may occur while the MFA system is active, but for which the system issues no alerts.

SQ10: Licensing and Training: Based on the results of this study, any anticipated need for additional licensing or training requirements for automated systems will be reported. This will take the form of general suggestions based on the training plan implemented in this study.

## METHODS

### Vehicles

Since MFA systems currently available on the market vary in terms of their capabilities and HMIs, the study is using vehicles with differing MFA functionalities across five different OEMs. One commonality among these systems is that each allows drivers to simultaneously activate longitudinal and lateral controls, allowing drivers to operate the vehicle with their hands off the steering wheel and feet off the pedals for several seconds (again, this capability is not promised or condoned by OEMs). Each system also generates alerts to notify drivers when they need to regain control of the vehicle. The research team has leased two of each of the following vehicles for the duration of the study:

- 2017 Audi Q7 Premium Plus 3.0 TFSI Quattro with Driver Assistance Package
- 2015 Infiniti Q50 3.7 AWD Premium with Technology, Navigation, and Deluxe Touring Package
- 2016 Mercedes-Benz E350 Sedan with Premium Package, Driver Assistance Package
- 2015 Tesla Model S P90D AWD with Autopilot Convenience
- 2016 Volvo XC90 T6 AWD R-Design with Convenience Package

A characterization of the MFA systems was conducted for each test vehicle. An understanding of how each MFA system works was developed, and each system's operational envelope was observed in various driving environments. (While the focus of this study is on the longitudinal and lateral automated systems, other advanced features—such as the blind spot warning—were included where relevant.) Characterization included training machine-vision algorithms to detect MFA system operation and active safety alerts from the instrument cluster, and also identified systems that prompted the driver to remain engaged. The characterization results are being used to inform both the data reduction process and the interpretation of results.

In addition to general characterization, vehicle characterization was also informed by previous work. Specifically, one output of Blanco et al. (2015) was a detailed collection of DVI characteristics that would support the driver operation of vehicles that include automation for lateral and longitudinal control. This report was used as a basis for evaluating the DVI characteristics of the mixed-function automated vehicles used in this study.

Alerts and prompts are distinguished by the level of control maintained by the lateral and longitudinal automation. This distinction has been established by the research team, in collaboration with OEM stakeholders. An alert indicates that the automated system requires driver intervention because it has reached a functional limit. A prompt does not indicate that the system has reached a functional limit, but rather notifies the driver to perform an action to remain engaged in the driving task (such as placing hands on the steering wheel).

Each vehicle has been equipped with Virginia Tech Transportation Institute's (VTTI) NextGen Data Acquisition System (DAS), the same system used in the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS; Dingus et al., 2015). As shown in Figure 1, the DAS continuously records video of the forward roadway, the driver's face, an over-the-shoulder (OTS) view of the driver's hands and lap area (includes a view of the instrument cluster), a view of the foot well, and the rear roadway. In addition to video feeds, the DAS continuously records audio in the vehicle. Continuous audio recording will capture any auditory alerts, prompts, voice commands, and cell phone use that occurs during the study. In regard to cell phone use, the focus of this study is on the prevalence and duration of non-driving-related tasks, not on the content of cell phone calls.


***Figure 1. Example of video views collected by the DAS.***

The DAS also records vehicle data, including speed, throttle position, brake application, acceleration, lane position, turn signal activation, and GPS coordinates. As previously noted, the DAS also records MFA system activations using a machine vision algorithm if this information is not available on the vehicle network. The research team is using VTTI's Mission Control software to monitor vehicle location, data storage, and mileage incurred over the course of the data collection period. Because the data is being collected, stored, and reduced in the same manner as in the SHRP 2 NDS, the extensive SHRP 2 NDS data set can provide a comparative sample for analysis in future studies.

**Participants**

This study will recruit a total of 120 drivers from the Northern Virginia/Washington, DC region. The study screens for participants who drive at least 14,400 miles per year, or 1,200 miles per month. Drivers are provided monetary incentive to drive at least 1,200 miles during their participation (see below). In addition, researchers verify that the distance between a participant's work and home address is 60 miles round trip (i.e., a 30-mile commute each way) or the equivalent if the participant drives while at work. As of March 31, 2017, 47 drivers have successfully completed the study.

Drivers are compensated up to $500 as follows: 1) up to $360 if their total mileage is under or equal to 1,200 miles; or 2) $500 if they exceed 1,200 miles. They are also lent a transponder that gives them free access to the high-occupancy toll (HOT) lanes managed by Transurban. This helps to ensure that participants are able to reach driving speeds required for MFA activation and create further incentive to participate in the study.

An equal number of males and females are being recruited from two age groups: 25–39 and 40–54 years old. Participants' frequency and perception of risky driving are being assessed via a subjective questionnaire which has been used in a previous NDS (Dingus et al., 2015). This measure serves as a way to control for the overall 'riskiness' of participants assigned to each vehicle.

In order to ensure that participants are accurately reporting their driving history, the research team verifies each participant's driving history in collaboration with Virginia Tech Human Resources. This check is intended to mitigate risk of damage to the study vehicles in a way that would negatively impact the project timeline.

Drivers will participate in the study for four weeks each in order to maximize their exposure to the MFA systems. Note that there is no baseline period for this study, as the MFA capabilities will be available to all participants at the time the vehicle is assigned to them.

Participants receive training that has been designed to mimic the information they might receive at a dealership prior to purchasing a similar vehicle. To this end, the research team developed training outlines through collaboration with OEM stakeholders, review of owner's manuals, dealership site visits, and online training materials. Care has been taken to develop training that is not overly in-depth, but still adequately covers the use of MFA features. All study screening, recruitment, training, and data collection activities have been approved by the Virginia Tech Institutional Review Board (IRB) prior to study execution.

**Procedures**

Potential participants are contacted by the recruitment group at VTTI and screened for their eligibility to participate. Eligible drivers then undergo a driving history check. This check is deemed necessary to reduce risk of a major problem (e.g., DUI, reckless driving) involving a study vehicle, which could impact data collection.

For those participants who are eligible to participate, a meeting is scheduled to visit the participant's home. At this time, the participant completes the informed consent process, which covers the rights and responsibilities as a participant. Furthermore, this visit ensures that there is a secure place to park the study vehicle. For one study vehicle, the Tesla Model S, this inspection also includes verifying that the participant has a garage with electrical outlets. This vehicle can only be assigned to participants who have the ability to charge the vehicle, using facilities available at or near their home or place of work.

At the home visit, each participant receives an orientation to the vehicle assigned to him/her as well as training regarding the use of MFA features, including a test drive. Participants are instructed that they alone are authorized to drive the study vehicle. After completing training and the vehicle test drive, and prior to taking possession of the vehicle, participants complete a subjective questionnaire, which is based on questionnaires used in previous test track research (Blanco et al., 2015), regarding their initial opinions of the vehicles and the MFA systems. Finally, an experimenter verifies the vehicle's condition using an inspection sheet, and photographs any issues with the vehicle. After completing all training, questionnaires, and verifying vehicle conditions, participants are loaned the study vehicle for the 4-week participation period.

Participants are surveyed at the onset of the study and again at days 7, 14, 21, and the final day of their participation. The subjective data collected from the questionnaires will be analyzed to assess participants' trust in the vehicle automation and their understanding of the MFA system's operation. This questionnaire has been adapted from previous test track studies using MFA systems (Blanco et al., 2015). Collecting questionnaire responses at multiple times throughout participation also allows insight into changes in trust and perception of the systems over time. At the end of the 4-week participation period, a researcher takes possession of the study vehicle, verifies the vehicle's condition, and administers a final questionnaire to the participant. Once the questionnaire is completed and the vehicle is returned, the participant is compensated and the research team ingests the data and prepares the vehicle for the next participant.

### Data Sampling & Analysis

The hallmark of NDSs is continuous data recording while participants are driving the study vehicles. The focus of this section is to describe the approach to sampling, reducing, and analyzing continuously recorded data. Fifteen-second epochs are being sampled from the continuously recorded data. The 15 seconds will be comprised of 10 seconds prior to and 5 seconds after the time of interest. Samples are taken during instances in which the MFA system was in use, instances in which the MFA system was available but not in use, instances in which the MFA was in partial use, and instances in which an alert was issued.

All periods in which the MFA system was available for use and also active will be identified using available data. Sampling is designed to generate equal representation of data across drivers and across time in the study, as well as to sample data as it is generated in order to minimize time between the completion of data collection and data analysis. The research team will sample 1,440 MFA activations, 1,440 instances of MFA availability without activation, 1,440 instances of MFA availability with partial activation, 1,440 Alerts, and all SCEs that can be identified. The breakdown by driver is as follows:

- Twelve 15-second epochs will be randomly sampled from the periods in which the MFA system was active (after sampling the first few MFA activations, samples will be taken every week of participation). Twelve samples per driver will provide a reliable statistical estimate of driver performance, and 15-second samples will allow the assessment of drivers' visual behavior and engagement in secondary tasks. This sampling method has been employed successfully in previous NDSs (Dingus et al., 2015).
- Twelve epochs per driver of instances in which the MFA system is available but only partially active will be sampled (i.e., only lateral or only longitudinal control is activated).
- Twelve epochs per driver of instances in which the MFA system is available but neither lateral nor longitudinal control is activated will be sampled.

Thus, a total of 4,320 epochs will be sampled. These samples will allow comparisons of driver behavior and roadway scenarios between levels of MFA activation (when such activation is available).

Additionally, for each driver, twelve 15-second epochs will also be randomly sampled from the time periods in which alerts were issued (again, the first few alerts will be sampled, followed by sampling for every week of participation). These 1,440 samples will be used to assess how long drivers take to regain control of the vehicle once an alert is issued (RQ 1.1). Samples will be used to investigate system performance (RQ 3) and non-driving tasks during MFA system activation (RQ 4). Concurrent with this effort, established kinematic algorithms will be used to trigger potential SCEs (e.g., hard decelerations, lane departures, high yaw rates). Together, these triggers will be used to identify potential SCEs. Trained data reductionists (see below) will inspect the videos associated with these triggered events to verify the occurrence of an SCE. The validated SCE triggers will then help to identify driver performance issues.

Equal amounts of each type of epoch will be selected from each week in the study within each driver's data. The exception is the set of SCEs, which will include all SCEs that can be identified. Note that the numbers discussed above are an estimation of the maximum number of epochs that will be sampled. If there are fewer epochs than listed above, or at least near the listed amount, then all will be sampled. Otherwise, stratified random sampling will be employed. Also note that this strategy allows for sampling to take place as data is ingested, in order that reduction and analysis can begin soon after data collection begins.

The sampling strategy will not attempt to adjust for exposure rate of MFA per driver. There are three reasons for this. First, the primary research objective is to make inferences about drivers and, thus, drivers are the population of interest. As such, as much information as possible about each driver's behavior at the time of his/her MFA use (or lack thereof) is desired. Second, of interest is drivers' performance under different MFA systems, which may vary between vehicle types. Therefore, sampling too little from some drivers may result in a loss of information for drivers using a particular system. Third, using the planned sampling approach will allow for sampling to occur as data arrives.

It is possible that not all 120 drivers will participate for four weeks. The data will be sampled as each driver completes each week in the study. If a driver does not complete all four weeks, those weeks will be considered as missing data. New drivers may be recruited in order to replace drivers with incomplete data.

For each sampled epoch, trained data reductionists (Figure 2) will use the recorded video, audio, and parametric data to analyze the driver, vehicle, and environmental factors that existed during each of the sampled MFA activations, alerts, and valid SCEs. The data will be used to describe the circumstances that led to the occurrence of each. All reduction will take place in a secure data reduction lab at VTTI. Reductionists are limited to short shifts to minimize vigilance decrements and are not allowed access to their cell phones to prevent video of drivers being released to the public.

*Figure 2. Data reduction at VTTI.*

Driver variable reduction will include an assessment of what behaviors were exhibited at the time of the event, including non-driving task engagement, evidence of drowsiness/impairment, and other aspects that might help characterize driver interaction with the automation (e.g., improper use of the automation, such as using the system in adverse weather or circumventing the need to hold the steering wheel). A 15-second eye glance reduction will be performed on all sampled MFA activations, alerts, and SCEs. These data will help characterize the degree to which drivers monitor the road and respond to alerts. The time taken to regain control will also be extracted.

Driver response to the sampled alerts will be assessed using the order of driving inputs performed (in a similar fashion to previous test track research by Blanco et al., [2015]), as shown in Figure 3 (e.g., eyes return to road, hands on steering wheel, brake pedal applied), how quickly each input was made, and how the recorded environmental variables might have affected driver response. Drivers' initial exposure to alerts will also be investigated.


***Figure 3. Sequence of Dependent Variables pertaining to driver behavior adapted from previous test track studies.***

The results will be compared to related test track research. For example, the research team will compare the observed transition times and sequences to the findings from the *Human Factors Evaluation of Level 2 and Level 3 Automated Driving Concepts* study that was performed for NHTSA (Blanco et al., 2015). Whether driver responses change over the course of their participation will also be assessed.

Vehicle variables—including speed and headway during the sampled MFA activations, alerts, and SCEs—are also being collected, allowing for an assessment of any issues in headway and automated lateral control during MFA activation. The maximum deceleration following an alert or SCE will be recorded. The environmental variables identified from the video will include an assessment of the roadway type, roadway markings, traffic density, relation to junction, weather conditions, and lighting conditions, as well as other variables that can define the driving context.

## PROJECT STATUS

Data collection for the project is currently underway, with 47 participants having completed the study. Nearly all participants have exceeded 1,200 miles of driving while in the study. Data reduction and analysis are also ongoing; however, no results are ready for presentation at this time. Data collection is scheduled to be completed in December 2017 with final analysis and reporting of the results due to NHTSA in April 2018.

## REFERENCES

Blanco, M., Atwood, J., Vasquez, H. M., Trimble, T. E., Fitchett, V. L., Radlbeck, J., … & Morgan, J. F. (2015, August). *Human factors evaluation of level 2 and level 3 automated driving concepts*. (Report No. DOT HS 812 182). Washington, DC: National Highway Traffic Safety Administration.

Dingus, T. A., Hankey, J. M., Antin, J. F., Lee, S. E., Eichelberger, L., Stulce, K., … & Stowe, L. (2015). *Naturalistic driving study: Technical coordination* *and quality control*. (SHRP 2 Report S2-S06-RW-1). Washington, DC: Transportation Research Board. Retrieved from http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-S06-RW-1.pdf

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., & Knipling, R. R. (2006). *The 100-car naturalistic driving study, phase II—Results of the 100-car field experiment.* (Report No. DOT HS 810 593). Washington, DC: National Highway Traffic Safety Administration.

FESTA Consortium (2014). FESTA Handbook Version 5 Deliverable T6.4 of the Field opErational teSt supporT Action (FESTA). Retrieved from: http://2doubmisw11am9rk1h2g49gq.wpengine.netdna-cdn.com/wp-content/uploads/sites/7/2014/06/FESTA_HBK_rev5_ref3-2.pdf

Grove, K., Atwood, J., Hill, P., Fitch, G., Blanco, M., Guo, F., & Richards, T. (2016*). Field study of heavy-vehicle crash avoidance systems: Final report (*Report No. DOT HS 812 280). Washington, DC: National Highway Traffic Safety Administration.

Grove, K., Atwood, J., Hill, P., Fitch, G., DiFonzo, A., Marchese, M., & Blanco, M. (2015, July 26-30). *Commercial motor vehicle driver performance with adaptive cruise control in adverse weather.* Paper presented at the 6th International Conference on Applied Human Factors and Ergonomics (AHFE), Las Vegas, NV.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., and Ramsey, D. J. (2006). The Impact on Driver Inattention on Near Crash/Crash Risk: An Analysis Using the 100 Car Naturalistic Driving Study Data (Report No. DOT HS 810 594*).* Washington, DC: National Highway Traffic Safety Administration.

Klauer, S. G., Guo, F., Sudweeks, J. D., & Dingus, T. A. (2010). An Analysis of Driver Inattention Using a Case-crossover Approach on 100-car Data. (Report No. DOT HS 811 334). Washington, DC: National Highway Traffic Safety Administration).

SAE International (2016). Surface Vehicle Recommended Practice J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

Wierwille, W. W., Bowman, D. S., Alden, A. A., Gibbons, R. B., Hanowski, R. J., Blanco, M., ... & Hickman, J. S. (2011). *Enhanced Camera/Video Imaging Systems (EC/VISs) for Heavy Vehicles*. (Report No. DOT HS 811 483). Washington, DC: National Highway Traffic Safety Administration.