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13. ABSTRACT (Maximum 200 words)

This report documents a multi-phased effort that oversaw the development and proof-of-concept validation of an integration architecture (IA) prototype designed to manage message presentation within a connected vehicle environment. A connected vehicle system (CVS) prototype was developed along the parameters defined during prior phases of research within the Human Factors for Connected Vehicles (HFCV) program. Following rounds of development and internal testing, participants were recruited to experience the CVS within a simulated connected vehicle environment. Thirty-two participants evaluated the system iteratively for two rounds, two groups per round, by driving the same pre-determined test route, designed to maximize exposure to various roadway environments. The first round relied on a think-aloud approach in an effort to capture as much subjective feedback as possible, with the intent to identify possible changes that should be made both based on observations made by researchers and preferences suggested by participants. Adjustments were made, creating a user-modified configuration that was then directly compared to the original configuration within a more normative driving environment in the second round. Objective and subjective measures were collected and analyzed in accordance with the targeted research questions. Ultimately, this effort demonstrates the need and resulting impact of a defined IA in managing message presentation in a CV environment.

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GLOSSARY OF TERMS AND ACRONYMS

CV	connected vehicle
CVS	connected vehicle system
DAS	data acquisition system
DGPS	differential global positioning system
DI	dynamic integrator
DVI	driver-vehicle interface
HFCV	Human Factors Connected Vehicle
IA	integration architecture
OEM	original equipment manufacturer
RSE	roadside equipment
USDOT	U.S. Department of Transportation
V2I	vehicle-to-infrastructure
V2V	vehicle-to-vehicle
VCC	Virginia Connected Corridor
VT NVC	Virginia Tech Northern Virginia Center
VTTI	Virginia Tech Transportation Institute

CHAPTER 1. INTRODUCTION

The U.S. Department of Transportation has initiated activities focused on advancing connectivity between vehicles and the roadway infrastructure. Connected vehicle technologies will enable the wireless exchange of data between vehicles (V2V) and between vehicles and infrastructure (V2I), significantly affecting both driving safety and convenience. Targeted applications will leverage these raw data exchanges to improve the safety, mobility, and sustainability of the transportation system, as well as enrich the driving experience through delivery of desired connected content to the vehicle occupants.

The Human Factors for Connected Vehicles research program seeks to understand how the raw data received from the network can be transformed into useful information, how to manage the information based on importance, and how to present this information to the driver in an appropriate manner. The management of information and presentation aspects associated with the driver-vehicle interface are key system components, and are therefore the focus of this research effort. While conducting Phases I and II of the HFCV program, the Virginia Tech Transportation Institute Team worked cooperatively with the USDOT to investigate the integration of connected vehicle systems into the vehicle, and to document design principles with the aim of assisting developers in the creation of safe and effective applications.

A key challenge for today's DVI designers is managing the dynamic flow of information (including new information not previously available to drivers) to ensure that the driver's perceptual and cognitive abilities are not exceeded or strained (Angell, 2012). Manufacturers have already started to develop vehicle-related technologies and applications that will use this information from the connected-vehicle roadway environment. One of the most important goals of CV technology is to inform drivers of safety and non-safety-related information in an effective manner. The concept of an integration architecture is one that is able to manage multiple technologies and applications operating independently of each other, yet co-existing within the same platform. With the potential for the number of available messages within a CV environment to be overwhelming, care must be taken when relaying information to the driver to ensure that unintended negative consequences do not diminish the anticipated safety benefits.

This document serves as the final report for a study conducted by VTTI where the IA, as currently envisioned (Doerzaph, Sullivan, Bowman, & Angell, 2013), was developed into a working prototype and evaluated within a representative CV environment. This on-road study used the discoveries and findings from past research conducted under the HFCV Program (Holmes, Klauer, Doerzaph, & Smith, in press; Klauer, Holmes, Harwood, & Doerzaph, in press; Krum, Holmes, Doerzaph, Bowman, & Smith , in press; Park; Allen, & Cook, in press; Ward, in press; Ward & Rahman, in press; Ward, Rahman, Mueller, & Velazquez, in press) as a platform for planning, designing, developing, testing, and executing the procedures outlined herein. This study built upon previous efforts to evolve the human factors knowledge base in preparation for the ongoing, and perhaps accelerating, deployment of connected vehicle systems. This project followed a proof-of-concept design approach, consisting of three defined phases.

1. The first phase oversaw the development of a working prototype representative of a CV DVI coupled with message management software as defined by the IA document.

2. The second phase (usability testing and evaluation) provided researchers and human factors experts the opportunity to experience the prototype interface on the Smart Road and Blacksburg-area roadways initially, and later in the Virginia Connected Corridor test bed environment in Fairfax County, Virginia. This phase allowed for further refinement and development of both the interface as well as the protocol employed as part of the controlled evaluation.

3. The third and final phase (controlled evaluation) consisted of recruiting members of the public from the Fairfax County region to participate in an on-road session where user preferences and system performance were iteratively examined. Participants were recruited to participate in a single condition, which targeted specific parameters and research interests. Instrumentation within the vehicle allowed for objective assessments to characterize feature-related impacts on driver safety within a real-world CV environment. Subjective feedback, primarily along the lines of user preferences, was also obtained.

All three identified phases contribute to the ongoing development and refinement of the Integration Architecture.

CHAPTER 2. METHOD

PHASE 1: WORKING PROTOTYPE DEVELOPMENT

The research team worked closely with the internal hardware and software developers to design and develop a working IA prototype. The development included designing the user interface, associated applications, and the dynamic integrator parameters (e.g., filtering, scheduling, prioritization, and presentation) based on guidelines provided within the Integration Architecture report developed as part of the preceding HFCV effort (Doerzaph, Sullivan, Bowman, & Angell, 2013). At a high level, the DI parameters work cooperatively to manage the anticipated density of messages that will likely exist within a CV environment. The DI, based on its defined parameters, should effectively determine what messages to present, the timing and order within which they are presented, and the method of presentation thereof. The priority matrix ensures that those messages deemed most relevant will always make it to the top of the order list, even trumping or interrupting lower-priority messages where applicable. Essentially, the DI's role is to ensure that messages that exist within a CV environment are presented in a methodical and efficient method, ensuring that the driver is appropriately informed without unnecessarily increasing workload within the driving environment.

At the heart of the Dynamic Integrator is the message management, where messages are arbitrated to determine which might be filtered (i.e., discarded), dynamically adjusted in relative priority, scheduled for presentation, and presented to the driver on the DVI (Doerzaph, Sullivan, Bowman, & Angell, 2013). Details of this process are as follows.

> **Filtering**: Messages that are not appropriate, given the current driving context, may be immediately blocked and not processed by the remaining integration stages. Filtering occurs based on user settings or when driving conditions indicate it is unsafe to provide a given message.
>
> **Prioritization**: When numerous applications are operating, multiple messages may be simultaneously submitted. When multiple messages are cleared by the filter, a prioritization process determines the relative importance of the messages and assigns presentation order accordingly.
>
> **Scheduling**: Timing is the function of the scheduling process, which assesses the metadata and context information to determine when each message should be presented. This process controls message cadence and ensures that drivers maintain the capacity to receive information while focusing on the primary task of driving. In some cases, the scheduling process may allow certain high-priority messages to interrupt lower priority messages.
>
> **Presentation**: In this process, messages that have been cleared for delivery are analyzed and distributed to the DVI for information rendering. The presentation process tracks the use of the DVI and publishes the information for the applications to use.

The platform implemented for testing as part of this effort was designed with flexibility in mind to the greatest extent possible, allowing for customization via the addition of new applications, adjustment of algorithm parameters, ability to turn algorithm parameters on or off, etc. The suite of applications developed during previous HFCV efforts was expanded to include a larger variety of applications and application sub-categories. Table 1 includes a list of applications that were developed and included in this study.

Table 1. Applications

Application Category	Application Sub-category	Description
Mobility/Reroute	Navigation	Mobility applications (primarily dynamic traffic rerouting information) Moving maps
In-Vehicle Signage	Speed Limit School Zone Road Sign Pedestrian Crossings	Non-imminent safety warnings providing information on important and safety-relevant changes in the roadway ahead
Advertising	Automotive Banking Food/Beverage Gas Promotions Retail	Advertisements and information regarding the presence of convenience-based businesses
Vehicle Information	Maintenance	Information regarding the mechanical and service state of the vehicle such as tire pressure and required maintenance
Internet/Social Network	Calendar E-mail News Social Media Text Messages	Facebook updates such as new posts from friends or news feeds Local and national headlines Meeting/appointment notices E-mails from work or personal e-mails
Public Transit	Metro	Public transit options that are located within the vicinity of the vehicle
Public Safety	Medical Care	Information provided to drivers regarding public safety notifications

As illustrated, the interface incorporated a range of message types and content, from common driving-related information to marketing and advertising applications of interest. In total, six primary categories (including 18 sub-categories) of prioritized application messages were developed and included within the prototype device. Messages were presented to the driver on a DVI positioned within the center-stack area. It's important to recognize that NHTSA's visual-manual driver distraction guidelines recommend against, among other activities, providing the driver with messages displaying text under the context of "social media content, text-based advertising and marketing, or text-based messages" during the act of driving (NHTSA, 2013). This notably affects two of the application categories, and numerous subcategories.

Message filtering, prioritization, scheduling, and presentation were accomplished by using the message metadata (POI, application category, etc.). Messages and associated metadata used in the study are presented in Appendix H.

The applications operated simultaneously and issued messages according to defined algorithms, simulating information that would be received from the vehicle or through CV communications. These messages were arbitrated according to the DI as outlined in the HFCV Phase II Integration Architecture report (Doerzaph, Sullivan, Bowman, &Angell, 2013). Testing of imminent safety messages was not included as they are the subject of other previous and ongoing research programs, such as the Safety Pilot Model Deployment efforts. Furthermore, in all cases, a safety-relevant message would have the highest importance, so priority evaluations associated with these message types were unnecessary.

In-Vehicle DVI

The research vehicle was equipped with a display that served as the in-vehicle DVI (Figure 1). The display, a Samsung Galaxy tablet with an 8.4” screen, was mounted in landscape view over the experimental vehicle’s center stack. The DVI operated on an Android platform and ran a VTTI-developed software program designed to simulate a CV and connected infrastructure environment, based on the IA as outlined in previous HFCV work. The software allowed for manipulation of the architecture through application filters based on the driving context, user preference, etc. Sygic was used to provide the turn-by-turn route guidance application.

Figure 1. In-vehicle DVI

Presentation Modality

Messages were presented to drivers on the Connected Vehicle System (CVS) display using a combination of presentation methods. Higher priority messages such as in-vehicle signage were presented to the driver using a visual icon displayed in the center of the screen (Figure 2), accompanied by speech. Lower priority messages were presented using bottom line text (Figure 3) accompanied by an auditory tone. In many cases, the user could request more detail if an issued message was of interest and they wanted to receive more information. For these message types, users could press anywhere on the initial message to request the additional details, which were then presented in the center of the screen using written text and speech (Figure 4). The initial placement and presentation modality of information on the DVI was largely based on the methods used and findings from a previous effort (Holmes et al., in press), supplemented by internal usability evaluations and feedback from Human Factors experts as part of phase 2.

Figure 2. Centered high-priority message

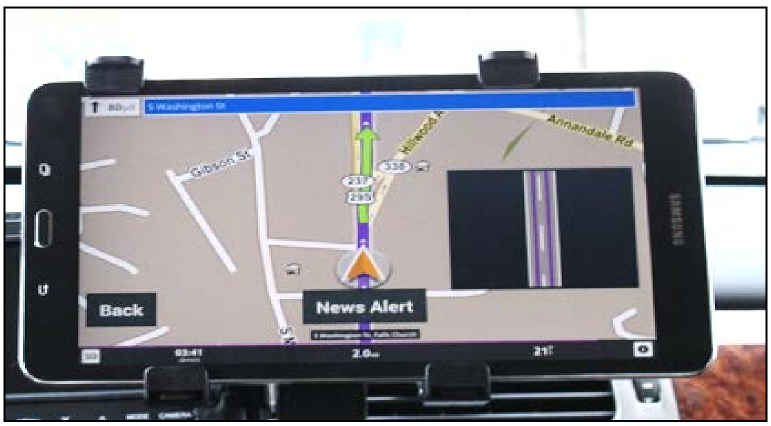

Figure 3. Bottom-line text for lower priority message

Figure 4. Additional Detail Message

PHASE 2: USABILITY TESTING AND EXPERT FEEDBACK

In-vehicle usability testing was performed to ensure that the DI behaved as expected. Researchers directly involved with this effort evaluated the performance of the architecture on the Virginia Smart Road and surrounding roadways within the New River Valley, making quick revisions and implementing changes to the algorithm based on testing observations. The test route (of 13.3 miles) used around the New River Valley (38 messages, 8 categories) provided a glimpse of what might be expected during testing, including challenges and limitations of the system.

Testing within these environments while the prototype was under development provided opportunities to evaluate parameter performance, evaluate and adjust parameter settings, and directly observe to what extent the DI managed conflicts appropriately. As this testing methodology was employed in parallel with development of the prototype, observations through routine testing were discussed with the developers where needed in an effort to continually refine. The overall intent was to ensure that the DI, as developed, was robust enough to support the phase 3 evaluations.

System capacity and driver performance variables as recorded were also validated in preparation for formal data collection. Through these efforts, message presentation channels, along with ways to interact with the messages, were adjusted as needed. Once comfortable with the architecture, researchers took the opportunity to expose human factors experts internal to VTTI to the configured route and test methodology in the Virginia Connected Corridor (VCC) test bed environment. Their input contributed to the final study protocol and design.

PHASE 3: CONTROLLED EVALUATION

A total of 32 participants were recruited to drive a predetermined route within the VCC test bed while interacting with the developed interface as part of the targeted user evaluations. During their drive, participants experienced in-vehicle messages in a manner that simulated an envisioned CV environment. Behavioral observations and feedback captured through a variety of methods allowed for evaluations of system performance and user perceptions.

Eligible individuals were recruited to participate in a single session as part of a two-round iterative evaluation, divided into four groups as illustrated below (see Table 2). As a proof of concept approach, the overall intention of these targeted groupings was to capture as much feedback as possible through direct interaction with the prototype interface, allowing for modifications that, once applied, would theoretically improve the user experience. Across each of the four groups, participants drove the same pre-determined test route comprised of portions of interstate and urban roadways. Only the configuration experienced and/or the protocol employed were altered between groups.

Table 2. Testing Configuration and Method per Group

Round	Group	Configuration	Method
Round1 (Initial Evaluation)	Group 1	Initial Configuration	Think-aloud approach used to capture participant feedback on system performance. Free interaction while driving.
	Group 2	Initial Configuration	Same approach as Group 1. Filters applied in real-time based on participant feedback.
Round 2 (Post-Modification Evaluation)	Group 3	Initial Configuration	Captured normative driving while interacting freely with feature. Think-aloud approach was not included so as not to interfere with interactions. This configuration was treated as baseline.
	Group 4	User Modified Configuration (Changes discussed in results section)	Same approach as Group 3, but with changes made to the interface targeting improved system performance based on feedback and observations from round 1. This allowed for direct comparison between configurations (vs. Group 3) across measures of interest.

The primary intent for the initial evaluation (Round 1) was to capture overall feedback and preferences related to system performance, identifying areas of improvement that could be addressed prior to subsequent testing. All participants within this round experienced messages within the initial system configuration. This configuration was considered representative of a fully operational IA based on the pre-existing template, and following internal development and evaluations. Following completion of study-related paperwork, vision tests, and a pre-drive questionnaire, participants were introduced to the CVS and the general concept of connected vehicle technology. They were asked to follow the instructions provided by the route guidance application for required directions to keep them on the intended route, throughout which messages would be issued at targeted points.

In the first evaluation group (Group 1), participants were asked to interact with the interface as they would were it a feature available in their own vehicle. In other words, participants were directed to envision that the messages received were real, and asked to interact or respond accordingly. Furthermore, participants were asked to provide feedback using a think-aloud approach, in a continual manner. This allowed for an on-going dialogue between the participant and the in-vehicle experimenter regarding the performance of the CVS, providing subjective feedback on message presentation, timing, context, frequency, likes/dislikes, etc.

In addition to the protocol outlined above, the second group of participants (Group 2) was instructed to notify the experimenter when they received a message type that they would prefer not to receive again during the remainder of the drive. Upon receiving this feedback, the second in-vehicle experimenter applied the associated filter in real-time to block messages from that particular category from subsequent display. This approach allowed for customization of the configuration based on the drivers' preferences and, by the end of the drive, revealed a snapshot of what a particular driver's user preferences might be.

The primary intent of the post-modification evaluation (Round 2) was to assess objective judgments and subjective feedback with a configuration modified to address shortcomings or areas for improvement identified during Round 1. This configuration will be hereafter referred to as the 'user modified' configuration. The changes made to the system were based on user feedback, performance, and the first two groups' interaction with the system. Specific changes made to the interface are discussed within the results section. Participants in this round experienced either the user-modified configuration (Group 4) or the original configuration from Round 1 (Group 3), serving as a baseline for comparison. As before, participants within both groups were instructed to interact with the interface as they would were it a feature available in their personal vehicles. The primary difference here was that the think-aloud approach was no longer included, so as to naturally observe interactions without introducing distraction as part of continuous dialogue.

The decision was made, collectively, to use the original configuration as the baseline comparison. Simply disabling the DI entirely, allowing for presentation of all messages without any of the implemented logic to control message flow, was considered an unfair comparison, albeit one that would almost certainly demonstrate the objective and subjective benefits of implementing an IA.

Equipment

Testing Facility

Data collection was conducted on the Virginia Connected Corridor test bed, located in Fairfax County in Northern Virginia along I-66 and on the parallel Routes 29 and 50. The VCC test bed covers a mixed driving environment of interstate highway, urban, and commercial areas (see Figure 5). The red dots illustrate locations of Roadside Equipment (RSE) installed within the test bed, although the overall number is currently expanding. The VCC is being developed as a connected vehicle test bed, and was available to support the testing needs of this effort. The final route chosen featured a 23.1-mile route (see Figure 6), specifically designed to maximize exposure to various roadways and driving environments.

Each participant drove the same pre-determined route a single time. The route was a mixture of interstate and urban/commercial roadways taking the participant on VA-7, US-50, I-495, VA-123, and US-29 (see Appendix F for study route). On average, it took participants 45 minutes (with a standard deviation of 6.3 minutes, ranging from 35.7-62.6 minutes) to complete the route.

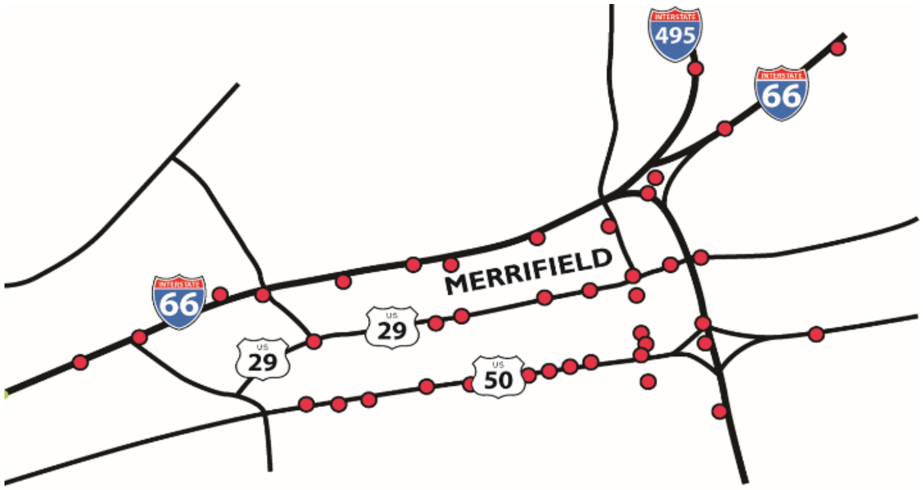

Figure 5. VCC test bed and RSEs locations

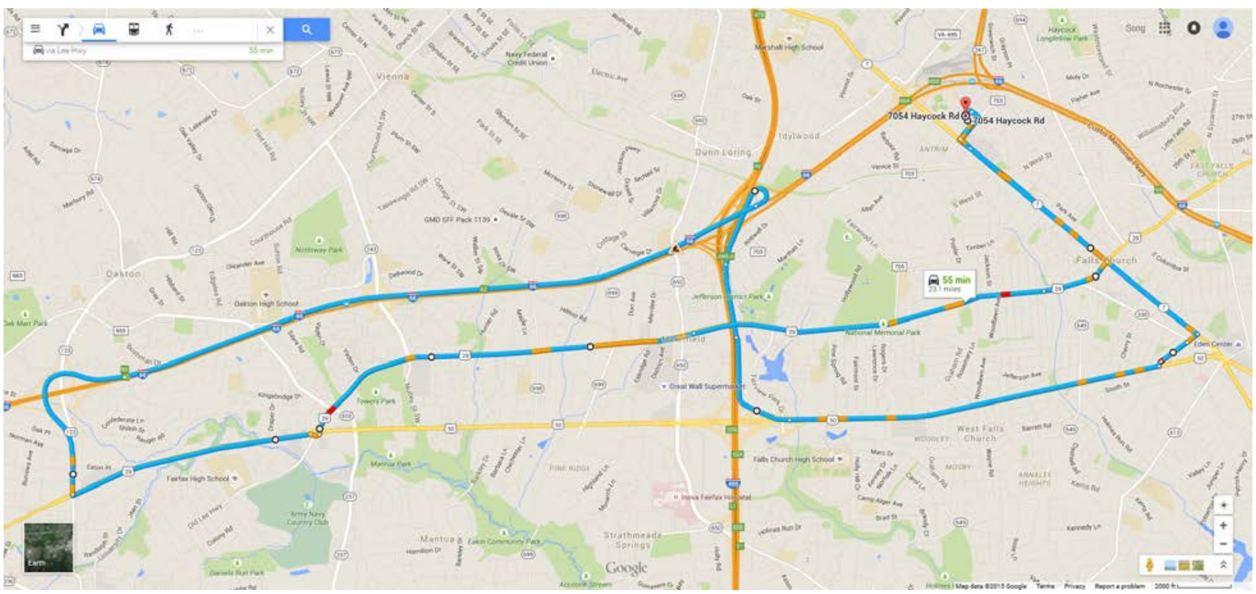

Figure 6. Study Route

A total of 71 messages were queued up for presentation during the route, distributed across the primary categories as illustrated in Figure 7. Since testing was conducted within a dense urban environment, the number of messages could have arguably been higher, as envisioned within a CV environment. Furthermore, as this was an evaluation of the DI, it was important to include a message queue that would challenge the interface, in particular creating opportunities for message conflict. Ultimately, participants were also experiencing this configuration out of the box, in a sense, with no preferential filters applied. Evaluations by human factors experts, along with sponsor representatives, suggested that the rate of message presentation was appropriate within the test environment.

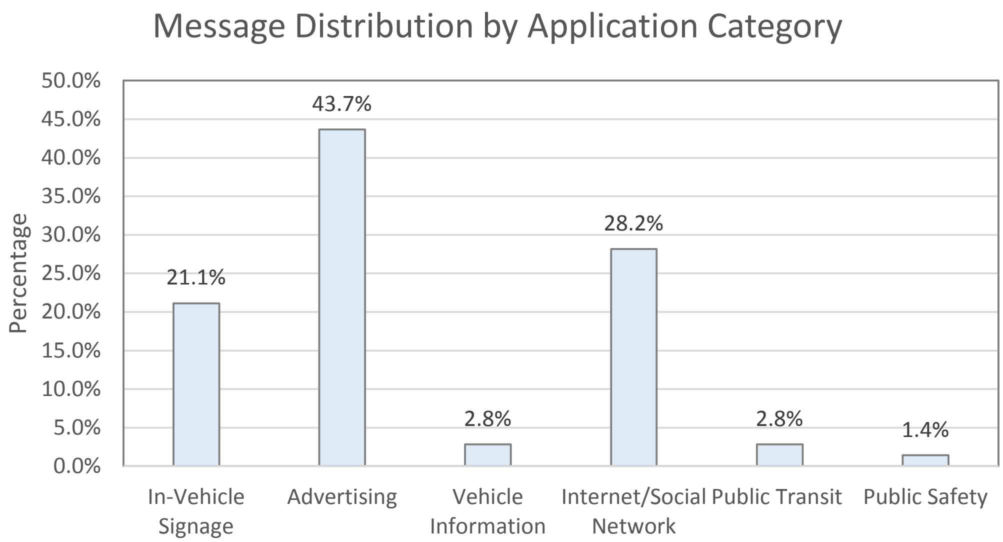

Figure 7. Distribution of messages among application categories

In an effort to control for repeatability of the driving environment experienced across participants, it was decided that message presentation would rely on geo-fencing as opposed to direct communication with the available RSEs. However, as the interface was fully functional across the defined parameters, the actual number of messages presented did vary from driver to driver based on individual interaction with the system and message management of the DI. A complete list of the actual messages presented to each participant is included in Appendix L (see Appendix I for the intended distribution of messages along the route).

Instrumentation

Although another vehicle was used for evaluating the IA prototype during the prototype development and internal evaluations, instrumentation and formal integration took place prior to Phase 3 on a 2008 Chevrolet Tahoe (Figure 8). This vehicle was equipped with a suite of instrumentation that allowed for both the operability of the prototype interface as well as the equipment needed to support reduction and analysis activities.

Figure 8. Experimental vehicle, 2008 Chevrolet Tahoe

The test vehicle was instrumented with VTTI's NextGen data acquisition system (DAS) (Figure 9), allowing for full-time capture of video, audio, and driving and interface-related parameters, including relevant information from the DVI (message presentation, interaction by the participant, etc.). A Verizon 4G personal Wi-Fi was leveraged to allow for wireless communication between the tablet and DAS. As referenced earlier, message presentation was tied to specific locations along the route using a Differential Global Positioning System (DGPS).

Figure 9. NextGen DAS main unit and in-vehicle setup

The DAS instrumentation package included five cameras capturing the following views in and around the host vehicle (Figure 10), clockwise starting in the upper left quadrant:

- participant's upper body/face,
- rear roadway (split-horizontal),
- forward roadway (split-horizontal),
- over-the-shoulder,
- close-up view of the tablet.

Figure 10. Camera views

Participants and Recruitment

Flyers (Appendix A) and Craigslist advertisements were the primary approaches used for participant recruitment. Individuals who responded to the ads were contacted by phone to gauge interest and to screen for eligibility. The telephone screening script and complete list of eligibility requirements are listed in Appendix B. Those who met the eligibility criteria for the study were scheduled to participate in a single session. A confirmation e-mail including appointment time, directions to the location, and a copy of the study's informed consent depending on the group they were recruited to participate in, was sent to each participant once scheduled. (Appendix C for think-aloud protocol, Appendix D for the normative driving protocols.)

Thirty-two people, all between the ages of 25 and 50, participated in this effort. Participant information is provided below in Table 3. The age distribution was consistent with past HFCV research (Holmes, Klauer, Doerzaph, & Smith, in press). All groups were balanced by gender to the extent possible. Although recruitment targeted an appropriate distribution of ages within the allotted age range, age was not a factor and therefore not included as part of the analysis.

Table 3. Participant Information

		Participant Age			
Group 1	*N*	*Average*	*Std Dev*	*Min*	*Max*
Female	3	37	10.69268	30	49
Male	5	32	3.605551	28	37
Overall	8	34	6.777062		
Group 2	*N*	*Average*	*Std Dev*	*Min*	*Max*
Female	4	39	9.5	28	49
Male	4	39	8.616844	30	48
Overall	8	39	8.396428	28	49
Group 3	*N*	*Average*	*Std Dev*	*Min*	*Max*
Female	4	37	5.715476	31	44
Male	4	36	8.266398	27	44
Overall	8	36	6.627863	27	44
Group 4	*N*	*Average*	*Std Dev*	*Min*	*Max*
Female	4	38	8.812869	27	47
Male	4	32	7.348469	26	42
Overall	8	35	8.066686	26	47

Protocol and Procedure

Upon arriving at the Virginia Tech Northern Virginia Center (VT NVC) participants were first required to provide proof of licensure to drive. The experimenter then reviewed the informed consent form with them before asking them to sign. This was followed by completion of a pre-drive questionnaire (Appendix E) designed to capture initial perceptions and preferences related to the concept of a connected vehicle interface. Finally, brief hearing and vision tests were conducted to confirm that participants met acceptable levels before heading out to the research vehicle.

Each participant was taken to the research vehicle by one of the in-vehicle experimenters and asked to sit in the driver’s seat. The front-seat experimenter sat in the front passenger’s seat while a second experimenter sat in the back seat behind the driver. The front-seat experimenter provided a brief overview of the study and procedures before introducing participants to the CVS. The participant received training on how to interact with the device (e.g., select more information, dismiss messages) as well as an overview of the range of message types to expect. Before leaving the parking lot, participants were informed of the driving route and their roles and expectations as participants. Specifically, participants were reminded to follow all traffic laws and regulations throughout the route and to maintain safe operation of the vehicle at all times. Questions were encouraged and addressed as appropriate.

The role of the front-seat experimenter was primarily to monitor the participant’s interaction with the display device, to provide route guidance as needed, and to monitor the environment for potential hazardous situations. The primary role of the back-seat experimenter was to monitor communication between the DAS and the display device, to take notes, and to cross check the participant's interaction with the display.

In all cases, participants were instructed to interact with the system as if it were in their own personal vehicle. As a reminder, participants in the initial evaluation round (Groups 1 and 2) were asked to provide feedback on the system's performance using a think-aloud approach. The think-aloud approach encouraged participants to provide unprompted feedback by vocalizing their thoughts on system performance in real time. Although instructed that all feedback was welcomed, researchers asked participants to consider the following points of emphasis: likes/dislikes about message presentation (modality, length of message display time, etc.), frequency, context, timing, usefulness, appropriateness of messages, etc. Participants in Group 2 were also asked to indicate when there was a message type that they would like to have filtered out for the remainder of the route. Filters were applied in real time based on this feedback, ultimately creating a snapshot of what a personalized system might look like for that driver.

The think-aloud approach was not employed in the second round where the user-modified configuration (Group 4) was evaluated and compared directly with the initial configuration (Group 3). The exclusion of the think-aloud feedback was intended to allow drivers to focus solely on driving and interacting with the system, capturing a more representative level of interaction.

In all groups, participants were asked to rate their level of agreement across three statements at two specified locations along the route to further assess the system's effectiveness (Appendix J). Once participants completed the driving route, they returned to the VT NVC where they completed a post-drive questionnaire (Appendix K), were paid for participation, and thanked for participating in the study. The post-drive questionnaire was designed to capture general thoughts about the system, including information such as likes/dislikes, usefulness, recall, etc., using a series of Likert-scale, open-ended, and preference questions.

Experimental Design

This was a between-subjects experimental design in which participants experienced a single DI system configuration. Data was collected from four groups as discussed earlier. Groups 1 and 2 provided valuable real-time feedback that was used to assess overall perceptions, filters likely to be applied, and opportunities to improve on the initial approach. Based on those observations, primary comparisons were made between participants who experienced the baseline, the initial DI configuration (Group 3), and the user modified DI (Group 4).

Research Questions

The following research questions drove the methodology of research efforts within this task.

1. How feasible is it to implement the Integration Architecture into a connected vehicle system environment? Simply put, how does the Integration Architecture handle a simulated CV environment, and what can we learn from hands-on observations?
2. What user preference adjustments to the architecture do drivers make or desire?

3. What is an appropriate determination of workload, based on a combination of internal and external demands? Furthermore, how should the architecture process and use this information?
4. Continue investigating appropriate driver-vehicle interface (DVI) characteristics to ensure message presentation is appropriate to the environment, while continuing to provide input into the DVI Design Assistance document
5. To what extent does the Integration Architecture increase driver safety in a CV environment?

Independent Variables

This study iteratively evaluated, and ultimately refined, where able, parameters within the Dynamic Integrator (i.e., filtering, prioritizing, scheduling, and presentation). The primary focus of this effort was to capture naturalistic exposure to the IA within a connected vehicle environment. Resultant observations allowed for further progress in defined parameters and aspects to be considered during future development of this type of interface. As such, this was a proof-of-concept effort by nature, although direct comparisons were allowable between the initial configuration (Group 3) and the user-modified configuration (Group 4, the latter incorporating modifications to the DI based on observations from Groups 1 and 2). These modifications are discussed in detail within the results section.

Dependent Variables

Although, in general, the focus of this effort was to iteratively evaluate and refine the IA as currently envisioned, this study measured the following variables where opportunities for comparison presented themselves:

- **Subjective measures –** collected through surveys and open dialogue between the participant and in-vehicle experimenters. Pre-study, in-vehicle, and post-study surveys captured general feedback about the CVS using various measures such as user preference, usefulness, appropriateness, etc., using a Likert type scale, open-ended, and ranking questions.

- **Eye-glance behavior –** observed on a predetermined segment of roadway for direct comparison across configurations of interest (Groups 3 and 4). Analysis of eye-glance behavior examined the propensity for glances with longer durations (e.g., greater than or equal to two seconds), total eyes-off-road time, etc.

- **Message acknowledgement –** proportion of messages acknowledged through compliance for applications suggesting modification to driving environment. This was measured by observing participant response following message presentation, primarily restricted to speed limit information and its impact, if any, on travel speed.

- **Message recall –** measured subjectively via a post-drive questionnaire.

- **Message interaction –** characterizing each participant's direct interactions, including completely ignoring, glancing at, touching to dismiss, touching for more details, etc., following each message presentation, as collected through recorded data and video reduction. Observations related to message interaction, especially when requesting additional detail, were used as indicators of participant interest in that message.

- **Vehicular control** - examined during specific segments within the test route, focusing on comparison of vehicular control prior to and during message presentation, in terms of:

  - **Lane maintenance –** the ability to maintain lane position and control of the vehicle while driving.

  - **Speed maintenance –** measures of vehicle speed, including mean speed and speed variance as related to speed limit.

Data Verification, Reduction, and Analysis

Data Verification

The collected data was loaded into a secure database at VTTI and first verified using an internally-developed tool called Hawkeye that allows for simultaneous review of parametric data and video (Figure 11). Video, audio, and variables of interests were cross-checked to ensure that they were valid and complete.

Figure 11. Review of data through Hawkeye

Data Reduction

Immediate research tasks following data collection included characterizing participant responses associated with each message presented. By reviewing collected video data, participants' reactions to each message presented were reduced across defined categories, including ignore, glance, and contact (direct interaction). The corresponding traffic condition as well as a brief description of each participant's behavior during the duration of each presented message was also examined. With this data, observed response rates assisted in guiding the proposed changes that resulted in the user-modified configuration, as well as comparisons between that configuration and the baseline condition.

Frame-by-frame eye-glance reduction was managed by VTTI's data reduction lab, focusing on defined segments of the driving route (interstate highway I-66, and an urban commercial area along US-29) for direct comparison between Groups 3 and 4. Analysis of eye-glance behavior allowed for assessing the propensity for glances with longer durations (e.g., greater than or equal to two seconds), total eyes-off-road time, etc., prior to, during, and following the message presentation. The list of definitions and codes of eye-glance locations inside and outside of the vehicle is included in Appendix M.

CHAPTER 3. RESULTS

SUMMARY OF RESULTS FOR INITIAL EVALUATION

As a reminder, observations and feedback captured during round one were used to expand on the research team's general understanding of user preferences, as well as to identify possible areas of improvement within the initial DI system configuration. A summary of the results and recommended system changes are presented below.

Objective Measures

The think-aloud approach applied in Groups 1 and 2, encouraged participants to freely make comments along the route in accordance with their perceptions across general system performance, message content, message presentation, etc. As this dialogue between the participant and in-vehicle experimenter likely impacted normal driving behavior, vehicular control data was not examined. Objective data analysis for Groups 1 and 2 is therefore focused simply on observed responses to issued messages.

Table 4 provides a high-level overview of the number of messages presented for each of the Group 1 participants. As a reminder, 71 messages were queued, but the actual number of presentations was dependent on the number and types of responses made by each participant. Notably, Group 2 participants are not included in these initial tables as their message counts were directly impacted by their requests to subdue message subcategories along the route. Table 4 also illustrates the number of messages where responses were observed, accounting for any observed response by the participant following message presentation. These responses include glances to the DVI and direct interaction with the screen (touch), which is also illustrated separately. On average, participants were observed glancing at and/or interacting with the screen following 82.1% of all messages presented (range of 60.5% to 92.9%). Interacting with the device, to request additional detail and/or to dismiss a message, for example, was observed following 26.0% of all messages presented (range of 3.9% to 63.0%).

Table 4. Observed Message Responses in Group 1

Group 1		Participant								Overall			
		300	301	302	303	304	305	306	307	Average	% of Presented*		
Messages Presented		76	71	71	72	70	71	73	71	71.9	Average	Min	Max
Response Observed	Any	46	57	66	60	62	63	53	64	58.9	82.1%	61%	93%
	Touch	3	16	15	8	14	21	46	26	18.6	26.0%	4%	63%

**across participants*

Among the 71 queued messages, 17 were presented in the center of the DVI screen (In-Vehicle Signage and Vehicle categories), and 54 were presented on the lower part of the screen (lower priority application categories). Due to the number/types of responses made by the participant, in Group 1, the average numbers of messages presented were 17 (center) vs. 55 (lower). The increase in the number of lower-screen messages is indicative of conflict cases, where a lower-priority message is trumped, but then re-issued once the high-priority message disappears. A breakdown of observed message responses by presentation locations is shown in Table 5.

Table 5. Observed Message Responses in Group 1 by Message Location

Group 1			Participant								Overall			
			300	301	302	303	304	305	306	307	Average	% of Presented*		
High Priority	Messages Presented		17	17	17	17	17	17	17	17	17.0	Average	Min	Max
	Response Observed	Any	11	15	16	12	12	14	11	16	13.4	78.7%	65%	94%
		Touch	3	9	7	3	3	10	10	10	6.9	40.4%	18%	59%
Low Priority	Messages Presented		59	54	54	55	53	54	56	54	54.9	Average	Min	Max
	Response Observed	Any	35	42	50	48	50	49	42	48	45.5	83.2%	59%	94%
		Touch	0	7	8	5	11	11	36	16	11.8	21.5%	0%	64%

**across participants*

The observed response rates were comparable between higher-priority messages presented in the center (78.7%), and lower-priority messages presented on the lower part of the screen (83.2%). Differences between these levels of message priorities are revealed once observations are broken down by response type. On average, participants interacted with 40.4% of center messages, compared to only 21.5% of lower-priority messages. These numbers should be interpreted carefully, however. Considering messages presented in the center were presented with speech and can, for all but two messages (Vehicle category), only be dismissed, the fact that more than one third of them were dismissed would suggest that in a fair number of cases, participants either found them of little use or possibly presented for too long. On the other hand, the only reason to interact with messages presented on the bottom of the screen was to request additional detail. As a group, participants found these messages worthy of additional detail in only 22% of the recorded cases.

When detailed information was requested across any message type, the resulting pop-up message was presented in the center of the screen accompanied by speech. Table 6 illustrates how participants responded.

Table 6. Additional Detail Message Interaction in Group 1

Group 1		Participant								Overall			
		300	301	302	303	304	305	306	307	Average	% of Requested*		
Additional Detail	Requested	0	9	9	7	11	12	38	17	12.9	Average	Min	Max
	Dismissed	0	9	9	5	6	9	38	17	11.6	85.9%	0%	100%

**across participants*

Compared to 40% for center messages, the dismiss rate reached a group average of 85.9% for messages with additional detail. A likely reason is that detail messages were presented for much longer than the higher-priority center messages (30 seconds vs. 10 seconds). Most participants, although they actively accessed the detailed information, may have found that the messages were presented for too long (i.e., participant processed messages in less than 30 seconds). If that is the case, by reducing the length of the detail message it is expected that distraction associated with the desire to dismiss these messages could be dramatically reduced.

To examine this potential issue further, all cases where detail information was requested were investigated for Groups 1 and 2. Combining the first two groups, there were 192 cases where participants requested additional detail. In 166 out of these 192 cases, detail information was dismissed, encompassing 51 out of the 56 included messages where detail information was available.

Figure 12 plots the dismiss rate against the duration of message presentation. Over all 166 cases, 69.3% were dismissed within 8 seconds, 77.7% were dismissed within 9 seconds and 81.3% within 10 seconds. It became quickly apparent during data collection involving Groups 1 and 2 that this was a targeted improvement that should be made. This finding is discussed further in the presentation of results involving Groups 3 and 4.

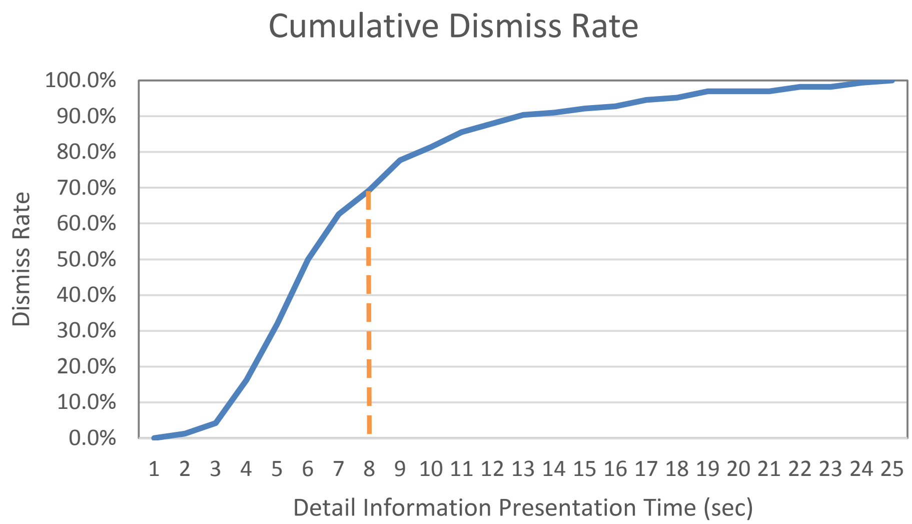

Figure 12. Cumulative dismiss rate of detail messages (individual cases)

The average length of the audio message associated with the additional detail information was 3.6 seconds (range of 2 seconds to 7 seconds), and, on average, participants waited 7.4 seconds from the beginning of detail messages (when audio started) before dismissing messages. This finding demonstrates that the majority of participants tended to dismiss detail messages after associated audio files finished playing (Figure 13). The only exception is the seven-second long audio file, because the only message (out of all 71) with a seven-second audio file was accessed only once within the first two groups.

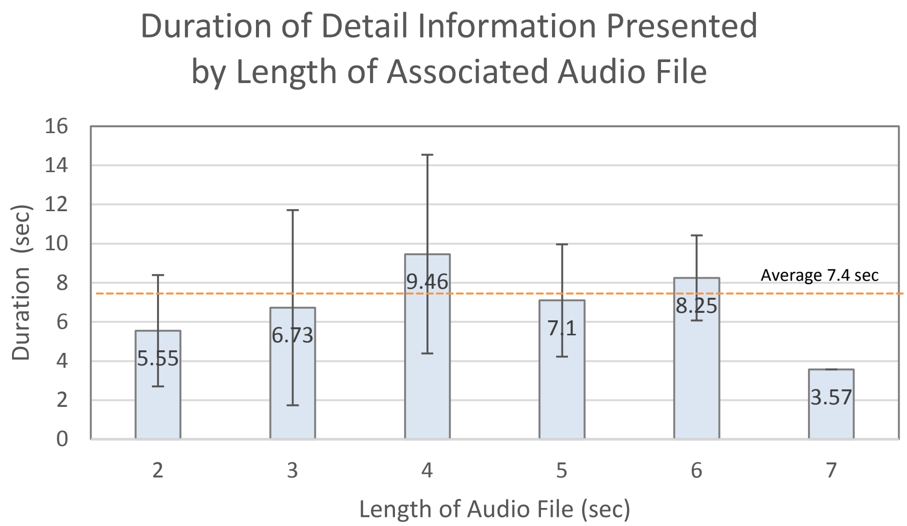

Figure 13. Duration of detail messages presented with their corresponding audio lengths

These results confirm that once participants select the additional detail information, they are ready to review the message; hence, the propensity to dismiss the message within a short timeframe. Based on these dismiss rates, it was determined that the detail window could be dramatically reduced downward from 30 seconds to 8 seconds and still be sufficient in length (at which point all audio files would be finished and approximately 70% of cases were dismissed, as shown in Figure 12) while potentially reducing unnecessary interactions with the DVI. This observation was a primary modification made prior to conducting evaluations for Group 4.

There is no doubt that participants' interest in responding to messages varied among different application categories. To determine this, observed message responses were broken down by application category (Figure 14). Note that the response included here is limited to direct interaction with the DVI, as this indicated whether a participant found the message useful or not. It is also important to clarify once again that the lower-priority messages presented on the bottom of the screen were limited in terms of information provided, so requesting additional detail was typically viewed as a sign that the message content was of interest to the user at that point in time.

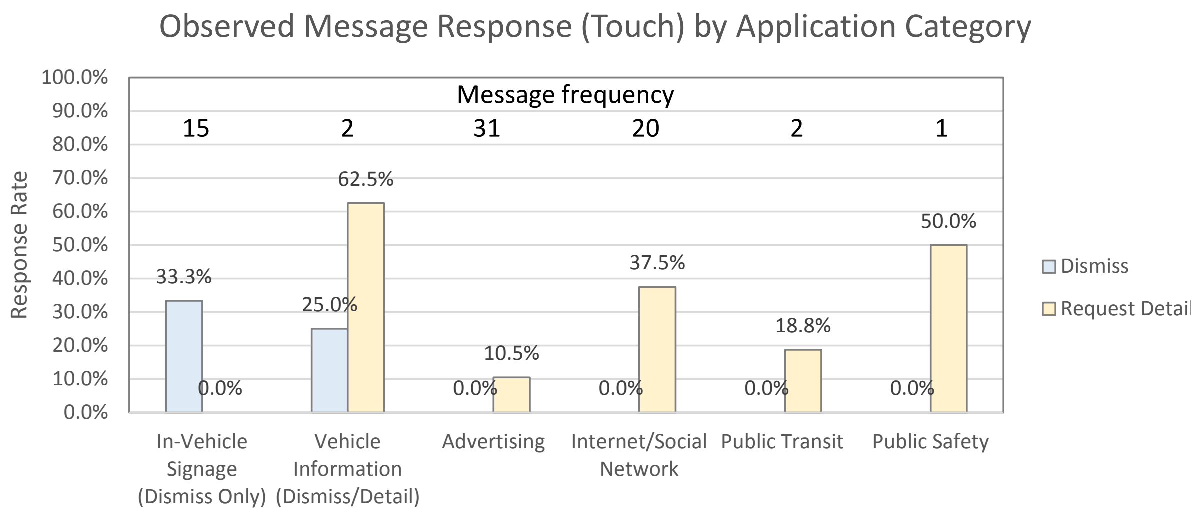

Figure 14. Observed message response (touch) by application category

These results indicate that of all bottom line messages, participants found Advertising and Public Transit less interesting, possibly due to the fact that they are less relevant to driving and do not contain a social component. On the other hand, being potentially relevant to driving, at least half of Vehicle Information and Public Safety messages were accessed for detailed information.

Vehicle Information and In-Vehicle Signage were the only two categories that could be dismissed upon presentation. Despite the high rate of additional detail requests, one fourth of Vehicle Information messages were dismissed directly. There is no detailed information associated with In-Vehicle Signage messages (speed limit and pedestrian crossing) and as they were presented with speech, it is hard to draw any conclusions about whether participants found them useful or not based on direct observations. The fact that one third of In-Vehicle Signage messages were dismissed is worth further investigation through subjective measures.

Participants accessed almost 40% of Internet/Social Network messages, and variance was observed among its subcategories (Figure 15). Participants found Calendar information useful (56.3% detail requested) as they were likely envisioning that they were on their daily commute to work and many of the calendar items were work related. Surprisingly, Text Messages followed with 45.0% detail requested, on average. When we examine text message interaction by source, it was not surprising to find that participants checked 62.5% of text messages from their immediate family members (dad and mom), 43.8% for messages from other relatives (uncle and grandpa), and 12.5% from friends. It should be noted that although participants were asked to treat these text messages as if real people sent them, the results might not be consistent if participants were using their own phones. Comparatively, E-mail, News, and Social Media interaction were less favored.

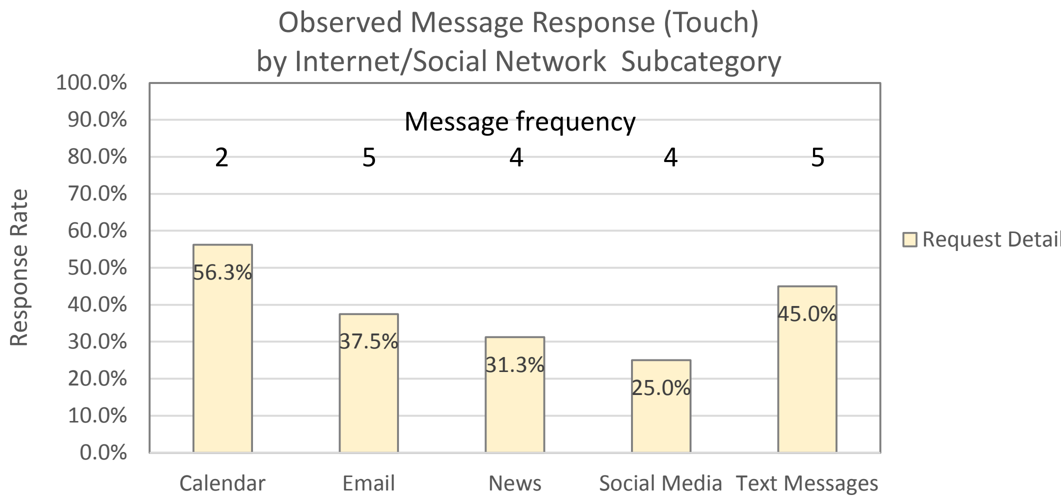

Figure 15. Observed message response (touch) by Internet/social network subcategory

As shown in an earlier table (Table 4), participants showed no coded response (eye-glance or directly interacting with the DVI) to 18.3% of messages presented (106 cases). Reasons for 'no response' were categorized for several reasons, as illustrated below (Figure 16).

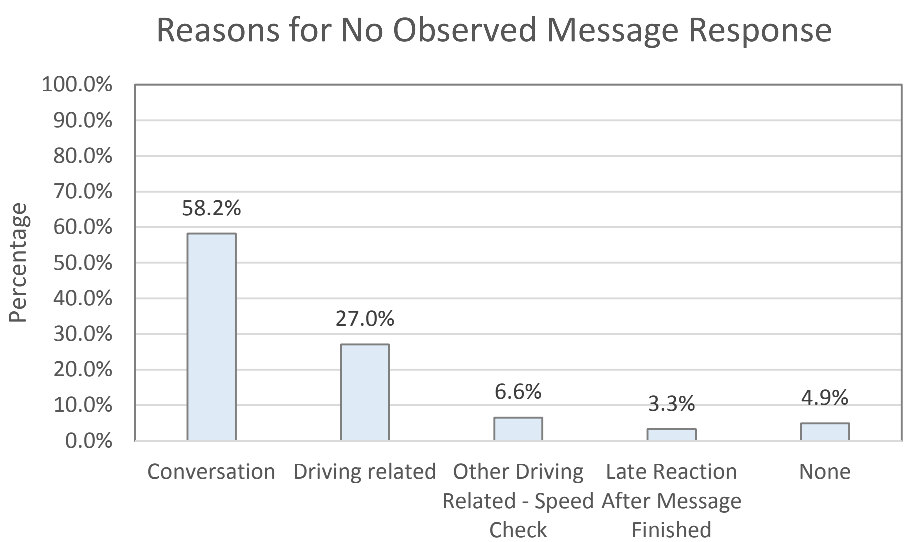

Figure 16. Reasons for no observed message response

Expectedly, conversation between the participant and the in-vehicle experimenter (think-aloud approach) was found to be the leading cause of participants not responding to messages. Among 106 cases where participants ignored messages and did not have any response to the DVI in Group 1, 58% (61 cases) of non-responses appeared to be due to conversation. As participants were asked to consider driving safety as their top priority, driving related tasks such as mirror checks and lane changes were the second leading reason why participants did not respond to messages. Speedometer checks are separated from other driving related tasks because this could be considered one of the un-coded responses to In-Vehicle Signage messages such as speed limits or school zones. Participants glancing at the speedometer immediately following an In-Vehicle Signage message without glancing at or touching the DVI may lead to the conclusion that presenting speech is useful in conveying certain messages to the driver. In rare cases, participants made late or no reactions, indicating that most responded to messages within a short timeframe.

The fact that conversation and driving related tasks ranked as the top two cited reasons during which participants made no observable response following these cases illustrates the propensity to ignore messages when workload is high. As a result, one would expect that drivers would be more interactive during times when mental workload is low. A total of 51 cases are included where a message was presented when the research vehicle was stopped for red light or due to heavy traffic. Within these cases, 78.4% elicited some observable participant response: either a glance or direct interaction. Although this percentage is lower than the response rate of 81.6% for all messages as discussed earlier, it should be noted that messages types presented when the vehicle was stationary were random and may not follow the overall category distribution. In fact, most of these messages were from the Advertising or Internet/Social Network category. In almost 40% of these cases, participants interacted with the DVI - a higher percentage than for the complete trip (31.5%), all Advertising messages (10.5%), or all Internet/Social Network messages (37.5%) separately. This finding confirms the influence of workload on the participant’s interaction with the interface.

Applied Filters

As previously discussed, Group 2 participants had the option of applying filters to subdue message categories along the route. Figure 17 illustrates the percentage of participants who applied each type of filter at any point across the 18 filters, for all applications, that were available. By the time participants reached the end of the route, half of the participants had applied filters for at least seven application categories. The filters more commonly requested included: automotive ads (75%; 6/8), banking ads (88%; 7/8), food ads (63%; 5/8), promotional ads (88%; 7/8), retail ads (75%; 6/8), metro public transportation (50%; 4/8), and social media (75%; 6/8). Conversely, no participants applied filters to block pedestrian crossing signage, road signage (not including speed limit), school zone signage, text messages, or vehicle maintenance information. It is not surprising that participants would choose to continue receiving messages with higher safety relevance. The only non-safety-related category, text messages, was likely retained due to participants’ willingness to stay connected and the less intrusive presentation modality (speech) employed once additional detail is requested. Participants showed a clear preference to block advertisements, as illustrated by the fact that at least one third of participants blocked all advertisement types; the most frequently applied filters (banking and promotional) also blocked ads. Table 7 provides a snapshot of filters applied by each participant.

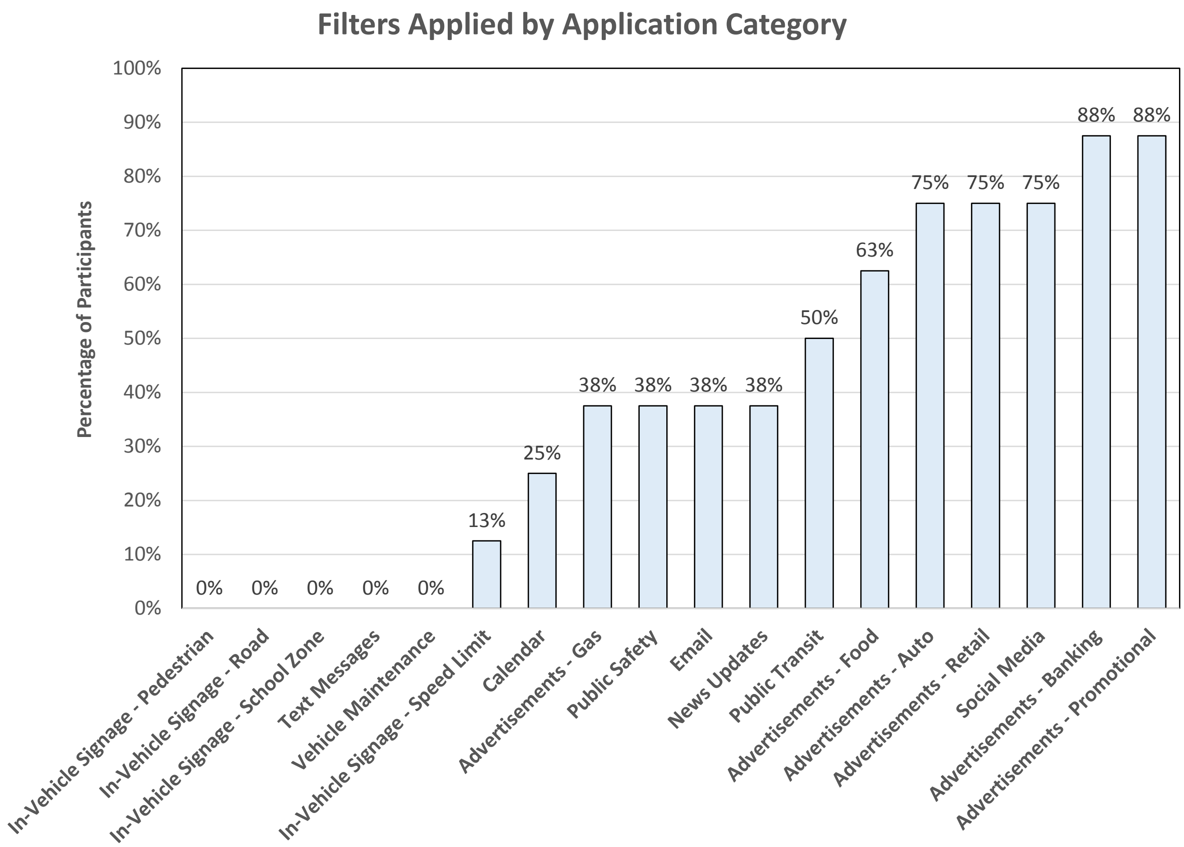

Figure 17. Group 2. Percent of participants that applied filters by filter type

Table 7. Filters Applied by Pariticipant

	Participant #								
Filters	***308***	***309***	***311***	***312***	***313***	***314***	***315***	***316***	Overall %
In-Vehicle Signage - Pedestrian Crossing									0%
In-Vehicle Signage - Road									0%
In-Vehicle Signage - School Zone									0%
In-Vehicle Signage - Speed Limit	**X**								13%
Advertisements - Auto	**X**	**X**	**X**	**X**	**X**			**X**	75%
Advertisements - Banking	**X**	**X**	**X**	**X**	**X**	**X**		**X**	88%
Advertisements - Food	**X**	**X**	**X**			**X**	**X**		63%
Advertisements - Gas	**X**	**X**			**X**				38%
Advertisements - Promotional	**X**	**X**	**X**	**X**	**X**	**X**	**X**		88%
Advertisements - Retail	**X**	**X**	**X**		**X**	**X**	**X**		75%
Public Safety		**X**	**X**	**X**					38%
Public Transit	**X**			**X**		**X**		**X**	50%
Calendar	**X**						**X**		25%
Email	**X**	**X**	**X**						50%
News Updates	**X**		**X**				**X**		38%
Social Media	**X**	**X**	**X**	**X**	**X**			**X**	75%
Text Messages									0%
Vehicle Maintenance									0%
Total Filters Applied	12	9	9	6	6	5	5	4	

Subjective Measures

Groups 1 and 2 experienced the initial system configuration and provided feedback on system performance in real time using a think-aloud approach. Additional feedback was provided through the pre-drive, in-vehicle, and post-study questionnaires. A summary of the results and observations is presented below.

Content analysis

A content analysis was performed to identify trends regarding system performance and individual preferences. Comments were categorized into five general categories related to: context, presentation, timing, frequency and system architecture. It should be noted that participants at times made comments applicable to multiple categories. The results presented herein (Table 8. Content Analysis Sumary) represent a high-level summary, highlighting the most frequent and relevant trends contained within participant comments in an effort to help guide changes that should be applied to create the user-modified configuration examined in Group 4. A complete representation of the content analysis can be found in Appendix M.

Table 8. Content Analysis Sumary

	Participants		General Comment	*Sub-Comment*	
CONTEXT - comments associated with or referencing how messages related to the driving environment	11/16	68.8%	Comments related to the context in which in-vehicle Speed Limit notifications should be presented	*7/11*	*Speed Limit alerts should be presented in the context of entering a new road/area with no sign*
				4/11	*Speed Limit is reduced/changed*
				1/11	*Entering a school zone*
				5/11	*When speeding*
	2/16	12.5%	*Pedestrian Crossing notification only issued when someone is in or entering the cross walk*		
	9/16	56.3%	*Vehicle maintenance messages not presented in the right context; not an immediate concern and did not need to be presented with high priority while driving*		
PRESENTATION - comments associated with the modality and display of information on the DVI	11/16	68.8%	Prefer messages be displayed using speech only	*10/11*	*specific to in-vehicle signage (speed limit and pedestrian crossing)*
	10/16	62.5%	Would like further customization of message presentation; Specifically desired ability to distinguish between message priorities (either through different tones or visual components)		
	5/16	31.3%	Adjust location of center (high priority) messages		
TIMING - comments associated with the amount of time information was displayed	5/16	31.3%	Information was displayed for too long		
FREQUENCY - comments associated with the flow of information	12/16	75.0%	messages were too frequent	*3/12*	*the frequency of tones/beeps associated with bottom line messages was too frequent*
				5/12	*all messages were too frequent*
				3/12	*messages related to advertisements were presented too frequently*
SYSTEM ARCHITECTURE - comments associated with the operation and general performance of the system	9/16	56.3%	would like the CVS to allow them to pause or display messages issued previously	*7/9*	*desired a log of previously played messages that they could access*
	6/16	37.5%	would like the system to be able to recognize emergency vehicles		
	4/16	25.0%	liked how the system interrupted a lower priority message with a higher priority, in-vehicle signage message	*3/4*	*liked when pedestrian crossing interrupted a lower priority message*
				1/4	*liked when speed limit message interrupted a lower priority message*

Survey

Data was collected from each participant from Groups 1 and 2 (16 total) in the form of pre-drive, in-vehicle, and post-study questionnaires. A number of questions were repeated across the pre-drive and post-study questionnaires to allow for measuring changes in preferences following exposure. Results for a selected number of questions are presented herein, with recorded responses presented in the Pre-Drive (Appendix E) and Post-Drive Questionnaires (Appendix K) in their entirety.

The pre-drive and post-study questionnaires asked participants to rate what type of information they thought was appropriate to receive while driving, using a scale of very inappropriate to very appropriate (Figure 18). For the pre-drive questionnaire, vehicle information, in-vehicle signage, and public safety had mean values over five, indicating that participants felt it may be more appropriate to receive this type of information while driving rather than other types such as e-mail, social media, advertisements, and text messages, which all had a mean value of less than three. To an extent, these trends are mirrored by the post-study results, although measurable increases in appropriateness are observed within the categories of e-mail, calendar, and text message-related notifications. For these categories, changes observed consisted of increases in favorability following exposure to the interface.

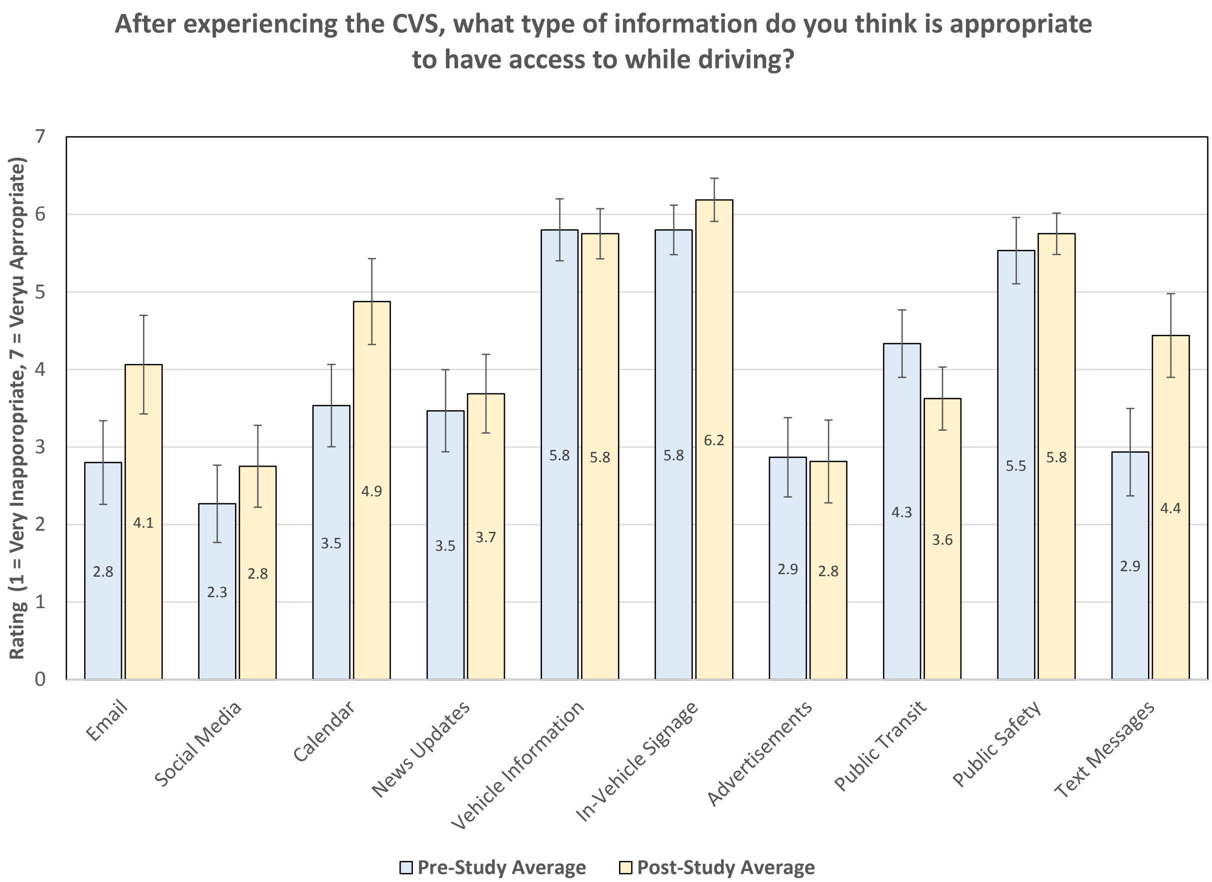

Figure 18. Pre-drive and post-study information appropriateness means

Table 9 illustrates modality preferences based on each application category and how participants would want information presented were this feature in their own personal vehicle. Speech was a preferred modality component across most of the message categories, either alone or in combination with another approach. Also telling, suggestions of 'none' likely indicate that this sample of participants wasn't interested in receiving this type of information. Interestingly, post-exposure, the proportion of those requesting 'none' either went down or, at the very least, stayed the same.

Table 9. Pre-Drive and Post-Study Modality Preference

	Modality								
Message Category	***Text***	***Speech***	***Tone***	***Text + Speech***	***Text + Tone***	***Speech + Tone***	***Text+Speech+ Tone***	***No Preference***	***None***
Email Pre-Drive	13%	25%	25%	0%	0%	13%	0%	0%	25%
Email Post-Drive	0%	31%	0%	13%	6%	6%	13%	6%	25%
Social Media Pre-Drive	13%	13%	13%	0%	0%	6%	0%	0%	56%
Social Media Post-Drive	13%	6%	6%	6%	0%	0%	13%	6%	50%
Calendar Pre-Drive	6%	31%	13%	19%	0%	6%	0%	0%	25%
Calendar Post-Drive	6%	19%	13%	6%	6%	19%	25%	0%	6%
News Updates Pre-Drive	6%	31%	19%	0%	0%	0%	0%	6%	38%
News Updates Post-Drive	25%	13%	6%	0%	6%	6%	6%	6%	31%
Vehicle Information Pre-Drive	19%	38%	0%	19%	0%	13%	0%	6%	6%
Vehicle Information Post-Drive	13%	19%	19%	19%	6%	0%	25%	0%	0%
In-Vehicle Signage Pre-Drive	38%	19%	13%	19%	0%	13%	0%	0%	0%
In-Vehicle Signage Post-Drive	19%	38%	6%	6%	0%	6%	25%	0%	0%
Advertisements Pre-Drive	19%	0%	6%	6%	0%	0%	0%	6%	63%
Advertisements Post-Drive	31%	0%	19%	0%	0%	0%	0%	6%	44%
Public Transit Pre-Drive	13%	25%	19%	0%	0%	0%	0%	19%	25%
Public Transit Post-Drive	25%	19%	19%	0%	6%	0%	0%	6%	25%
Public Safety Pre-Drive	13%	50%	6%	6%	6%	6%	0%	13%	0%
Public Safety Post-Drive	6%	38%	13%	6%	6%	6%	19%	6%	0%
Text Messages Pre-Drive	6%	38%	19%	6%	0%	6%	0%	0%	25%
Text Messages Post-Drive	6%	13%	19%	6%	6%	19%	19%	0%	13%

In-vehicle questions were administered at two predetermined points along the route: after exiting I-66 and upon completion of the route. These two segments were chosen to allow for comparison between the targeted driving environments. Specifically, the first segment (from US-50 through exiting I-66) represented a highway environment while the second segment (US-29) represented more of a commercial and urban environment. Participants were asked to provide a number value representative of their level of agreement or disagreement with three statements using a scale of strongly disagree to strongly agree (Figure 19). It should be noted that for the second segment, participants were asked to consider only the messages presented during that section when rating their level of agreement. This allowed the separate segments, and thus environments, to be compared. The mean values were comparable between the segments, with average values related to usefulness and desirability above neutral rating (value of 4).

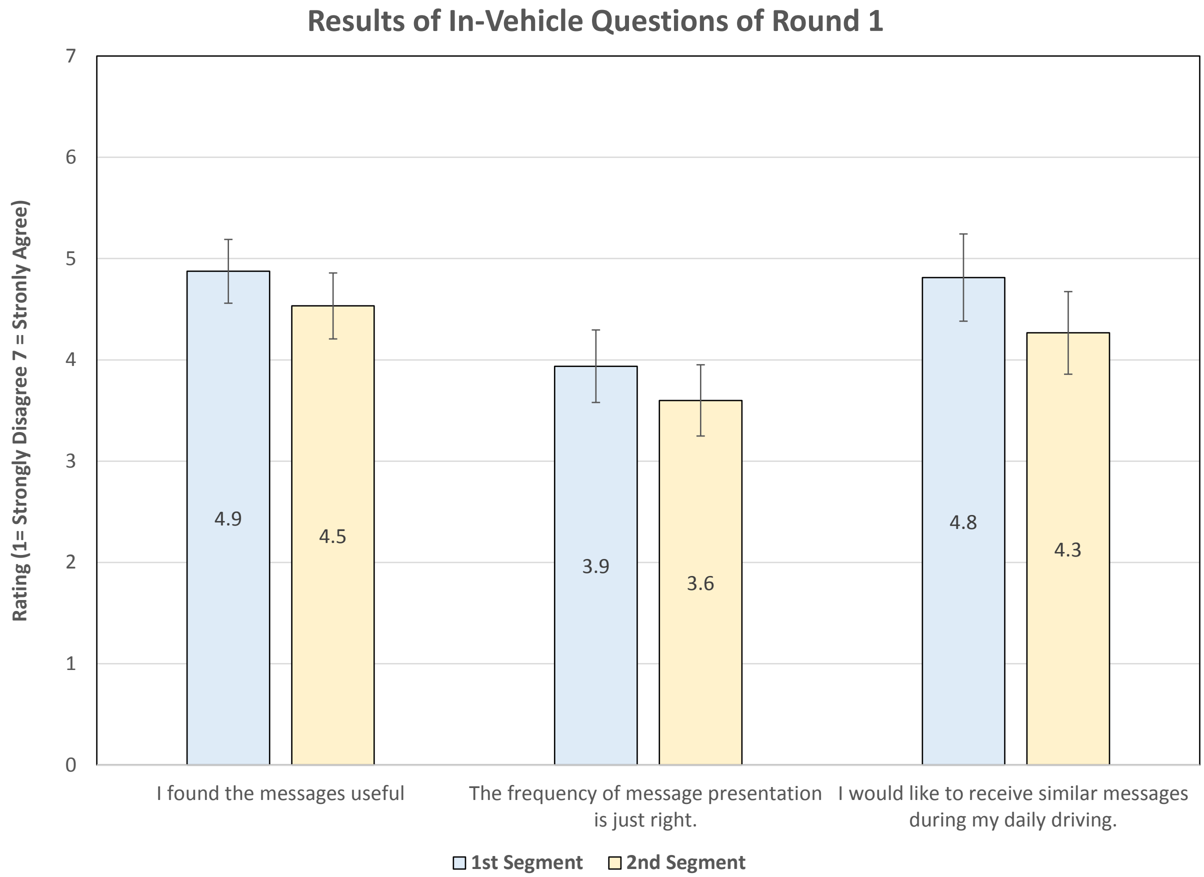

Figure 19. In-vehicle Questions Captured during Round 1

The post-study survey also included a series of questions that evaluated recall and user preferences associated with the CVS, the applications, presentation, etc. Table 10 summarizes the mean user preference ratings associated with CVS performance, amount of information presented, and the frequency of information presented. The ratings indicate that participants in Groups 1 and 2 felt that the CVS performed well and was to their expectations. They also felt that information was issued too frequently during the route, which is directly in line with the open-ended comments captured as part of the think-aloud approach.

Table 10. Group 1 & 2 Post-Study Performance and Frequency Questions: Mean Values

Question	Rating Scale	Mean Rating
"My immediate impression of the CVS is that it performed well and to my expectations?"	1=strongly disagree; 7=strongly agree	5.37
"How would you rate the amount of information presented within the messages?"	1=way too little; 7=way too much	4.3
"How would you rate the overall frequency of information presented during the drive?"	1=much too infrequent; 7=much too frequent	4.9

Figure 20 illustrates the mean ratings for perception of usefulness of the overall CVS and for applications experienced using a scale from one (not at all useful) to seven (very useful). The participants rated in-vehicle signage and public safety information higher (greater than 5 and likely more useful), while rating social media, advertisements, and public transit information lower (less than 3). Not surprisingly, these categories were also among the most frequently filtered out by participants in Group 2. The social media filter was applied by 75% (6/8) of participants, while half applied the public transportation filter. Every participant applied at least two advertisement filters and a third applied filters to block all advertisements.

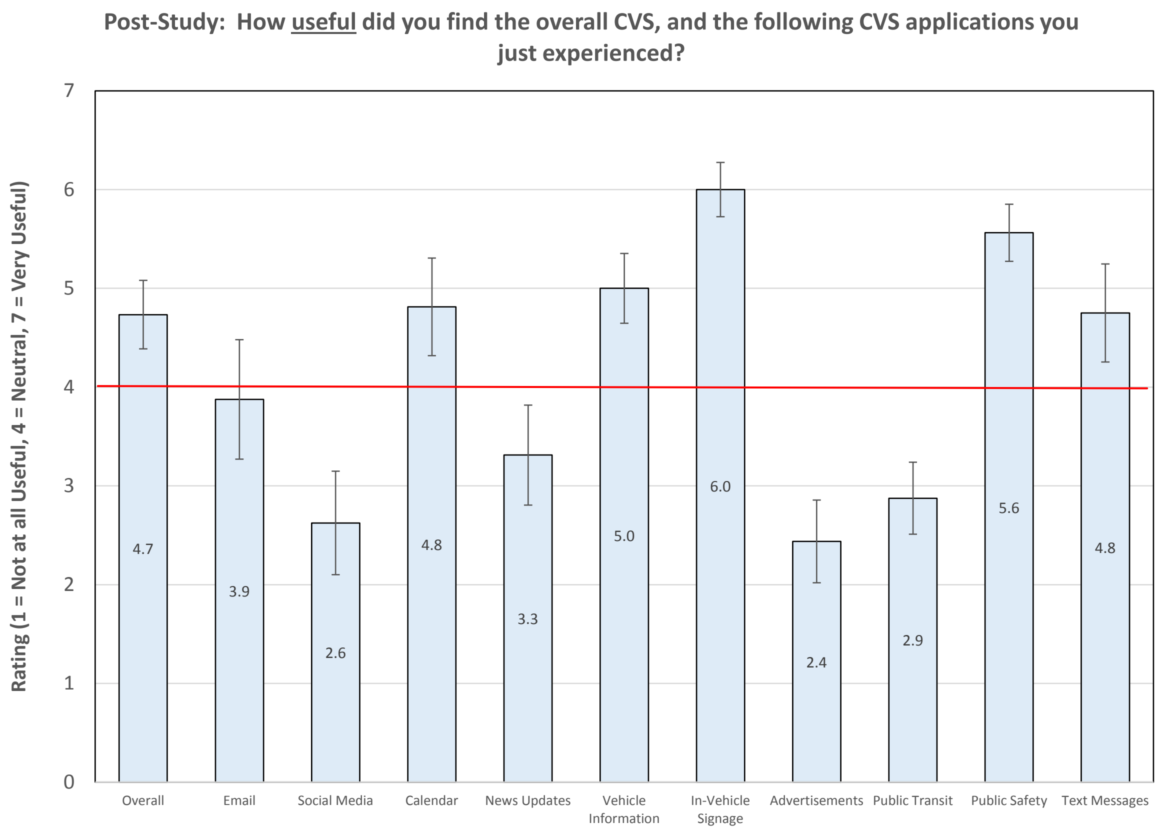

Figure 20. Application usefulness question for post-study – round 1

When asked if additional information was requested from any of the messages, 93.8 percent (15/16) said yes. Those who responded 'yes' were asked which messages they requested additional information from and why. Based on participant recall, 60% (or 9 of 15) of additional detail requests were related to text or e-mail messages, 33.3% (or 5 of 15) were related to vehicle maintenance, and 13.3% (or 2 of 15) were related to calendar updates. Those who responded 'no' were asked to explain why they did not request additional information. The single participant who responded with 'no' indicated that their focus should be on driving and therefore they chose not to request any additional detail.

When asked if they would like the ability to control the types of notifications they received, 100% of participants, not unexpectedly, stated yes. When asked if they would like the ability to prioritize messages by message type, 100% of the participants also said yes. Ultimately, users would prefer the ability to customize the DI parameters, at least at a high level, to suit their personal preferences.

The following table provides a summary of the most frequent responses provided within the open-ended questions included in the post-drive questionnaire.

Table 11. Post-Drive Open-Ended Questions – Frequent Responses

What aspects of the CVS did you like?		
Participants		**General Comment**
8/16	50.0%	Comments associated with driving related information (e.g., liked the speed limit, pedestrian crossing, and/or school zone notifications
5/16	31.3%	Comments associated with the use of speech modality (e.g., liked speech for speed-related messages, speech for text related messages)
What aspects of the CVS did you dislike?		
Participants		**General Comment**
8/16	50.0%	Comments associated with disliking advertisements (e.g., too frequent, general dislike)
3/16	18.8%	Comments associated with social media (e.g., general dislike, distraction prone)
3/16	18.8%	Comments associated with frequency of message presentation (e.g., tones were too frequent, advertisements too frequent)
Is there anything about the CVS you would change?		
Participants		**General Comment**
6/16	37.5%	Comments associated with customization of the CVS (e.g., ability to modify message prioritizations, use different tones)
6/16	37.5%	Comments associated with the interface and message design (e.g., change colors, adjust size and/or layout, choose from different icons)
3/16	18.8%	Comments associated with having the ability to use voice commands

Summary of User Responses Following Groups 1 and 2

Positive Aspects

Based on observations and feedback provided throughout the two groups in round one, the following positive aspects of the IA prototype were identified.

- The prototype managed message presentation in a reasonable manner such that none of the participants found the messages presented to be difficult to understand or access.

- In-vehicle signage that is driving related is generally favored.

- The presentation of in-vehicle signage incorporating speech was considered useful, allowing participants to be informed of messages while still focusing on the roadway. This also suggests that visual cues of higher priority messages presented in the center of the DVI are likely to be less necessary. Speech was also preferred when participants chose to access details of text messages and e-mails.

- System prioritization was also considered useful when the system interrupted a lower priority message with a higher priority, in-vehicle signage message. This is a key component of the IA, and is likely to be a regular occurrence within a dense CV environment.

- A feature for enabling users to filter out unwanted message categories was frequently suggested by Group 1 participants. Group 2 participants, who were able to fully experience the filters during their driving session, also favored this feature.

Usability Concerns and Potential Changes

- Participants commented that information was displayed on the DVI for too long, especially for additional detail messages. The vast majority of detail messages were manually dismissed within the 30-second display period instead of being allowed to auto-clear.

- Participants felt that messages were displayed too frequently. They generally disliked advertisements and social media messages and had fewer interactions with them on the DVI.

- There was a greater propensity to dismiss higher priority messages presented in the center of the screen accompanied by speech. Participants often said this was because the original message location tended to obscure route guidance information. Message location adjustment was suggested by some participants.

- Auditory cues were preferred by some participants to visual cues. Speech was often cited as a preferred presentation modality.

- Participants frequently commented that vehicle maintenance messages were not presented in the right context. Participants showed a high propensity for requesting additional detail when these messages were presented, yet, based on user in-vehicle subjective feedback, they felt that the general maintenance information provided in the message details was not important enough and could wait. This disconnect existed due to drivers' basing their initial interpretation on the original icon's high-priority appearance, although in hindsight, the 'maintenance required' verbiage likely also contributed.

- Further customization of message presentation was suggested. For example, using different tones or visual components for bottom line messages in different categories to help distinguish one message type from another.

- Participants suggested limiting the use of the touch screen and avoiding hand(s) off the wheel by promoting a voice controlled DVI that would use verbal commands to interact with messages.

- The majority of participants would like the system to allow them to pause messages and/or display previously played messages, or to generate a log of previously played messages that they could access if so desired.

- Further changes suggested for in-vehicle signage included presenting speed limit notifications in the context of entering a new road/area with no sign or when the driver is speeding. In addition, the presentation of pedestrian crossing notifications could be made more intelligent by using V2X communication, causing notifications to occur only when a person was in or entering the crosswalk.

- Additional messages participants indicated that they would like the system to present include approaching emergency vehicles.

DYNAMIC INTEGRATOR CHANGES

Based on in-vehicle and analytical observations, accompanied by feedback provided between the two groups in round one, the following changes were implemented to create a 'user-modified' system configuration for targeted testing in round two. These are the changes that were expected to provide the greatest impact among those that could be accommodated within the scope and timeline of this effort. Participants provided a number of other useful comments that the research team considered. Many of these would be addressed with the ability for the interface to accept customization to the individual logic and presentation parameters, and were therefore not considered within these design changes.

High Priority Message Location Adjustment

With the initial system configuration, higher priority messages were presented in the center of the DVI and accompanied by speech (Figure 2). Five participants (31.3%, or 5/16) specifically commented that the presentation of these high priority messages should be relocated. Furthermore, the desire to dismiss these messages is likely to be reduced if the message display no longer hides other relevant information. To address this, the research team adjusted the location of these higher priority messages to the left center of the DVI (Figure 21), leaving the center portion of the screen unobscured, thus allowing for continuous feedback on vehicle position with respect to travel road and upcoming maneuvers. This adjustment also required that the size of the message be reduced by 20%.

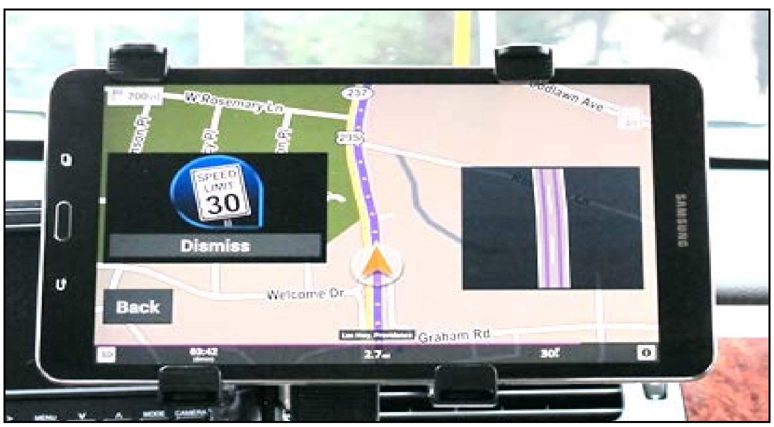

Figure 21. High priority messages – modified placement

Duration of Additional Detail Messages

As a reminder, when a user requested additional details for a given message the resulting pop-up was displayed for 30 seconds, accompanied by speech. Reduction and analysis revealed that almost 90% of additional detail messages were dismissed manually in Group 1, and 31.3% of participants made at least one comment suggesting that the messages were presented for too long. Based on observation and user feedback, the additional detail window display time was reduced down to 8 seconds. This value was based on an observed 7.4 second average time to dismiss, coupled with the known longest speech message at 7 seconds. By 8 seconds, the participant had dismissed almost 70% of the messages. This new duration was expected to be sufficient for presenting any message in its entirety, and to potentially reduce unnecessary interactions with the DVI (eye-glance and pressing the dismiss icon).

Modification to Vehicle Maintenance Icon

Following trips with Groups 1 and 2, a decision was also made to change the vehicle maintenance icon. Participants felt that general maintenance information was not an immediate concern and did not need to be presented with the perceived urgency the icon suggested. By replacing the engine icon with a wrench icon (Figure 22), it was anticipated that the message would appear less urgent—while still relevant to the message content—to encourage interaction more in line with the intended level of importance. Text in the icon, ‘Maint Req’d’, which is likely to be less obvious than the symbol, remained the same. In hindsight, it likely would have been more appropriate to modify the text as well, since the detailed information was more along the lines of notification that a maintenance item would be due soon, as opposed to required immediately.

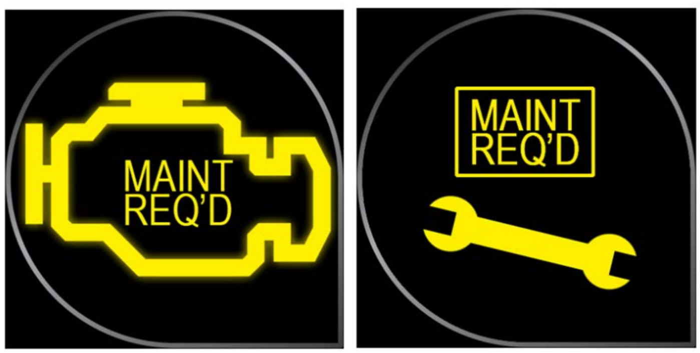

Figure 22. Vehicle Maintenance Icon – old (left), new (right)

SUMMARY OF RESULTS FOR POST-MODIFICATION EVALUATION

As a reminder, round two of user testing was conducted to allow for direct comparisons of normative driving while interacting with two configurations of the prototype interface:

Group 3 – the original configuration used in Groups 1 and 2.

Group 4 – the 'user modified' configuration.

It was determined early on between the research team and the sponsor that including a true baseline comparison where the IA was turned-off would not serve as a useful comparison. It was instead determined that the research team would compare the original configuration with the configuration that was considered improved following the targeted modifications. It is important to note, however, that this limits the ability of this research effort to support analysis related to increasing driver safety (research question 5).

Objective Measures

Message interaction rates in Groups 3 and 4 are provided in Table 12 below. Expectedly, as with Group 1, significant variance was observed among individual participants. Overall response rates as a percentage of messages displayed were slightly higher for Group 4.

Table 12. Observed Message Response in Group 3 and Group 4

Group 3		Participant									Overall				
		317	318	319	320	321	322	324	325		Average		% of Presented*		
Messages Presented		71	71	71	57	70	71	71	71		69.1		Average	Min	Max
Response Observed	Any	63	24	71	43	63	58	46	46		51.8		74.9%	34%	100%
	Touch	24	9	30	31	9	11	0	0		14.3		20.6%	0%	54%

**across participants*

Group 4		Participant									Overall				
		327	328	329	330	331	332	333	334		Average		% of Presented*		
Messages Presented		71	68	71	68	71	71	71	71		70.3		Average	Min	Max
Response Observed	Any	62	63	25	63	62	43	70	71		57.4		81.7%	35%	100%
	Touch	17	24	8	17	8	0	22	48		18.0		25.6%	0%	68%

**across participants*

To directly investigate any measureable impact following the location adjustment for higher priority messages, responses associated with In-Vehicle Signage messages were examined (Table 13). As a reminder, these message types don't include the option to request addition detail and can only be dismissed. It was anticipated that by moving the location of higher priority messages to the left center of the DVI and reducing the size slightly, participants would feel less compelled to dismiss them following their presentation. With the original configuration, Group 3 participants dismissed, on average, 23.3% of all In-Vehicle Signage messages. The dismiss rate did reduce slightly in Group 4 with the user-modified configuration (20.8%) but the difference was not significant (t-test $p = 0.44$).

Table 13. In-Vehicle Signage Message Response in Group 3 and Group 4

Group 3		Participant								Overall			
		317	318	319	320	321	322	324	325	Average	% of Presented*		
Messages Presented		15	15	15	15	15	15	15	15	15.0	Average	Min	Max
Response Observed	Glanced	9	6	15	9	11	7	5	4	8.3	55.0%	27%	100%
	Dismissed	7	5	13	1	1	1	0	0	3.5	23.3%	0%	87%
	Ignored	1	4	0	2	1	3	3	6	2.5	16.7%	0%	40%
	Speedometer Check	5	5	0	4	3	5	7	5	4.3	28.3%	0%	47%

**across participants*

Group 4		Participant								Overall			
		327	328	329	330	331	332	333	334	Average	% of Presented*		
Messages Presented		15	14	15	14	15	15	15	15	14.8	Average	Min	Max
Response Observed	Glanced	11	10	9	11	12	1	14	15	10.4	69.2%	7%	100%
	Dismissed	1	0	6	0	1	0	3	14	3.1	20.8%	0%	93%
	Ignored	1	2	1	1	0	8	0	0	1.6	10.8%	0%	53%
	Speedometer Check	3	2	5	2	3	6	0	0	2.6	17.5%	0%	40%

**across participants*

However, it should be noted that the location change was expected to influence participants only when they visually interacted with the screen. These messages included a speech component, so the visual message displayed could be considered as redundant by some. As shown in Figure 23, on average, Group 3 participants dismissed 35.3% of In-Vehicle Signage messages they glanced at while driving, while Group 4 participants dismissed 24.9%. After adjusting the location of higher priority messages, the average interaction rate (in terms of dismissing, which could be considered a distraction) was reduced by more than 10%. Although the t-test shows no significant difference ($p = 0.29$) among the two groups, the observed trend does suggest an improvement gain following the modifications.

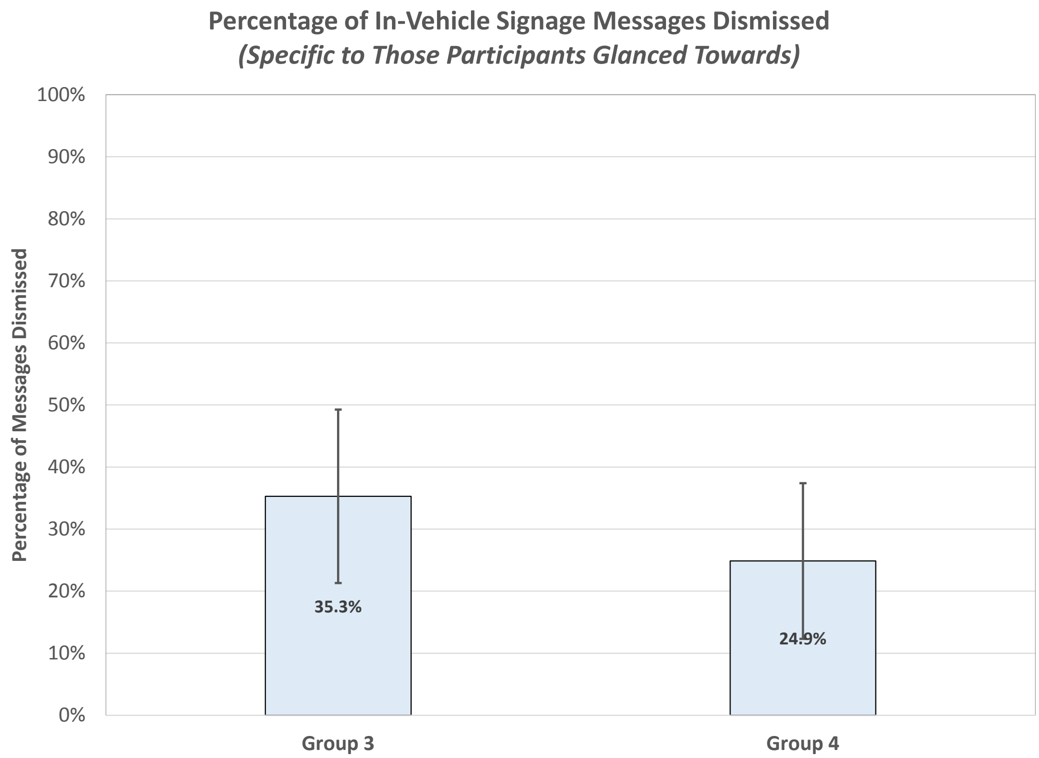

Figure 23. Dismiss rate of in-vehicle signage messages at which participants glanced

Another primary change made between Groups 3 and 4 was reducing the detail message display duration from 30 seconds down to 8 seconds. This reduction was expected to reduce the frequency of dismissals, resulting in fewer glances and interactions. Due to the shortened expiration window, messages, on average, were presented for a significantly shorter duration for Group 4 participants ($p = 0.00$). Figure 24 illustrates that the average presentation time of messages where additional detail was requested was twice as long for Group 3 participants as for Group 4.

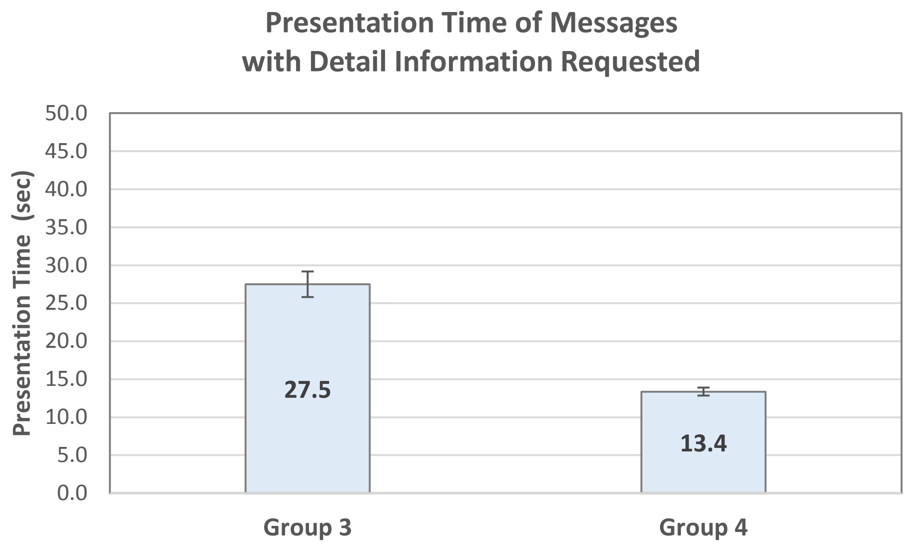

Figure 24. Average presentation time of messages with detail information requested

Table 14 illustrates that, owing to this change, the frequency of dismissals was reduced from 69.1%, on average, down to 36.6%, a significant decrease (t-test, $p = 0.04$). This observation indicates that reducing the duration of additional detail messages meant they were more likely to expire before participants felt compelled to dismiss them. Consequently, participants were theoretically less distracted.

Table 14. Additional Detail Message Interaction in Group 3 (Top) and Group 4 (Bottom)

Group 3		Participant									Overall			
		317	318	319	320	321	322	324	325	Average		% of Requested*		
Additional Detail	Requested	16	3	15	30	8	9	0	0	10.1		Average	Min	Max
	Dismissed	15	3	15	8	4	4	0	0	6.1		69.1%	0%	100%

*across participants

Group 4		Participant									Overall			
		327	328	329	330	331	332	333	334	Average		% of Requested*		
Additional Detail	Requested	15	24	2	17	7	0	17	33	14.4		Average	Min	Max
	Dismissed	4	2	1	0	5	0	3	27	5.3		36.6%	0%	82%

*across participants

The last configuration change made was modifying the Vehicle Information messages' vehicle maintenance icon as well as relocating these messages to the left center of the display (Table 15). This change was expected to more closely resemble the less-than-urgent general maintenance notification. Findings indicated that there was a reduction in the overall desire to dismiss higher-priority messages following the location change. Interestingly, the frequency of requesting additional detail actually increased for Group 4. As requested detail is an indication that the message was of interest to the driver, it is hard to gauge the modification's impact. Without the think-aloud approach here, capturing feedback directly associated with the message is difficult as well. Furthermore, considering that the sample size is very limited, it is ultimately impossible to draw any meaningful conclusions from these observations.

Table 15. Vehicle Information Message Interaction in Group 3 (Top) and Group 4 (Bottom)

Group 3		Participant									Overall			
		317	318	319	320	321	322	324	325		Average		% of Presented*		
Messages Presented		2	2	2	2	2	2	2	2		2		Average	Min	Max
Response Observed	Dismissed	1	1	0	0	0	1	0	0		0.38		19%	0%	50%
	Detail Requested	1	0	1	2	2	1	0	0		0.88		44%	0%	100%

*across participants

Group 4		Participant									Overall			
		327	328	329	330	331	332	333	334		Average		% of Presented*		
Messages Presented		2	2	2	2	2	2	2	2		2		Average	Min	Max
Response Observed	Dismissed	1	0	0	0	0	0	0	0		0.13		6%	0%	50%
	Detail Requested	1	2	0	2	1	0	2	2		1.25		63%	0%	100%

*across participants

Comparisons of Vehicular Control

It was expected that with access to the user-modified configuration, Group 4 participants would be able to focus more on driving and thus have better overall control of the vehicle, leading to improved lane position and speed maintenance. Considering the sample size and anticipated variance across individuals, within-subject comparisons of vehicular control data were performed to examine impacts following message presentation across the sample. For each participant, comparisons associated with mean vehicle speed and the standard deviation of lane offset were made before and during message presentation. Therefore, it was critical that comparisons made were considered valid only if the average speeds for both the pre- and within-message presentation periods were not significantly lower than the posted speed limit (free flow traffic), as was having reliable lane offset data for cases where lane offset was measured. It is also important to note that the duration of the pre-presentation period matched, in all cases, the duration of message presentation across which the comparison of these measures were made.

Based on configuration changes and potential responses to different application categories, three groups of comparisons were made, targeting:

1. speed limit messages,
2. other In-Vehicle Signage messages, and
3. messages where additional detail was requested.

Following the presentation of speed limit messages, it was expected that participants would adjust their speed closer to the speed limit. As the location of the message was simply adjusted for Group 4 without modifying message content, it's not surprising to see that the percentage of speed-related messages resulting in participants modifying their speed closer to the speed limit is comparable between the two groups (Figure 25, $p = 0.80$ for two proportion z-test). This finding would suggest that, overall, the messages positively impacts driver behavior, at least within this test sample. The frequency of cases where the standard deviation of lane offset decreased following message presentation, indicating improved lane maintenance, was comparable as well ($p = 0.89$ for two proportion z-test). A repeated measures analysis of variance (ANOVA) revealed no difference ($p = 0.70$) between the two groups in terms of the standard deviation of lane offset.

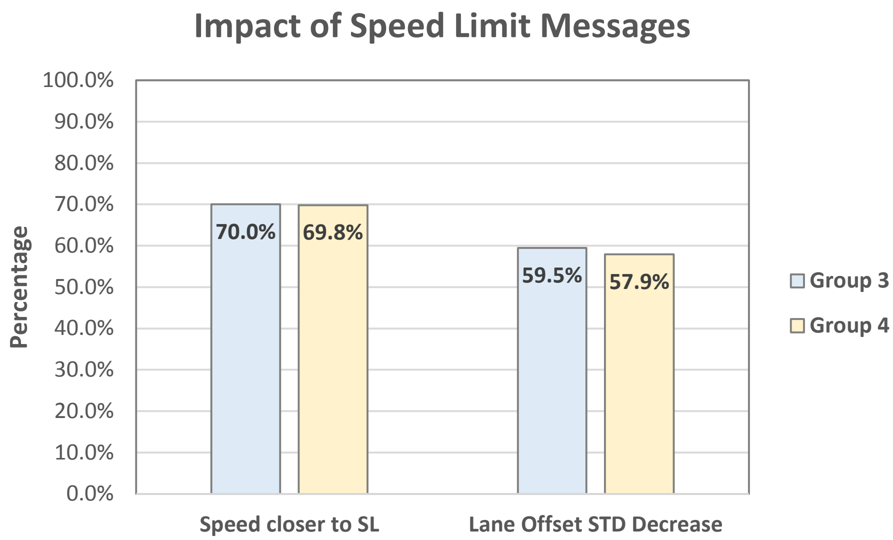

Figure 25. Percentage of speed limit messages presented that led to adjustment of speed and lane offset

This trend of similarities continues when focusing on messages related to school zones or pedestrian crossings, where it was expected that participants would likely slow down marginally in response to message presentation. This proved true, as over 50% of messages resulted in a measureable speed decrease across both groups, with no significant differences between the two (Figure 26, $p = 0.74$ for two proportion z-test). Realistically, the lack of differences is unsurprising as the content and information provided was consistent across both groups. Modifications based on feedback provided by earlier participants were made to address unnecessary interactions, but ultimately the issuance of this information, whether modified or not, is relevant to the environment and participants demonstrate a desire to comply. Variance with respect to lane maintenance had a significant decrease ($p = 0.00$ comparing before and after message presentation for repeated measures ANOVA) and saw a decrease in over 60% of measured cases across both groups ($p = 0.85$ for two proportion z-test), again suggesting more awareness of the driving environment following presentation of these high priority message types.

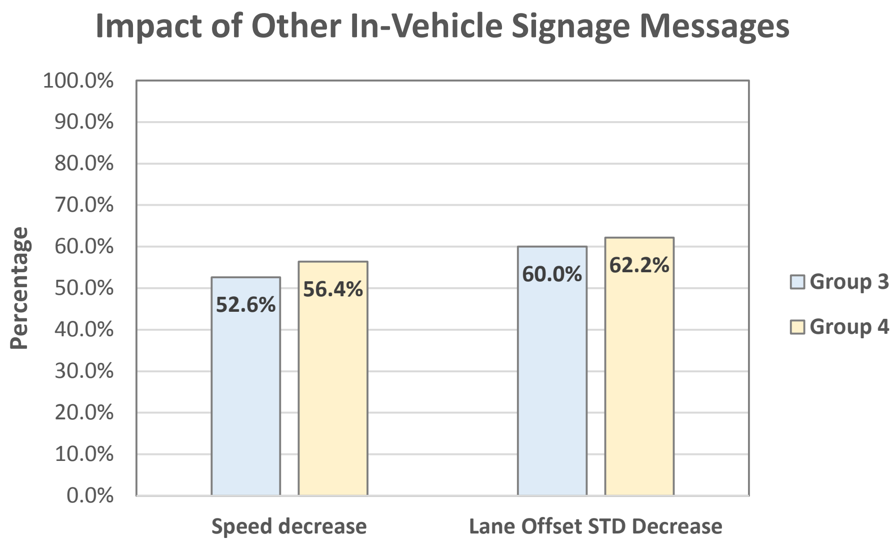

Figure 26. Impact of other in-vehicle signage messages on vehicular control data

Analysis of Eye-Glance Behavior

As previously mentioned, eye-glance behaviors were observed frame by frame within two specified segments of roadway incorporating interstate highway I-66 and an urban commercial area along US-29. Each segment took about 5 minutes to drive in a free flow traffic condition, for a total of approximately 10 minutes of total eye-glance reduction per participant, on average. Due to the fact that a large number of advertising messages were presented in the urban commercial area and many Internet/social network messages were presented on the interstate highway segment, message density was relatively higher on these segments compared to the rest of the trip. These segments with high message presentation density provided a good opportunity for the DI to demonstrate its message management capability. There were 12 messages presented on the I-66 segment, and 15 messages on the US-29 segment, distributed across message categories as shown in Table 16.

Table 16. Distribution of messages on two eye-glance reduction segments

	I-66	US-29
In-Vehicle Signage	2	4
Advertising	0	7
Vehicle Information	1	0
Internet/Social Network	7	4
Public Transit	1	0
Public Safety	1	0
Total	***12***	***15***

Allowing for direct comparisons across configurations of interest, eye-glance behavior data was analyzed across Groups 3 and 4 during instances specific to where messages were presented. Note that eye-glance data was excluded when the vehicle was stationary due to traffic, etc., as the workload of participants was low when stopped. The three measures that were investigated included:

1. frequency of non-driving related glances,
2. total duration of non-driving related glances, and
3. frequency of long non-driving related glances (>= 2 seconds).

Driving and non-driving related glances are defined in Table 17.

Table 17. Definition of Driving and Non-Driving Related Glances

	Location
Driving Related	Forward, Left/Right Windshield, Left/Right Window/Mirror, Rearview Mirror, Instrument Cluster, Over-the-Shoulder
Non-Driving Related	Center Stack, Interior Object, Message/Tablet, Passenger, No Eyes Visible, Other

These measures are broken down by application categories and compared across Groups 3 and 4. Figure 27 shows the frequency of non-driving related glances per message and Figure 28 shows the total duration of non-driving related glances per message. Overall, there appear to be no measureable differences between the two groups with respect to overall glance frequency and total duration of non-driving related glances. By category, messages related to Vehicle Information encourage a higher number of non-driving related glances per message, on average, and for the longest total duration. This holds true for both Groups 3 and 4. This is likely due to the fact that users spent more time reviewing the maintenance-related message once additional detail was accessed. The change of the vehicle maintenance icon did not appear to impact performance related to eye-glance behavior. On the other hand, In-Vehicle Signage messages, which were presented with speech and without the option to request additional detailed information, introduced the least and shortest non-driving related glances. This application category presented information to participants in the least distracting way.

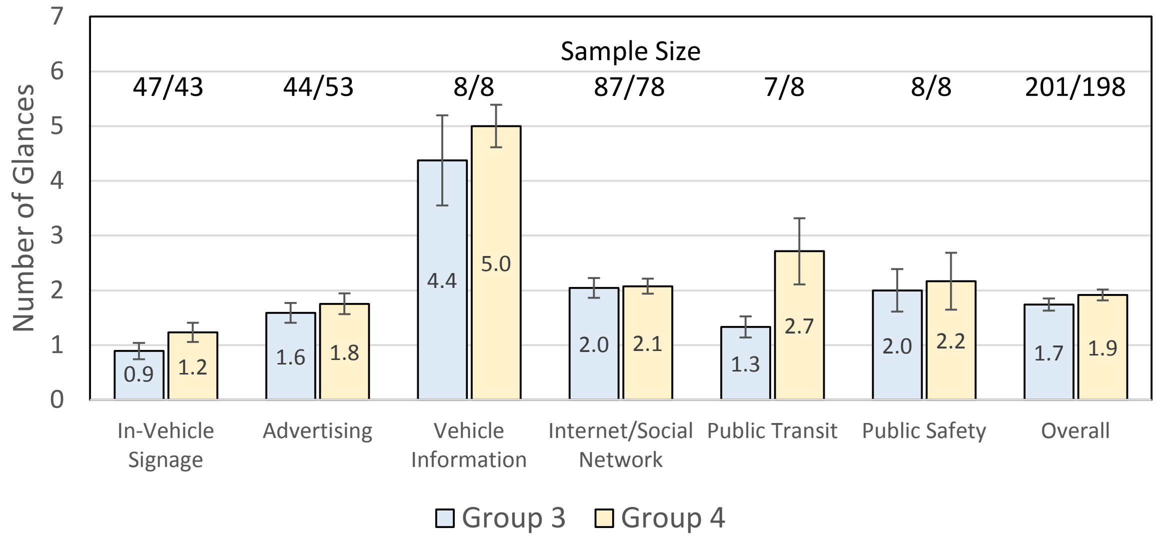

Figure 27. Frequency of non-driving related glances per message

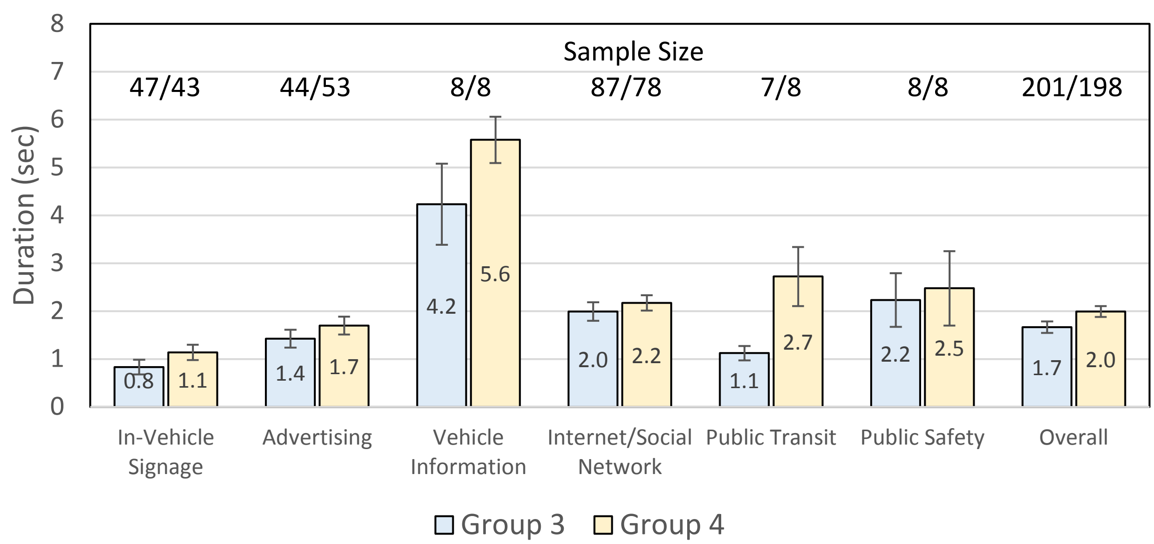

Figure 28. Total duration of non-driving related glances per message

Figure 29 shows the percentage of long non-driving related glances (defined as those greater than or equal to 2 seconds) out of all non-driving related glances. In general, neither configuration nor application category appeared to encourage a high proportion of long glances across the examined applications. This is a positive finding in that the interface, either in its original configuration or the user-modified configuration, did not illicit glance durations that would be considered safety critical.

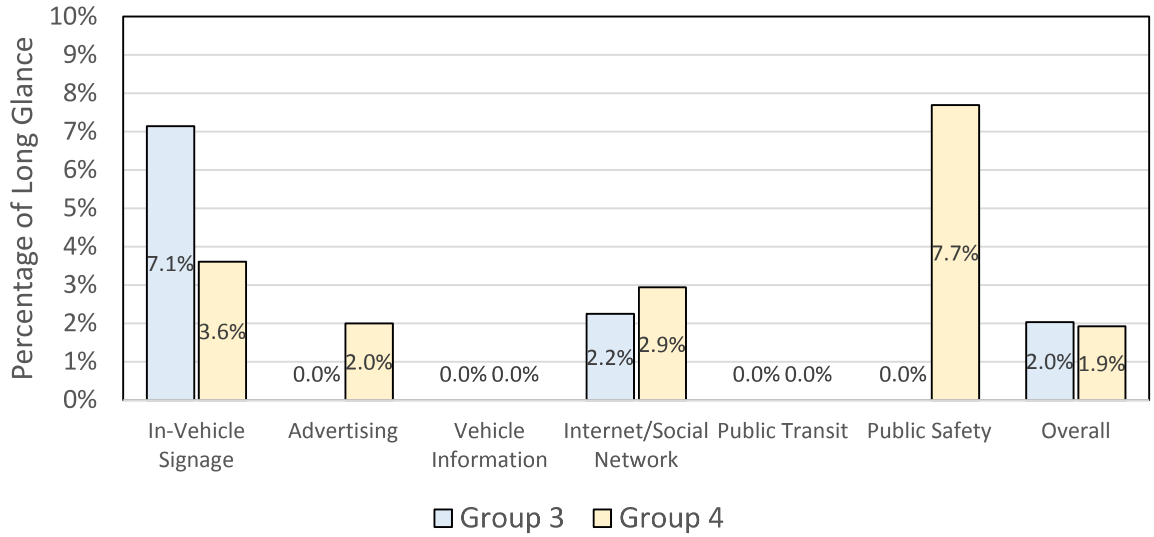

Figure 29. Frequency of long non-driving related glances

From the figures above, it is hard to draw any conclusions about the improvement gained from the modifications made, as both frequency and total duration of non-driving related glances were comparable between the two groups.

Subjective Measures

As with Groups 1 and 2, each participant in Groups 3 and 4 completed a pre-drive, in-vehicle, and post-drive survey. The pre-drive questionnaire was designed to capture general feedback on how appropriate it was to receive messages from certain categories while driving, along with how the messages were presented. Figure 30, below, displays the mean values for Groups 3 and 4 when asked, both in the pre- and post-driving questionnaire, to rate how appropriate (1 = very inappropriate, 4 = neutral, 7 = very appropriate) it was to receive message notifications from each message category while driving.

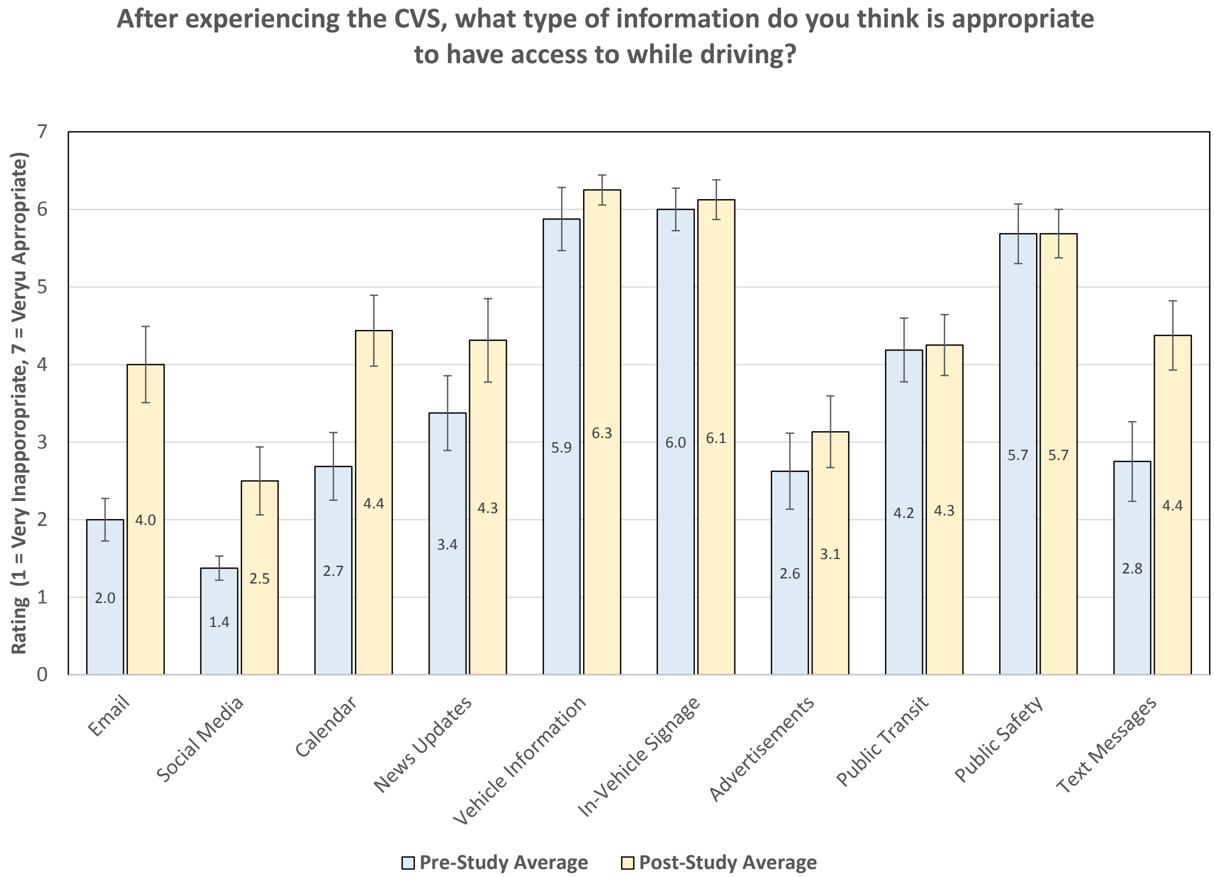

Figure 30. Message appropriateness question for pre- and post-study – round 2

At a high level, those messages that respondents felt were appropriate to have access to were limited to the vehicle information, in-vehicle signage, and public safety messages. Public transit was closer to neutral, on average, and the rest fell between inappropriate and neutral. For many message types, the differences in appropriateness before and after exposure to the interface remained fairly consistent. However, e-mail, social media, calendar, and text message related notifications all saw measureable gains in appropriateness across the sample. This likely suggests that, following exposure, participants either felt these categories were more appropriate than they initially realized, or that the manner in which they were presented as part of an integrated feature increased the overall appropriateness.

The post-study message appropriateness results were broken down by groups and are shown in Figure 31. Drivers from Group 3 and Group 4 gave comparable message appropriateness ratings to all categories except for calendar, news updates, and text messages (based on non-overlapping error bars). As a whole, there is a fair amount of separation across application categories similar to what was observed following the round of data collection. Vehicle information, in-vehicle signage, and messages related to public safety are consistently rated high in terms of appropriateness.

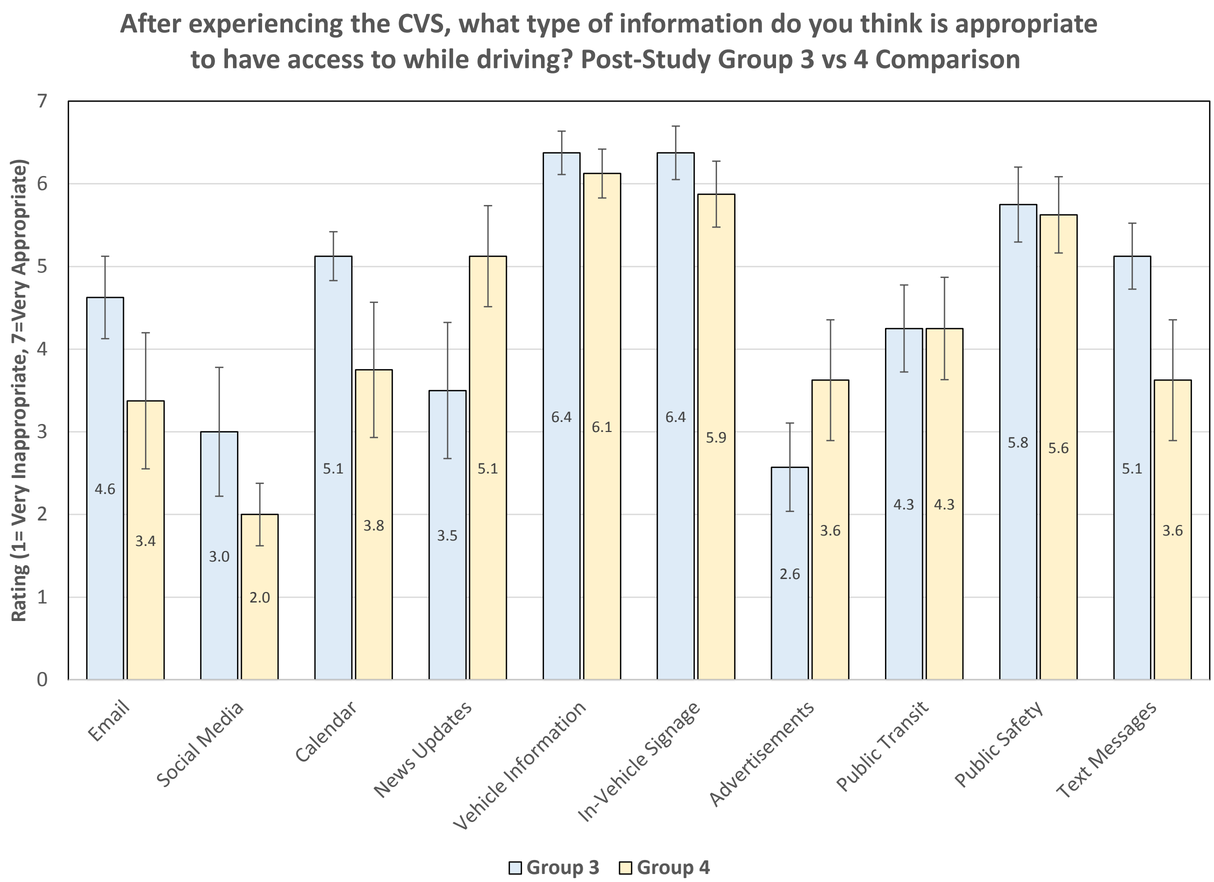

Figure 31. Post-study: Group 3 vs. Group 4 for message appropriateness

Table 18, below, displays the modality preferences based on each application category and how the participants would want information presented were this feature in their own personal vehicle. In the pre-drive questionnaire, 50% and 63% of the participants selected 'none' for social media and advertisements respectively, suggesting that they were not interested in receiving this type of information. There was a general preference for speech-only for e-mail (38%), calendar (31%), news updates (31%), vehicle information (38%), public safety (50%), and text messages (38%). The preference for speech-only increased for the post-drive questionnaire with participants favoring it for e-mail (63%), social media (31%), calendar (56%), news updates (44%), vehicle information (63%), in-vehicle signage (50%), public transit (31%), public safety (50%), and text messages (56%). These increases likely reflect the method in which the additional detail, once requested, was presented since it included a speech component.

Table 18. Pre-Study: Group 3 and Group 4 Modality Preference

	Message Modality								
Message Category	***Text***	***Speech***	***Tone***	***Text + Speech***	***Text + Tone***	***Speech + Tone***	***Text+Speech+ Tone***	***No Preference***	***None***
Email Pre-Drive	0%	38%	19%	0%	0%	13%	6%	0%	25%
Email Post-Drive	0%	63%	6%	0%	0%	13%	0%	13%	6%
Social Media Pre-Drive	0%	19%	25%	0%	0%	0%	6%	0%	50%
Social Media Post-Drive	0%	31%	13%	0%	0%	6%	0%	13%	38%
Calendar Pre-Drive	0%	31%	19%	19%	0%	6%	0%	0%	25%
Calendar Post-Drive	0%	56%	13%	0%	0%	25%	0%	6%	0%
News Updates Pre-Drive	6%	31%	19%	0%	0%	0%	0%	6%	38%
News Updates Post-Drive	0%	44%	19%	0%	0%	13%	0%	0%	25%
Vehicle Information Pre-Drive	19%	38%	0%	19%	0%	13%	0%	6%	6%
Vehicle Information Post-Drive	0%	63%	6%	0%	0%	25%	6%	0%	0%
In-Vehicle Signage Pre-Drive	38%	19%	13%	19%	0%	13%	0%	0%	0%
In-Vehicle Signage Post-Drive	0%	50%	13%	0%	6%	19%	13%	0%	0%
Advertisements Pre-Drive	19%	0%	6%	6%	0%	0%	0%	6%	63%
Advertisements Post-Drive	13%	25%	0%	0%	6%	6%	0%	25%	25%
Public Transit Pre-Drive	13%	25%	19%	0%	0%	0%	0%	19%	25%
Public Transit Post-Drive	0%	31%	13%	0%	0%	25%	0%	6%	25%
Public Safety Pre-Drive	13%	50%	6%	6%	6%	6%	0%	13%	0%
Public Safety Post-Drive	0%	50%	13%	0%	0%	25%	6%	6%	0%
Text Messages Pre-Drive	6%	38%	19%	6%	0%	6%	0%	0%	25%
Text Messages Post-Drive	0%	56%	6%	6%	6%	6%	0%	13%	6%

The in-vehicle survey asked participants to rate their level of agreement (1= strongly disagree, 4 = neutral, 7 = strongly agree) with three statements following the two segments of roadway. The mean ratings for each statement are presented in Figure 32. It appears that there was greater variation (although not significant) between Group 3 (mean = 3.88) and Group 4 (mean = 5.13) during the second segment when asked if they agreed with the statement, “I found the messages useful.” The small positive increase in responses may indicate a trend that suggests changes made did, in fact, address some of the immediate concerns and issues Groups 1 and 2 participants presented.

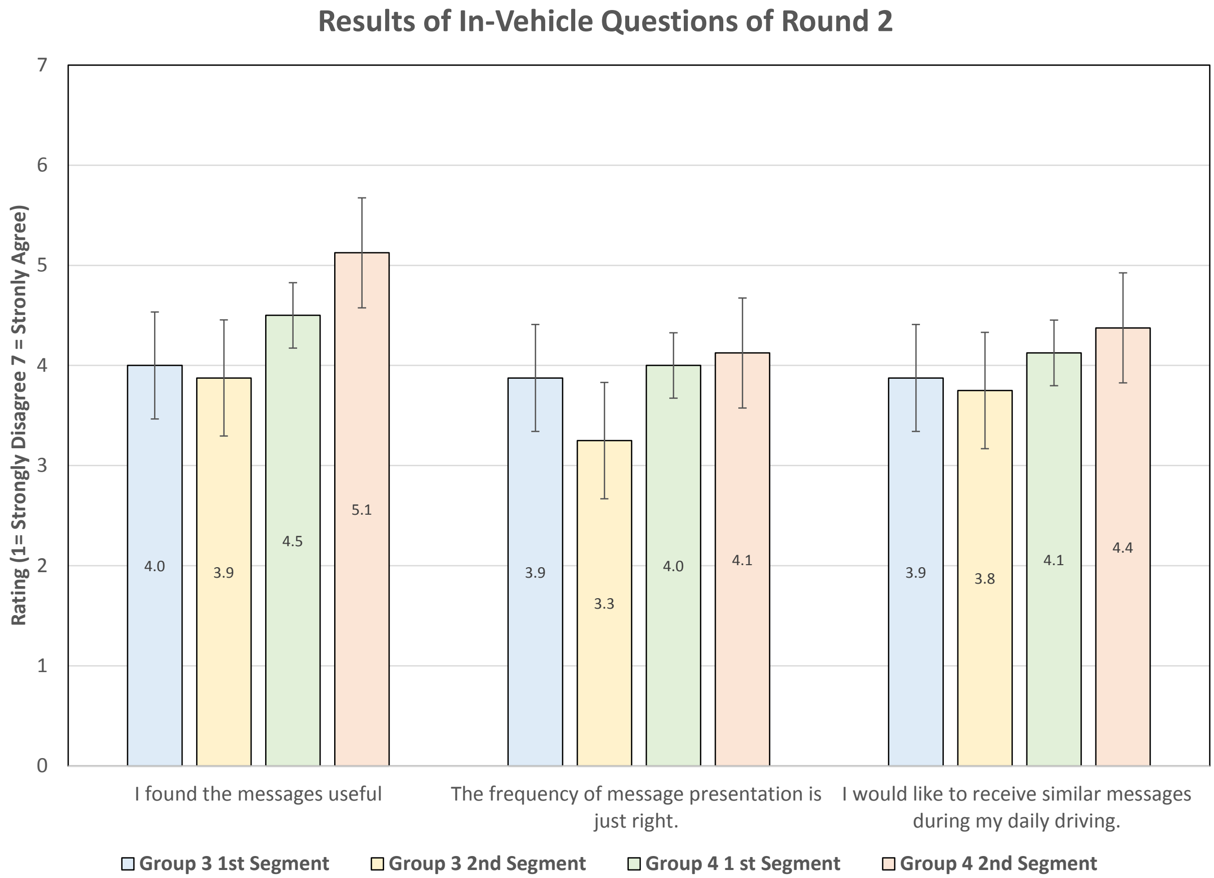

Figure 32. Results of in-vehicle questions of round 2: Group 3 and Group 4 comparison

The post-drive survey asked a series of questions that evaluated user preference associated with the CVS, the applications, presentation, etc. Highlights of these responses are included below (Table 19). Mean ratings are consistent overall, indicating that users were primarily pleased with overall performance, even for the condition without the targeted modifications.

Table 19. Group 3 & 4 Post-Study Performance and Frequency Questions: Mean Values

Question	Rating Scale	Group 3	Group 4
"My immediate impression of the CVS is that it performed well and to my expectations"	1=strongly disagree; 7=strongly agree	5.5	5.4
"How would you rate the amount of information presented within these messages?"	1=way too little; 7=way too much	4.3	4.6
"How would you rate the overall frequency of information presented during the drive?"	1=much too infrequent; 7=much too frequent	5.0	4.4

When asked to rate the amount of information presented within the messages using a scale from 1-7 where 1 indicates information was presented much too infrequently while 7 indicates information was presented much too frequently (Figure 33), the mean rating for many categories was closer to neutral for both Group 3 and 4. Advertisements had a mean rating greater than 5 for both Group 3 and 4, suggesting participants felt that this information was presented too frequently. Social media had a higher mean rating (5.375) in Group 3 than in Group 4 (4.25) suggesting that participants in Group 3 felt these messages were presented too frequently, while those in Group 4 were more neutral. Participants in Group 3 also gave higher ratings than Group 4 for calendar (Group 3 = 4.625; Group 4 = 3.625) and text messages (Group 3 = 4.875; Group 4 = 3.875). These differences indicate that for these categories, on average, participants in Group 3 felt the information was presented too frequently, while participants in Group 4 felt more neutral about the frequency of messages.

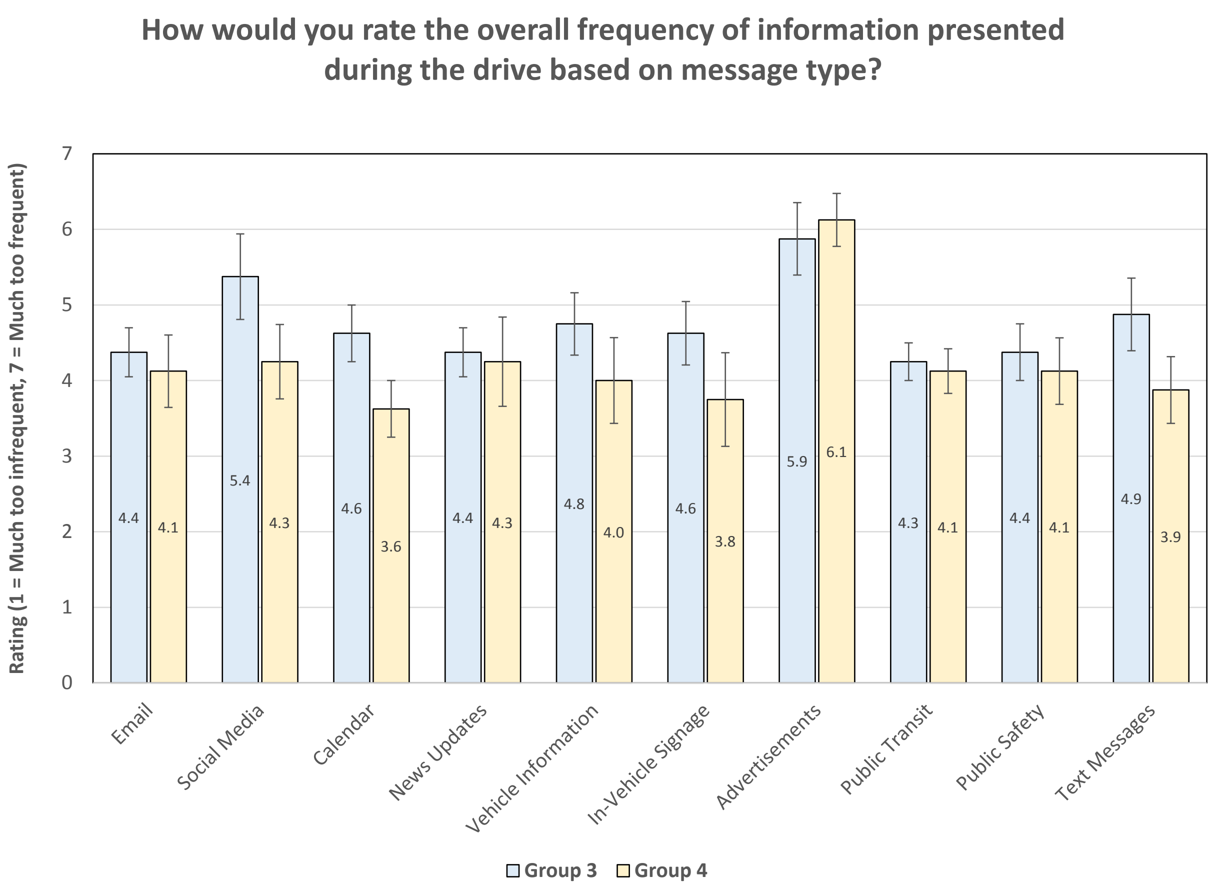

Figure 33. Post-study: overall frequency of information – Groups 3 and 4

The following table provides a summary of the most frequent responses provided within the open-ended questions included in the post-drive questionnaire.

Table 20. Post-Drive Open-Ended Questions – Frequent Responses

What aspects of the CVS did you like?		
Participants		**General Comment**
9/16	56.3%	Comments associated with in-vehicle signage information (e.g., liked speed limit and/or pedestrian crossing notifications)
8/16	50.0%	Comments associated with text and emails (e.g., liked text and/or email messages)
4/16	25.0%	Comments associated with voice prompts (speech modality)
What aspects of the CVS did you dislike?		
Participants		**General Comment**
12/16	75.0%	Comments associated with advertisements, primarily addressing the presentation frequency and general dislike
Is there anything about the CVS you would change?		
Participants		**General Comment**
6/16	37.5%	Comments associated with decreasing the overall message frequency
2/16	12.5%	Comments associated with increasing the customization capabilities of the CVS (e.g., customize prioritization, message differentiation through different tones)

Improvements of Dynamic Integrator Changes

In round two, the initial system configuration was directly compared with a user-modified system configuration where the following changes were implemented. Improvements are summarized based on observations and feedback provided throughout two groups in round two.

High Priority Message Location Adjustment

With the location adjustment of higher priority messages from the center to the left center of the DVI, the route guidance information was no longer obscured. Specific to messages that participants glanced towards, a significant reduction in dismiss rates was observed following the modified presentation location.

Duration of Additional Detail Messages

Another primary change made between Groups 3 and 4 was reducing the detailed message display duration from 30 seconds down to 8 seconds. Due to the shortened expiration window, messages where additional detail was requested, on average, were presented for a significantly shorter duration for Group 4 participants, resulting in a significant reduction in frequency of dismissal. This indicates that reducing the duration of additional detail messages meant they were more likely to expire before participants felt compelled to dismiss them.

Modification to Vehicle Maintenance Icon

The last configuration change made was to the appearance of the vehicle maintenance icon in the Vehicle Information messages. It was expected that this change would more closely resemble the less-than-urgent general maintenance notification. With a very limited sample size, no significant difference in how participants reacted to these messages was identified. In hindsight, it would have been more impactful to also adjust the message text, as the implied urgency was likely still too high.

CHAPTER 4. DISCUSSION

The chosen study design proved effective, as the targeted groups allowed for capturing a useful range of objective and subjective measures. Groups in the initial evaluation were effective in generalizing responses, but more importantly, for interpreting preferences based on open dialogue and responses to administered questionnaires. Based on these observations, modifications were made to the initial IA (Group 3) resulting in a 'user-modified' configuration (Group 4), and the comparisons therein allowed for a greater range of objective assessments.

INITIAL EVALUATION DISCUSSION

The initial evaluation was specifically designed to capture as much subjective feedback as possible. The think-aloud approach was used to capture perceptions and preferences in real-time, so as not to rely solely on reflection within a post-drive questionnaire. This feedback provided opportunities for content analysis via assessing feedback that represented opinions across the sample of drivers. Furthermore, feedback provided throughout the route, in conjunction with the objective observations, supported the targeted adjustments made for the user-modified configuration. Ultimately, these initial groups provided additional insight into overall preferences and suggestions for change, tied to natural exposure within a CV environment.

A common theme throughout data collection indicated a strong preference for the inclusion of speech within an interface of this design. Speech was provided by default for higher priority messages, but available for the lower priority messages only when additional detail was requested. This approach was selected both to simply include speech for lower priority messages only when requested, and also to minimize the amount of information participants would have to read. Pre- and post-drive questionnaire responses revealed that the desire for speech across most message categories was high.

Objective data collection involving Groups 1 and 2 revealed that over 30% of the high-priority center-screen messages were dismissed before their assigned expiration of 10 seconds. Accompanied by speech, these messages were presented visually in the center of the screen, on top of the on-going route guidance. Feedback captured using the think-aloud approach revealed that many times these messages were dismissed due to the fact that they blocked route-guidance information participants deemed useful to driving. As a result, relocating the presentation of these high-priority messages to the left side of the screen was a targeted change made within the user-modified configuration.

Data collection further revealed that over 85% of the additional-detail messages were dismissed before their assigned expiration of 30 seconds. These were presented in the same location as the high priority messages, and thus yielded the same conclusion that they blocked relevant route-guidance information. Subjective feedback confirmed that these messages were presented for far too long, and the decision was made to adjust presentation time down to 8 seconds, as the majority (69%) had been manually dismissed within this timeframe, and this time was still long enough to accommodate the longest audio file.

Observations of no-response following message presentation also provided further insight into management of driver workload, revealing cases where messages should not be presented once assessment of workload is incorporated as part of the IA. The IA should be capable of anticipating upcoming driving maneuvers (e.g., lane change, signal change) and modify the timing of message presentation.

The ability to apply filters is one that participants readily took advantage of, providing a clear indication of which message types, at least within this environment, were of interest. By the end of the route, many of the advertisement related messages were subdued, along with social requests. Across the 18 message categories and sub-categories, participants, on average, filtered out 7.

POST-MODIFICATION DISCUSSION

Following the implementation of solutions based on major usability issues identified through the initial evaluation, testing continued with Groups 3 and 4, allowing for comparisons to be made between the initial and user-modified configurations. Observations demonstrated that, for the high-priority messages that drivers glanced towards, the dismissal rate dropped from 35% down to 25% due to the adjusted presentation location. Furthermore, dismissal rates of requested additional detail messages dropped from 69% down to 37% for Groups 3 and 4, respectively, supporting the decision to reduce display time for these message types.

Although comparisons across vehicular control did not reveal differences between the two conditions at a high level, assessing performance across both demonstrated a positive impact on vehicle speed following the presentation of messages related to speed limit. Across both conditions, participants altered their speed to be closer to the speed limit in approximately 70% of all cases for both configurations. The lack of differences herein was not surprising, as the general presentation of information within the environment was unchanged, and targeted modifications were simply designed to reduce distraction and unnecessary interaction.

Eye-glance analysis did more to reveal differences across message applications than behavioral differences between the initial and use-modified configurations. Messages related to vehicle information (maintenance) resulted in a higher frequency of glances per presentation. The modification made to the maintenance icon, unfortunately, did little to quell the perceived urgency of this message, which was intended to be informational.

Importantly, overall agreement that the CVS performed well was high for both Groups 3 and 4. Although no significant findings were reported, Group 3 presented some interesting trends in the results section, particularly with regard to the higher rating of e-mail, calendar, and text message applications for usefulness and appropriateness of the messages.

The open-ended responses were consistent in that the majority of participants, whether they experienced the initial system configuration or the user-modified configuration, felt that the frequency of messages could be reduced and that the majority of the messages were useful. Expectedly, a common theme was the desire to filter certain messages and customize notifications to distinguish priority. The majority of participants did not like advertisements being presented and felt that they were too distracting and were presented too frequently.

Moreover, the majority of participants liked the in-vehicle messages, particularly speed limit notifications and the use of speech to present the information. The use, size, and location of a visual icon in addition to speech is an area that might benefit from further research.

CHAPTER 5. CONCLUSION

This proof-of-concept effort continued where previous work left off, developing a working interface that would allow for evaluating the IA, as currently envisioned (Doerzaph, Sullivan, J. Bowman, & Angell, 2013) within a representative CV environment. The research team worked closely with engineers at VTTI to create a representative interface that would allow for the customizability required for data collection (phase 1). Through bench- and in-vehicle testing, refinements continued and included feedback related to the device and study design from human factors experts (phase 2). A formal evaluation involving participant drivers was conducted within the Virginia Connected Corridor environment (phase 3), directly targeting the identified research questions.

The formal evaluation consisted of four groups of participants. Group 1 allowed drivers to experience the CVS while driving along a pre-determined route, during which a think-aloud approach was used to capture as much feedback as possible related to preferences, perceptions, likes/dislikes, etc. Participants in Group 2 were provided with the opportunity to take this approach a step further, by requesting what message categories they would like to filter out due to disinterest. These groups, combined, provided a useful representation of driver opinions, but more importantly helped guide adjustments that were intended to improve the overall user experience.

Groups 3 and 4 thereafter provided opportunities to evaluate user performance and perceptions in a more representative environment without the extended conversation between the participant and experimenter. Group 3 exposed participants to the original configuration, while those in Group 4 experienced the user-modified configuration, incorporating the adjustments made following analysis of objective and subjective data captured during Groups 1 and 2.

Details in terms of how this ensuing research addressed the targeted research questions are provided below. Ultimately, this proof-of-concept demonstrated the usefulness and impact provided by an IA within a CV environment. With further development and testing, information gained can continue to feed into guidelines associated with an optimal system configuration that will benefit original equipment manufacturers (OEMs), suppliers, system developers, etc.

ANSWERS TO RESEARCH QUESTIONS

The methodology of research efforts within this task was driven by five research questions, repeated below. Responses to these research questions are provided below following the conclusion of this study.

1. **How feasible is it to implement the Integration Architecture into a connected vehicle system environment? Simply put, how does the Integration Architecture handle a simulated CV environment, and what can we learn from hands-on observations?**

The research team, while overseeing an internal development team at VTTI, was able to effectively implement the IA into a connected vehicle environment as currently envisioned.

Certainly, the IA is complex, yet it is required to effectively manage message presentations within a CV environment. Although the initial configuration was the result of countless hours of development and internal testing, formal evaluations quickly revealed the existence of adjustments that could be made in an effort to continually refine the IA. The prototype DI administered the management of messages as expected even with the known limitations of the system. There is a great deal to learn from this effort in terms of additional research areas worth targeting. Ultimately, this effort demonstrated that with references and standards allowing for appropriate prioritization guidelines, a well-executed interface with effective message presentation is certainly achievable.

Importantly, the research team learned that the potential to overwhelm a driver with messages is easily achieved within certain environments. Messages chosen and presented along the route represented only a fraction of the number of messages that are possible given the number of business and infrastructure-related opportunities that exist for notification. That considered, 56% of participants made comments suggesting that the message frequency was too high. Outside of a controlled environment, the availability of filters to subdue selected message types plays a critical role in reducing messages a driver is clearly not interested in.

The DVI and methods in which messages are presented are crucial in terms of providing drivers with the level of information needed without increasing the potential for distraction. A CV environment will present a wide range of non-driving related message types, and it is important to communicate relevance/importance in such a manner that drivers don’t feel compelled to respond if focus is required elsewhere.

It was easy to identify possible areas of improvement during the early stages of data collection. Improvements were made, of course, in an effort to create a ‘user modified’ configuration; other possible changes were subsequently revealed, but would have required additional development and time that this proof-of-concept effort could not support. Minor alterations that the study could accommodate, including re-locating the high priority messages and reducing display time for additional detail messages, were shown to provide additional benefit.

2. What user preference adjustments to the architecture do drivers make or desire?

Expectedly, drivers made full use of their ability to filter out messages they weren’t interested in. For Group 2 participants, the majority of participants (63%; 5/8) applied filters to many advertisement sub-categories (automotive, banking, food, promotion, and retail), along with public transit (50%; 4/8) and social media (75%; 6/8) requests by the time they completed the test route. On average, participants applied 7 filters out of the available 18 message categories and sub-categories.

Interestingly, the message categories participants most frequently chose to suppress directly correspond with content that should not be presented visually while driving, per NHTSA’s visual-manual distraction guidelines (NHTSA, 2013). Along these same lines, the majority of participants who had a preference for how social media and text message-related notifications were presented felt the visual component should be eliminated, preferring to emphasize speech feedback sized instead.

Comments captured revealed other desires as well. For example, a majority (56%) of round 1 drivers expressed a desire for the ability to pause a message or even display a list of previously displayed messages to go back to if missed (or trumped). It is important to note that there are distraction-related concerns for doing so that would need to be evaluated. In general, participants found the speed limit messages useful, although comments suggested that these should be presented simply when entering a new roadway or area with no signs (44%) and/or when the speed limit changed (25%). Similarly, comments were also made suggesting that pedestrian crossing notifications should only be made when a pedestrian is present (13%).

Other items that should be investigated further include providing users with the ability to modify presentation duration and the prioritization parameters. In general, performance and subjective feedback support the prioritizations applied within the tested configurations, but users may have differing opinions on how messages are prioritized, especially when considering sub-categories (e.g., advertisements). It's likely that a user may be interested in a variety of advertisement categories, but would prioritize certain subcategories (e.g., food) over another.

Overall, drivers expressed a general desire to have more input in customizing the parameters to their liking. Having the ability to customize (where applicable) allows the user to make desired personal changes such as adjusting message expiration time, when a message is presented (start or end of trip), types of message based on destination (local versus out of town travel), and the ability to go back to previously presented information. Drivers, in general, want to have more control over how, when, and what is presented.

3. **What is an appropriate determination of workload, based on a combination of internal and external demands? Furthermore, how should the architecture process and use this information?**

A combination of external and internal factors, including secondary task engagement, traffic flow, road type (commercial versus highway), and individual differences all contribute to driver workload. Drivers tended to access more information when workload was low (e.g. traffic stopped), while ignoring messages when workload was high (such as during a lane change, or conversation). In a total of 51 cases in Group 1, messages were presented when the research vehicle was stopped for a red light or due to heavy traffic, most of which happened to be from the Advertising or Internet/Social Network category. The rate of observed interaction was 40% while stopped, noticeably higher compared to the overall trip average (31.5%), all advertising messages within the entire trip (10.5%), and all Internet/social network messages in the entire trip (37.5%). Comparatively, among 106 cases where participants ignored presented messages and did not show any coded response in Group 1, over 85% was due to high workload (58% due to conversation, and 27% due to lane change/mirror check).

The architecture can be further improved to optimize the presentation timing based on a driver's workload and minimize the workload it takes for drivers to access its information. For example, the IA should recognize when the participant is engaged in a phone conversation, as this would theoretically be tied into the in-vehicle interface, and lower-priority messages would be subdued during periods of phone conversation. It's far easier for the IA to accommodate driving-related workload. For example, activation of the turn signal indicating an upcoming maneuver, assessments of traffic density, etc. could negate the issuance of non-driving-related messages.

4. Continue investigating appropriate driver-vehicle interface characteristics to ensure message presentation is appropriate to the environment, while continuing to provide input into the principles document.

The presentation of information remains an area for further research. Although this study suggested that speech was the preferred modality for most application categories, further research should consider other factors such as workload, hearing impairment, interference with the vehicle's audio and navigation systems, etc. Speech certainly benefits message-types that would otherwise require a level of reading that would be inappropriate while driving (e.g. text messages), as it was likely a strong contributor within this effort in terms of minimizing longer off-road glances

Determining the appropriate length of message presentation should be a focus of additional research as well. Adjustments were made within this effort, but it's likely that presentation durations should vary across message types and priority levels. Furthermore, special considerations should be made related to the location of message presentation on the screen. The original configuration deemed that high-priority messages be presented in the center of the DVI, complementing the implied urgency and/or relevance to the driving environment. However, observations quickly revealed that the route guidance information of importance was also presented in the center, and was obstructed whenever a higher-priority or additional detail messages was issued.

5. To what extent does the Integration Architecture increase driver safety in a CV environment?

Relative to an environment where messages are issued in a free-flowing manner, the IA is expected to increase driver safety within a CV environment by managing message presentation across the parameters of filtering, scheduling, and prioritization. This approach takes into consideration what should be presented to the driver based on defined criteria, even allowing for trumping of messages in cases where the need to present a higher priority message is determined.

Ultimately, it was determined that the IA not be compared to a free-flowing environment, as this would be considered stacking the deck. Instead, the initial configuration was compared to one that was 'user-modified' following targeted modifications based on earlier subjective and objective observations. Although measureable differences weren't necessarily achieved, both demonstrated positive influence in driver behavior, as the majority of speed limit messages resulted in adjustments in speed closer to the speed limit.

Assuming that CV environments with an overwhelming number of messages are in our future, it is critical that all attempts are made to determine the optimum method of presentation, targeting driving and glance behavior as factors to consider.

LIMITATIONS OF RESEARCH

It should be noted that this study was conducted using a simulated CV V2I environment, which presented limitations and challenges that would not have been present in a fully integrated and connected vehicle environment. As a prototype system, some further improvements can be made in the future.

First, the selected approach relied on an existing route-guidance application running in the background, while the prototype interface managed the remaining applications. As such, the CVS messages were not always in sync with navigation application and there were cases where the audio from the messages played simultaneously with the navigation application's audible directions. This was minimized to the extent possible, but varying rates of interaction impacted the timing of messages as discussed throughout the report.

Second, the prototype interface was limited in its ability to customize and vary messages using multiple criteria. In ideal circumstances, the timing and modality of message presentation should have variability based on the unique characteristics of each message.

A third limitation is related to the current interface's lack of consideration for driver workload. However, this effort provided additional insight into how to incorporate workload into the IA's decision making. Workload estimations should be incorporated into message management, and message demand could be estimated based on presentation modality and driving context. For example, it may be more appropriate to present vehicle maintenance related messages only when the engine is first turned on rather than in the middle of a typical commute, unless the operation or safety of the vehicle is compromised.

Furthermore, the system can be improved to recognize repeat messages. In the current configuration, the system bundles both visual and audio channels. Both channels were triggered for repeated messages even when some of them (mostly audio) had finished in the previous presentation, leading to messages becoming redundant and distracting.

The user-modified configuration in the final phase was based on the most critical observations made from drivers' feedback and performance data. There were others changes considered that were not adopted in the user-modified configuration due to time constraints, but which would be worth considering in future research. These include accommodating expired messages that drivers can recall, or linking certain messages to navigation, phone, etc. Another consideration was making message backgrounds transparent or of varied color so that information presented behind the messages was not entirely obstructed, which could potentially address drivers' desirability to dismiss messages.

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APPENDIX A. RECRUITMENT FLYER

Wanted for Research Study

The Virginia Tech Transportation Institute (VTTI) is seeking individuals, in the Fairfax County, Virginia area who:

- are 25-50 years old
- have a valid U.S. driver's license
- use a touch screen on a Smart phone or tablet

➢ Drive our Research Vehicle on Public roads around I-66, US 29, US 50, & I-495
➢ Total participation time: 1 visit, during the daytime, lasting about 2.5 hours
➢ This research project pays $95 for full participation
➢ Your data will be kept strictly confidential

If you are interested in learning more,

Please contact us at: e-mail[redacted]
Reference "the Delta Study" in your message
All inquiries welcome!

www.vtti.vt.edu

APPENDIX B. PHONE SCRIPT

HFCV - NOVA (Delta) Screening Questionnaire

Note to Researcher:

Initial contact between participants and researchers may take place over the phone. If this is the case, read the following Introductory Statement, followed by the questionnaire. Regardless of how contact is made, this questionnaire must be administered verbally before a decision is made regarding suitability for this study.

Introductory Statement:

After prospective participant calls or you call them, use the following script as a guideline in the screening interview.

Hello. My name is _____ and I'm with the Virginia Tech Transportation Institute. We are currently recruiting people to participate in a research study in the Northern, Virginia area. This study involves participating in one session lasting approximately 2.5 hours during daytime hours. You will be asked to evaluate technology while you are driving on the public roads in the Fairfax, Virginia area.

This study has several parts to it. First, we would need you to come to our office in Falls Church, VA to fill out a short demographic questionnaire and pass a simple vision and hearing test. The second part of the study involves driving our research vehicle around a pre-planned route, mostly on I-66, US 29, US 50 and I-495 during which time you will experience some in-vehicle messages. Two experimenters will be in the vehicle with you during the drive. The research vehicle is instrumented with data collection equipment, including video cameras which will record you while you drive. All participants will be asked to come in for a session during normal business hours (M-F, 8-5).

This project pays $95 in the form of a check for full participation ($90 for participation in the study and $5 to cover parking). Does this sound interesting to you?

If yes, I need to go over some screening questions to see if you meet all the eligibility requirements. Any information given to us will be kept secure and confidential.

Do I have your consent to ask the screening questions? If yes, continue with the questions. If no, then thank him/her for their time and end the phone call.

1. Do you have a valid U.S. driver's license?
    - Yes - If yes, how long have they had a license?____________________
    - No

2. What is your current age? _______________(Stop if not 25-50 years old)

3. On Average how many days a week do you drive? ______________

4. Are you a U.S. Citizen?
    - Yes
    - No

If not a U.S. Citizen: Do you have a green card?

- Yes
- No

5. Are you willing to provide your social security # should you participate, as required by the University? (explain they will be asked to complete a W-9 if they ask why)
    - Yes
    - No (If No, then they do not qualify)

Please note that for tax recording purposes, the fiscal and accounting services office at Virginia Tech (also known as the Controller's Office) requires that all participants provide their social security number to receive payment for participation in our studies. Or if a VT employee they may provide their VT employee #.

6. Do you use a touch screen smartphone or tablet at least 5 times a week?

Yes______ No_____

7. Are you comfortable interacting with technology while driving (e.g., following route guidance from a navigation system)?

- Yes _____
- No _____

8. Are you familiar with using navigation and route guidance devices?

- Yes _____
- No ______

9. Are you available to participate in a session during normal office hours (M-F, 8-5)?

- Yes _______
- No _______

10. Are you able to drive an automatic transmission without assistive devices or special equipment?

- Yes
- No

11. Have you had any moving violations in the past 3 years? If so, please explain.

- Yes ____
- No

12. Have you been involved in any auto accidents in the past 3 years? If so, please explain.

- Yes ____
- No

We need to ask a few questions about your medical history…

13. Do you have a history of any of the following medical conditions? If yes, please explain.

a. Neck or back pain or injury to these areas

- Yes_____________
- No __________

b. Head injury, stroke, or illness or disease affecting the Brain

- Yes_____________
- No __________

c. Current Heart condition (cannot be current heart condition, which limits their activity)

- Yes_____________
- No ___________

d. Current respiratory disorder or any condition which requires oxygen

- Yes_____________
- No ____________

e. Epileptic seizures or lapses of consciousness within the past 12 months

- Yes_____________

- No ___________

f. Chronic migraines or tension headaches (more than 1/month during the past year)

- Yes_____________
- No ___________

g. Current Inner ear problems, dizziness, vertigo, or any balance problems

- Yes_____________
- No ____________

h. Uncontrolled Diabetes?

- Yes_____________
- No _________

i. Have you had major surgery in the past 6 months? Eye surgery/procedure in the past 6 months?

- Yes_____________
- No _________

j. Are you taking any substances on a regular basis which could impair your motor skills or your ability to drive?

- Yes_____________
- No __________

14. (Females only) Are you currently pregnant? Yes__________ No________ (if "yes," politely inform the participant: while being pregnant does not disqualify you from participating in this study, you are encouraged to talk to your physician about your participation to make sure that you both feel it is safe. If you like, we can send you a copy of the consent form to discuss with your physician. Answer any questions)

15. Are you able to fluently read, write, and speak English

- Yes __________
- No ___________

16. Do you have normal, or corrected to normal, hearing and vision? Both eyes? Ears? If no, please explain.

- Yes __________
- No ____

17. For this study, you will be asked to drive without sunglasses. Will this present a problem should you be eligible to participate?

- Yes __________
- No ___________

Do you wear eyeglasses that tint or darken in the sunlight (while seated in a vehicle)?

- Yes __________
- No ___________

If not Eligible: Would you like to be contacted for future studies? Yes: ______ No: _______

Please send Database Information Letter: Name: ___________________________

E-mail or mailing address: ______________________________ YOB: ____________________

If Eligible:

Name: _____________________________ Phone: ___________________________________

E-mail or mailing address: ____

Availability: ____

Scheduled on (date & time):____

Town or city: ___________________ approximate travel time to VT NVC: ____________

Would you like to be contacted for future studies? Yes: ______No: ______YOB:__________

Primary Vehicle: ___________________________ Specialty License: ____________________

Criteria For Participation

1. Must hold and able to present a valid U.S. driver's license at time of participation and be an experienced driver (at least 2 years).
2. Must be 25-50 years old.
3. Must currently drive at least 3 days a week (on average).
4. Must be a U.S. citizen or permanent resident (green card holder).
5. Must be willing to provide SSN or VT ID #.
6. Must use a touch screen smartphone or tablet at least 5 times a week on average.
7. Must be familiar with using navigation and route guidance devices.
8. Must be comfortable interacting with technology while driving (e.g., following route guidance from navigation device)
9. Must be available during normal office hours.
10. Must be able to drive an automatic transmission without assistive devices or special equipment.
11. Must not have more than two driving violations in the past 3 years.
12. Must not have caused an injurious accident within the past 3 years.

13. Health Questions:

    a. Cannot have a history of neck or back conditions which still limit their ability to participate in certain activities.

    b. Cannot have a history of brain damage from stroke, tumor, head injury, recent concussion, or disease or infection of the brain.

    c. Cannot have a current heart condition which limits their ability to participate in certain activities.

    d. Cannot have current respiratory disorders or disorders requiring oxygen.

    e. Cannot have had epileptic seizures or lapses of consciousness within the last 12 months.

    f. Cannot have chronic migraines or tension headaches (averages no more than one per month).

    g. Cannot have current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems.

    h. Cannot have uncontrolled diabetes (have they been recently diagnosed or have they been hospitalized for this condition, or any changes in their insulin prescription during the past 3 months)

    i. Must not have had any major surgery within the past 6 months (including eye procedures).

    j. Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities).

14. If pregnant, encourage them to speak with their doctor first.

15. Must be able to fluently read, write, and speak English

16. Must have normal (or corrected to normal) hearing and vision in both eyes.

17. Eyeglasses must not tint or darken in the sunlight while sitting inside the research vehicle. Must be able to drive without sunglasses.

APPENDIX C. INFORMED CONSENT GROUPS 1 & 2

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

Title of Project: Validations of Integrated DVI Configurations

Investigators: Zac Doerzaph, Luke Neurauter, LaTanya Holmes, Miao Song, and Nicholas Britten; Virginia Tech Transportation Institute

I. THE PURPOSE OF THIS RESEARCH PROJECT

Connected vehicle systems (CVS) is an upcoming technology that will allow vehicles to communicate with other vehicles, roads, buildings, and traffic signs. This technology is expected to improve roadway safety, mobility, and efficiency. It is currently envisioned that drivers will be notified of information relevant to their location or direction of travel, presented to the driver on an in-vehicle display.

This research will examine the performance of a CVS device that manages message presentation, with the intent that messages are prioritized and presented when appropriate. Your feedback and opinions related to message presentation is of interest. The results of this study will help to further refine design considerations for future CVS applications.

II. PROCEDURES

During your time here you will be asked to perform the following tasks.

1. Read this Informed Consent Form and sign it if you agree to participate.
2. Show a valid driver's license.
3. Complete a brief pre-drive questionnaire.
4. Complete vision and hearing tests.
5. Undergo training, including the opportunity to practice interacting with a CVS while parked.
6. Drive an instrumented vehicle on a predetermined route in and around Fairfax County, Virginia. While you are in the vehicle, digital video including your face and audio will be recorded. Two experimenters will be in the car at all times.
7. Maintain safe operation of the research vehicle and follow all laws, posted signs, speeds, etc.
8. Follow route guidance provided by a navigation system and/or the in-vehicle experimenter.
9. Experience the CVS and provide feedback using a think aloud approach on messages presented throughout the drive.
10. Complete a brief post-drive questionnaire related to the CVS. This questionnaire will not be associated with you or your name in any way.

Digital cameras will record continuous video and audio of you while the vehicle is turned on. A data acquisition system will also be recording continuous driving performance data which includes speed, GPS location, lane position, driver head pose, and multi-axis accelerometers.

It is important that you understand we are not evaluating you in any way. We are collecting information about how drivers interact with a CVS. By participating you are helping us evaluate an important aspect of this upcoming technology. Any tasks you perform, or opinions you have will only help us do a better job of designing the systems and providing recommendations. Therefore, we ask that you perform to the best of your abilities. The information and feedback that you provide is very important to this project. This experiment is expected to last approximately 2.5 hours.

III. RISKS

Caution should be exercised when operating an unfamiliar vehicle. Be aware that accidents can happen at any time while driving.

As a participant, you may be exposed to the following risks or discomforts by volunteering for this research:

1. The risk of an accident normally associated with driving an unfamiliar automobile on public roads during the daytime hours while using new and unfamiliar technology.
2. Possible fatigue due to the length of the experiment.
3. Please be aware that events such as equipment failure, stray or wild animals entering the road, pedestrians, and weather changes may require you to respond accordingly. If at any point in the session the experimenter believes that continuing the session would endanger you or the equipment, he/she will stop the testing.
4. If you are pregnant you should talk to your physician and discuss this consent form with them before making a decision about participation.
5. While you are driving the research vehicle, cameras will videotape you. Due to this fact, we ask that you do not to wear sunglasses (or glasses which tint in sunlight). If this, at any time, impairs your ability to drive the vehicle safely, please notify the experimenter.

The following precautions will be taken to ensure minimal risk to you:

1. The study takes place on a pre-determined route that the experimenters are familiar with.
2. You may take breaks or decide not to participate at any time.
3. Study hours have been selected to avoid peak travel and rush hour traffic.
4. Two experimenters will be present in the vehicle at all times, one in the front seat and one in the back seat. However, as long as you drive the research vehicle, it remains your responsibility to drive in a safe and legal manner.
5. The vehicle is equipped with a driver's side and passenger's side airbag supplemental restraint system, fire extinguisher, and first-aid kit. The experimenter has a cell phone
6. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.

7. The experiment will run only during clear weather or rain that does not require more than the lowest wiper setting.
8. You will be required to wear the lap and shoulder belt restraint system while in the car.
9. In the event of a medical emergency, or at your request, VTTI staff will arrange medical transportation to a nearby hospital emergency room.
10. You do not have any medical condition that would put you at greater risk, including but not restricted to history of brain damage, current heart condition, or surgery within in the last 6 months.
11. You will be trained how to use the in-vehicle system while the vehicle is parked so you will be familiar with it when you are driving.
12. The experimenter will not engage in casual conversation with you during the driving portions of the study.
13. The experimenter will not prompt you for feedback on the systems during demanding traffic situations such as merges.

In the event of an accident or injury in the automobile, the automobile liability coverage for property damage and personal injury is provided. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expenses would go to the insurer of the other party's vehicle) would apply in case of an accident for all volunteers and would cover medical expenses up to the policy limit. For example, if you were injured in an automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by this policy.

Participants in a study are considered volunteers, regardless of whether they receive payment for their participation; under Commonwealth of Virginia law, workers compensation does not apply to volunteers; therefore, if not in an automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses. For example, if you were injured outside of this automobile during the project, the cost of transportation to the hospital emergency room would be covered by your insurance.

IV. BENEFITS

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is made to encourage you to participate. Participation in this study will contribute to the improvement of connected vehicle systems which could increase the safety of our nation's surface transportation system.

V. EXTENT OF ANONYMITY AND CONFIDENTIALITY

The data gathered in this experiment will be treated with confidentiality. Shortly after participation, your name will be separated from your data. A coding scheme will be employed to identify the data by participant number only (e.g., Participant No. 1). You may elect to have your data withdrawn from the study if you so desire, but you must inform the experimenters immediately of this decision so that the data may be promptly removed. It is possible that the

Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

All video and other data recorded in this study will be stored in a secured area at Virginia Tech. Access to the data files will be under the supervision of the Principal Investigator and lead VTTI researchers involved in the project. All data will be encrypted at the time of data collection and will be decrypted only for approved analyses. It is possible that, after data collection is complete one copy of study data will be transferred to the National Highway Traffic Safety Administration, also known as the project sponsor, (the U.S. Department of Transportation) for permanent storage and oversight. Please note that they will follow the same procedures for protecting participant confidentiality.

Authorized project personnel and authorized employees of the NHTSA will have access to the study data that personally identifies you or that could be used to personally identify you and may use it for authorized purposes both during and after data collection. As explained below, other qualified research partners may also be given limited access to your driver, vehicle, and driving data, solely for authorized research purposes and with the consent of an IRB. This limited access will be under the terms of a data sharing agreement or contract that, at a minimum, provides you with the same level of confidentiality and protection provided by this document. However, even these qualified researchers will not be permitted to copy raw study data that identifies you, or that could be used to identify you, or to remove it from the secure facilities in which it is stored without your consent.

VI. COMPENSATION

You will be paid $95.00 for complete participation. If you choose to withdraw before completing the study, you will be compensated for the portion of time of the study for which you participated. If these payments are in excess of $600 dollars in any one calendar year, then by law, Virginia Tech is required to file Form 1099 with the IRS. For any amount less than $600, it is up to you as the participant to report any additional income as Virginia Tech will not file Form 1099 with the IRS.

VII. FREEDOM TO WITHDRAW

As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. Furthermore, you are free not to answer any question or respond to experimental situations without penalty. If you choose to withdraw while you are driving, please inform the experimenter of this decision and he/she will provide you with transportation back to the building.

VIII. APPROVAL OF RESEARCH

Before data can be collected, this research must be approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech and by the Virginia Tech Transportation Institute. You should know that this approval has been obtained. This form is valid for the period listed at the bottom of the page

IX. PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in this study, you will have the following responsibilities:

1. To follow the experimental procedures as well as you can.
2. To inform the experimenter if you have difficulties of any type.
3. To wear your seat and lap belt.
4. To abstain from any substances that will impair your ability to drive.
5. To obey traffic regulations and maintain safe operation of the vehicle at all times.
6. To drive the test vehicle in a safe and responsible manner.
7. To treat the driving task as the primary task and interact with the system only when it is safe to do so.

X. PARTICIPANT'S PERMISSION AND ACKNOWLEDGMENTS

I understand that VTTI and NHTSA (the project sponsor) may show my digital audio (sound) and video files including my face for research and research reporting purposes in presentations at conferences and briefings while the study on ongoing and after the study is complete.

Check all that apply:

- ☐ I am not under the influence of any substances or taking any medications that may impair my ability to participate safely in this experiment.
- ☐ I am in good health and not aware of any health conditions that would increase my risk including, but not limited to lingering effects of a heart condition.
- ☐ I have informed the experimenter of any concerns/questions I have about this study.
- ☐ I understand that digital video including my face image and audio will be collected as part of this experiment.
- ☐ If I am pregnant, I acknowledge that I have either discussed my participation with my physician, or that I accept any additional risks due to pregnancy.

XI. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

____

Participant Signature Date

Experimenter Signature   Date

Should I have any questions about this research or its conduct, I may contact:

Dr. Zac Doerzaph	[redacted
Luke Neurauter	[redacted
LaTanya Holmes	[redacted]
Miao Song	[redacted]

If I should have any questions about the protection of human research participants regarding this study, I may contact:

Dr. David Moore,
Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects
Telephone: [redacted
E-mail: [redacted]

APPENDIX D. INFORMED CONSENT GROUPS 3 & 4

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects V2

Title of Project: Validations of Integrated DVI Configurations

Investigators: Zac Doerzaph, Luke Neurauter, LaTanya Holmes, Miao Song, and Nicholas Britten; Virginia Tech Transportation Institute

I. THE PURPOSE OF THIS RESEARCH PROJECT

Connected vehicle systems (CVS) is an upcoming technology that will allow vehicles to communicate with other vehicles, roads, buildings, and traffic signs. This technology is expected to improve roadway safety, mobility, and efficiency. It is currently envisioned that drivers will be notified of information relevant to their location or direction of travel, presented to the driver on an in-vehicle display.

This research will examine the performance of a CVS device that manages message presentation, with the intent that messages are prioritized and presented when appropriate. Your feedback and opinions related to message presentation is of interest. The results of this study will help to further refine design considerations for future CVS applications.

II. PROCEDURES

During your time here you will be asked to perform the following tasks.

1. Read this Informed Consent Form and sign it if you agree to participate.
2. Show a valid driver’s license.
3. Complete a brief pre-drive questionnaire.
4. Complete vision and hearing tests.
5. Undergo training, including the opportunity to practice interacting with a CVS while parked.
6. Drive an instrumented vehicle on a predetermined route in and around Fairfax County, Virginia. While you are in the vehicle, digital video including your face and audio will be recorded. Two experimenters will be in the car at all times.
7. Maintain safe operation of the research vehicle and follow all laws, posted signs, speeds, etc.
8. Follow route guidance provided by a navigation system and/or the in-vehicle experimenter.
9. Experience the CVS.
10. Complete a brief post-drive questionnaire related to the CVS. This questionnaire will not be associated with you or your name in any way.

Digital cameras will record continuous video and audio of you while the vehicle is turned on. A data acquisition system will also be recording continuous driving performance data which includes speed, GPS location, lane position, driver head pose, and multi-axis accelerometers.

It is important that you understand we are not evaluating you in any way. We are collecting information about how drivers interact with a CVS. By participating you are helping us evaluate an important aspect of this upcoming technology. Any tasks you perform will only help us do a better job of designing the systems and providing recommendations. Therefore, we ask that you perform to the best of your abilities. The information that you provide following your drive today is very important to this project. This experiment is expected to last approximately 2.5 hours.

III. RISKS

Caution should be exercised when operating an unfamiliar vehicle. Be aware that accidents can happen at any time while driving.

As a participant, you may be exposed to the following risks or discomforts by volunteering for this research:

1. The risk of an accident normally associated with driving an unfamiliar automobile on public roads during the daytime hours while using new and unfamiliar technology.
2. Possible fatigue due to the length of the experiment.
3. Please be aware that events such as equipment failure, stray or wild animals entering the road, pedestrians, and weather changes may require you to respond accordingly. If at any point in the session the experimenter believes that continuing the session would endanger you or the equipment, he/she will stop the testing.
4. If you are pregnant you should talk to your physician and discuss this consent form with them before making a decision about participation.
5. While you are driving the research vehicle, cameras will videotape you. Due to this fact, we ask that you do not to wear sunglasses (or glasses which tint in sunlight). If this, at any time, impairs your ability to drive the vehicle safely, please notify the experimenter.

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5. The vehicle is equipped with a driver's side and passenger's side airbag supplemental restraint system, fire extinguisher, and first-aid kit. The experimenter has a cell phone
6. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.

7. The experiment will run only during clear weather or rain that does not require more than the lowest wiper setting.
8. You will be required to wear the lap and shoulder belt restraint system while in the car.
9. In the event of a medical emergency, or at your request, VTTI staff will arrange medical transportation to a nearby hospital emergency room.
10. You do not have any medical condition that would put you at greater risk, including but not restricted to history of brain damage, current heart condition, or surgery within in the last 6 months.
11. You will be trained how to use the in-vehicle system while the vehicle is parked so you will be familiar with it when you are driving.
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All video and other data recorded in this study will be stored in a secured area at Virginia Tech. Access to the data files will be under the supervision of the Principal Investigator and lead VTTI researchers involved in the project. All data will be encrypted at the time of data collection and will be decrypted only for approved analyses. It is possible that, after data collection is complete one copy of study data will be transferred to the National Highway Traffic Safety Administration, also known as the project sponsor, (the U.S. Department of Transportation) for permanent storage and oversight. Please note that they will follow the same procedures for protecting participant confidentiality.

Authorized project personnel and authorized employees of the NHTSA will have access to the study data that personally identifies you or that could be used to personally identify you and may use it for authorized purposes both during and after data collection. As explained below, other qualified research partners may also be given limited access to your driver, vehicle, and driving data, solely for authorized research purposes and with the consent of an IRB. This limited access will be under the terms of a data sharing agreement or contract that, at a minimum, provides you with the same level of confidentiality and protection provided by this document. However, even these qualified researchers will not be permitted to copy raw study data that identifies you, or that could be used to identify you, or to remove it from the secure facilities in which it is stored without your consent.

VI. COMPENSATION

You will be paid $95.00 for complete participation. If you choose to withdraw before completing the study, you will be compensated for the portion of time of the study for which you participated. If these payments are in excess of $600 dollars in any one calendar year, then by law, Virginia Tech is required to file Form 1099 with the IRS. For any amount less than $600, it is up to you as the participant to report any additional income as Virginia Tech will not file Form 1099 with the IRS.

VII. FREEDOM TO WITHDRAW

As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. Furthermore, you are free not to answer any question or respond to experimental situations without penalty. If you choose to withdraw while you are driving, please inform the experimenter of this decision and he/she will provide you with transportation back to the building.

VIII. APPROVAL OF RESEARCH

Before data can be collected, this research must be approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech and by the Virginia Tech Transportation Institute. You should know that this approval has been obtained. This form is valid for the period listed at the bottom of the page

IX. PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in this study, you will have the following responsibilities:

1. To follow the experimental procedures as well as you can.
2. To inform the experimenter if you have difficulties of any type.
3. To wear your seat and lap belt.
4. To abstain from any substances that will impair your ability to drive.
5. To obey traffic regulations and maintain safe operation of the vehicle at all times.
6. To drive the test vehicle in a safe and responsible manner.
7. To treat the driving task as the primary task and interact with the system only when it is safe to do so.

XII. PARTICIPANT'S PERMISSION AND ACKNOWLEDGMENTS

I understand that VTTI and NHTSA (the project sponsor) may show my digital audio (sound) and video files including my face for research and research reporting purposes in presentations at conferences and briefings while the study on ongoing and after the study is complete.

Check all that apply:

- ☐ I am not under the influence of any substances or taking any medications that may impair my ability to participate safely in this experiment.
- ☐ I am in good health and not aware of any health conditions that would increase my risk including, but not limited to lingering effects of a heart condition.
- ☐ I have informed the experimenter of any concerns/questions I have about this study.
- ☐ I understand that digital video including my face image and audio will be collected as part of this experiment.
- ☐ If I am pregnant, I acknowledge that I have either discussed my participation with my physician, or that I accept any additional risks due to pregnancy.

XIII. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

____

Participant Signature   Date

Experimenter Signature Date

Should I have any questions about this research or its conduct, I may contact:

Dr. Zac Doerzaph	[redacted]
Luke Neurauter	[redacted]
LaTanya Holmes	[redacted]
Miao Song	[redacted]

If I should have any questions about the protection of human research participants regarding this study, I may contact:

Dr. David Moore,
Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects
Telephone: [redacted]E-mail: [redacted]u

APPENDIX E. PRE-DRIVE QUESTIONNAIRE

Note: The percentages in italics indicate the overall percentage breakdown of responses per question. All percentages are based off of N=32 unless documented otherwise

HFCV Pre-Drive Questionnaire

Thank you for participating in this study today. You will be asked to drive a research vehicle in a 'Connected Vehicle' environment. A connected vehicle environment is one where vehicles communicate with each other and the infrastructure (roadways, traffic signals, businesses, etc.) Corresponding messages are presented visually to the driver on an in-vehicle interface, accompanied either through speech or an auditory tone, all as part of a Connected Vehicle System (CVS). The questions presented below will ask you to provide your initial thoughts on the CVS and applications.

The following table breaks down categories of expected message types within a Connected Vehicle environment, providing examples of each to clarify associated message types. Please review prior to answering the included questions.

Application Category	Application Sub Category	Description
Mobility/Re-Route	Navigation	Mobility applications primarily included dynamic traffic re-routing information. Moving maps
In-Vehicle Signage	Speed Limit School Zone Road Sign Pedestrian Crossings	Non-imminent safety warnings will provide information on important and safety-relevant changes in the roadway ahead.
Advertising	Automotive Banking Food/Beverage Gas Promotions Retail	Advertisements and information regarding the presence of convenience-based businesses.

Vehicle Information	Maintenance	Information regarding the mechanical and service state of the vehicle such as tire pressure and required maintenance.
Internet/Social Network	Calendar/Meeting Notices E-mail News Social Media Text Messages	Facebook update such as new post from friends or news feeds. Local and national headlines Meeting/Appointment notices E-mails from work or personal e-mails
Public Transit	Metro	Public transit options, which are located within the vehicle vicinity.
Public Safety	Medical Care	Information provided to drivers regarding public safety notifications

1) Considering the magnitude of information available in a Connected Vehicle environment, what type of information do you think is appropriate to receive notification of while driving?

	Very Inappropriate (1)	(2)	(3)	Neutral (4)	(5)	(6)	Very Appropriate (7)
E-mail	1 (38%)	2 (31%)	3 (9%)	4 (9%)	5 (0%)	6 (9%)	7 (3%)
Social Media	1 (59%)	2 (25%)	3 (3%)	4 (3%)	5 (3%)	6 (3%)	7 (3%)
Calendar	1 (34%)	2 (13%)	3 (13%)	4 (13%)	5 (19%)	6 (3%)	7 (6%)
News Updates	1 (19%)	2 (28%)	3 (3%)	4 (31%)	5 (3%)	6 (0%)	7 (16%)
Vehicle Information	1 (6%)	2 (0%)	3 (0%)	4 (6%)	5 (19%)	6 (22%)	7 (47%)

In-Vehicle Signage	1 (0%)	2 (3%)	3 (0%)	4 (3%)	5 (31%)	6 (22%)	7 (41%)
Advertisements	1 (38%)	2 (25%)	3 (0%)	4 (16%)	5 (9%)	6 (6%)	7 (6%)
Public Transit	1 (9%)	2 (6%)	3 (9%)	4 (31%)	5 (22%)	6 (13%)	7 (9%)
Public Safety	1 (3%)	2 (3%)	3 (3%)	4 (16%)	5 (13%)	6 (25%)	7 (38%)
Text Messages	1 (44%)	2 (19%)	3 (3%)	4 (9%)	5 (6%)	6 (13%)	7 (6%)

2) If the information below were available in your personal vehicle, how would you like this information to be presented? Select all that apply.

	Text	Speech	Tone	No Preference	None
E-mail	Text	Speech	Tone	No Preference	None
Social Media	Text	Speech	Tone	No Preference	None
Calendar	Text	Speech	Tone	No Preference	None
News Updates	Text	Speech	Tone	No Preference	None
Vehicle Information	Text	Speech	Tone	No Preference	None
In-Vehicle Signage	Text	Speech	Tone	No Preference	None
Advertisements	Text	Speech	Tone	No Preference	None
Public Transit	Text	Speech	Tone	No Preference	None
Public Safety	Text	Speech	Tone	No Preference	None
Text Messages	Text	Speech	Tone	No Preference	None

	Modality								
Message Category	***Text***	***Speech***	***Tone***	***Text + Speech***	***Text + Tone***	***Speech + Tone***	***Text+Speech+ Tone***	***No Preference***	***None***
Email	6%	31%	22%	0%	0%	13%	3%	0%	25%
Social Media	6%	16%	19%	0%	0%	3%	3%	0%	53%
Calendar	3%	31%	16%	13%	0%	9%	0%	3%	25%
News Updates	6%	31%	22%	0%	0%	3%	3%	9%	25%
Vehicle Information	13%	41%	3%	9%	6%	13%	6%	6%	3%
In-Vehicle Signage	22%	25%	16%	13%	6%	9%	6%	3%	0%
Advertisements	13%	13%	9%	3%	0%	3%	0%	6%	53%
Public Transit	9%	25%	16%	0%	0%	3%	6%	16%	25%
Public Safety	13%	47%	6%	3%	6%	6%	13%	6%	0%
Text Messages	3%	34%	22%	3%	0%	9%	3%	0%	25%

APPENDIX F. STUDY ROUTE

Directions

1. Head southwest on Haycock Rd toward Leesburg Pike

2. Turn left onto VA-7 E

3. Turn right onto S Roosevelt St

4. Continue onto South St

5. Turn left to stay on South St

Continue on Arlington Blvd. Take I-66 W, Fairfax Blvd and US-29 to W Broad St in Falls Church

6. Take the 1st right onto Arlington Blvd

7. Take the Interstate 495 N ramp to Tysons Corner

8. Merge onto I-495 N

9. Take exit 49B-A for Interstate 66 W toward Front Royal

10. Merge onto I-66 W

11. Take exit 60 to merge onto VA-123 S/Chain Bridge Rd toward Fairfax

12. Turn left onto Fairfax Blvd

13. Turn right toward US-29

14. Turn left toward US-29

15. Slight right onto US-29

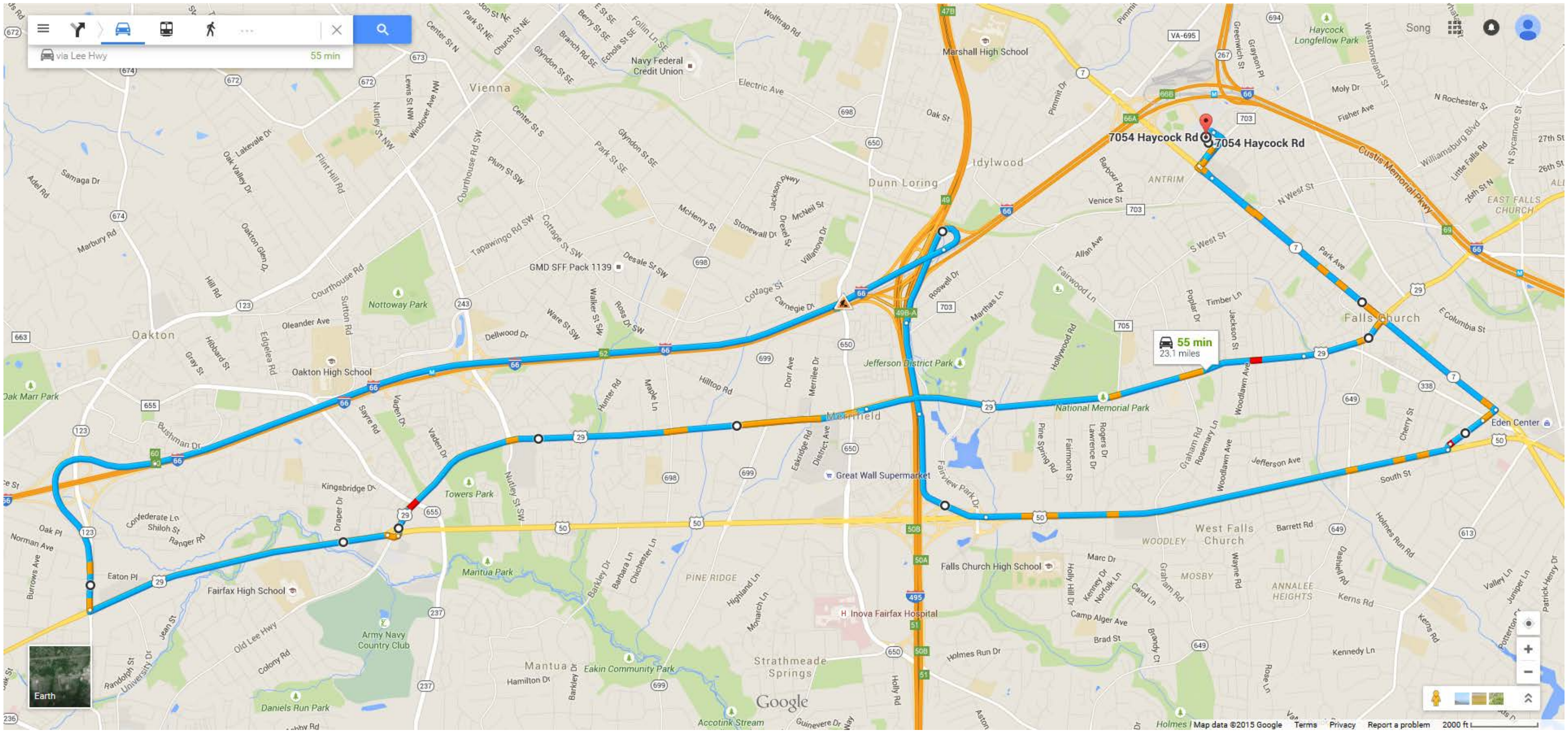
Continue on W Broad St. Drive to Haycock Rd in Idylwood

16. Turn left onto W Broad St

17. Continue onto VA-7 W/Leesburg Pike

18. Turn right onto Haycock Rd

19. Turn left onto Falls Church Dr



via Lee Hwy
55 min
7054 Haycock Rd
7054 Haycock Rd
55 min
23.1 miles
Vienna
Oakton
Dunn Loring
Idylwood
Merrifield
Falls Church
West Falls Church
Mantua
Strathmeade Springs
Oakton High School
Marshall High School
Fairfax High School
Falls Church High School
Inova Fairfax Hospital
Great Wall Supermarket
Eden Center
Navy Federal Credit Union
GMD SFF Pack 1139
Nottoway Park
Towers Park
Mantua Park
Jefferson District Park
National Memorial Park
Army Navy Country Club
Eakin Community Park
Daniels Run Park
Earth
Map data ©2015 Google

APPENDIX G. MESSAGES

Message #	Location	Text	Access to More Details?	More Details Message	Message Priority
1	LeftCenter	Speed Limit 45	No		1
2	BottomLine	Hotel Special	Yes	Free night at Star Hotel	4
3	BottomLine	Cheap Gas	Yes	$5.00 off $50.00 gas purchase	4
4	BottomLine	Burger Special	Yes	Deluxe burger, fries and soda 3.99 at Big Burger	4
5	BottomLine	Breaking News	Yes	Gas pipeline explosion shuts down local highway.	4
6	LeftCenter	Pedestrian Crossing	No		2
7	BottomLine	Message from Uncle Mike	Yes	Did you see that play?	4
8	BottomLine	News Alert	Yes	Local high school team wins championship	4
9	BottomLine	Tire Sale	Yes	Buy 3 tires, get 4th free	4
10	BottomLine	Gym Membership Special	Yes	One month free with 12 month contract	4
12	BottomLine	E-mail from Tanya	Yes	My train leaves at 4:00 p.m.	4
11	LeftCenter	Pedestrian Crossing	No		2
13	BottomLine	Meeting Cancelation Notice	Yes	Team meeting will be rescheduled two weeks from today	4
14	BottomLine	Item has shipped	Yes	Estimated delivery in 2-3 days	4

Message #	Location	Text	Access to More Details?	More Details Message	Message Priority
15	LeftCenter	Speed Limit 55	No		1
16	LeftCenter	Sharp Curve Ahead	No		1
17	LeftCenter	Speed Limit 55	No		1
18	LeftCenter	Vehicle Maintenance	Yes	Vehicle due for air filter change in 2,000 miles	3
19	BottomLine	Message from Liz	Yes	What time is the meeting tomorrow?	4
20	BottomLine	Message from Dad	Yes	Did you see the game last night?	4
21	BottomLine	Metro Station	Yes	Vienna Metro Station Exit 62	4
22	BottomLine	News Alert	Yes	Volunteer organization raises $20,000 for medical research	4
23	BottomLine	Message from Grandpa	Yes	Come take out the trash.	4
24	BottomLine	New Meeting Notice	Yes	Project meeting Friday at 3:00 p.m.	4
25	BottomLine	Friend Request	Yes	New friend request from Paul	4
26	BottomLine	News Feed	Yes	#Gobucks	4
27	LeftCenter	Speed Limit 55	No		1
28	BottomLine	Medical Care	Yes	Emergency Medical Care Exit 60	4
29	LeftCenter	Speed Limit 30	No		1
30	BottomLine	Low Mortgage Rates	Yes	Low mortgage rates - Apply today at Newman Bank	4

Message #	Location	Text	Access to More Details?	More Details Message	Message Priority
31	BottomLine	Mattress Sale	Yes	Mattress Sale - Buy one set, get 2nd half off at Mattress Max	4
32	BottomLine	Hot Wing Special	Yes	$0.29 hot wing special at Wings, Wings, and More Wings	4
33	LeftCenter	Speed Limit 35	No		1
34	BottomLine	Lunch Special	Yes	Lunch Special 3 toppings, & large drink for $5.99 at Carrie's	4
35	BottomLine	Pharmacy Promotions	Yes	Free flu shots	4
36	LeftCenter	School Zone	No		1
37	BottomLine	Car Care	Yes	Free tire rotation and balance	4
38	BottomLine	Motorcycle Sale	Yes	Sale on all used motorcycle	4
39	BottomLine	Tailgate Special	Yes	Tailgate special $34.99 at All Sports Restaurant	4
40	BottomLine	Auto Part Sale	Yes	10% off entire purchase today only	4
41	BottomLine	Free Checking	Yes	Free checking when you open an account today at Banking 1, 2, 3	4
42	LeftCenter	Speed Limit 40	No		1
43	BottomLine	Lease Special	Yes	Now leasing, 1st month free rent at Best Apartments	4
44	BottomLine	Metro Station	Yes	Vienna Metro Station - Left Nutley Street	4

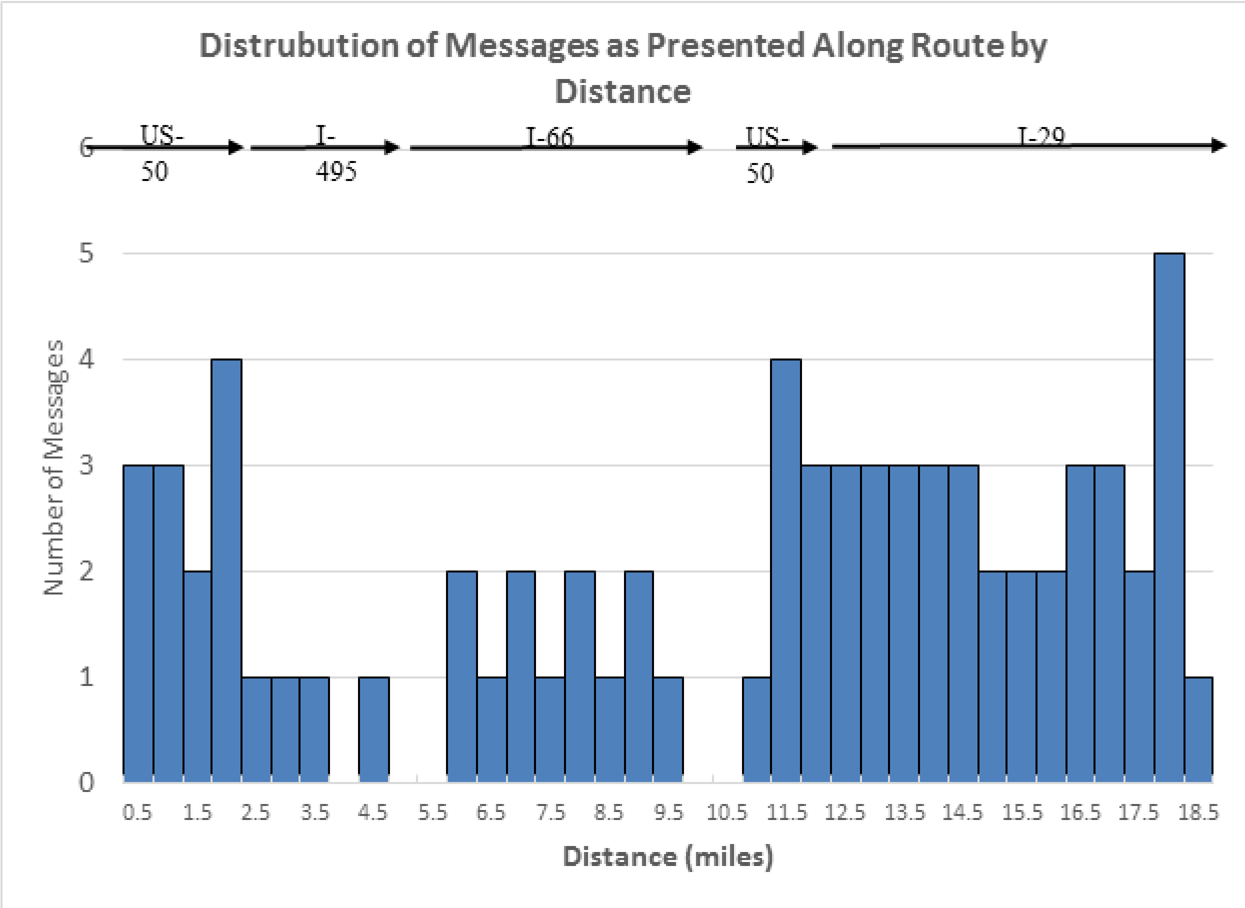
Message #	Location	Text	Access to More Details?	More Details Message	Message Priority
45	BottomLine	Coffee Special	Yes	Buy 3 cups of coffee get 1 free	4
46	BottomLine	Item has shipped	Yes	Estimated delivery in 5 -7 days	4
47	LeftCenter	Vehicle Maintenance	Yes	Vehicle due for oil change in 1,000 miles	3
48	BottomLine	Message from Mom	Yes	Call me when you get a chance	4
49	BottomLine	Cheap Gas	Yes	$5.00 off $50.00 gas purchase	4
50	BottomLine	Dry Cleaning Special	Yes	All garments $1.99 each	4
51	BottomLine	Storage Special	Yes	One month free with 12 month contract	4
52	BottomLine	Pharmacy Promotions	Yes	Free health screening	4
53	BottomLine	Home Improvement Sale	Yes	Home improvement sale at Builder's Market	4
54	BottomLine	25% off Sale	Yes	Today only, 25% off entire purchase at Daybreak Kid's Clothing Store	4
55	BottomLine	Friend Request	Yes	New friend request from Emma	4
56	BottomLine	Kids Eat Free	Yes	1 free kids meal per adult entree purchase of at least $10.00	4
57	BottomLine	E-mail from Melissa	Yes	Please send your schedule for next week	4
59	BottomLine	Pizza Special	Yes	2 large 2 toppings pizza for $12.99 Monday - Friday before	4

Message #	Location	Text	Access to More Details?	More Details Message	Message Priority
				5:00 p.m. at Sam's Pizza	
58	BottomLine	Bill Pay Notice	Yes	New bill pay notice due the 1st	4
60	LeftCenter	Speed Limit 40	No		1
61	BottomLine	Tire Sale	Yes	Lifetime free tire rotation and balance with purchase of new set of tires	4
63	BottomLine	News Feed	Yes	Basketball fever	4
62	LeftCenter	Pedestrian Crossing	No		2
64	BottomLine	Dry Cleaning Special	Yes	Two for one Tuesdays	4
65	LeftCenter	Speed Limit 30	No		1
66	LeftCenter	Pedestrian Crossing	No		2
67	BottomLine	Auto Sale	Yes	0% interest for 60 months on select 2015 models	4
68	BottomLine	Cheap Gas	Yes	$5.00 off $50.00 gas purchase	4
69	BottomLine	Hotel Special	Yes	Free Night at Star Hotel	4
70	BottomLine	News Alert	Yes	County animal shelter to hold rescuethon for dogs and cats in need of a forever home	4
71	BottomLine	Burger Special	Yes	2 for 1 burgers at Joe's	4

APPENDIX H. MESSAGES AND METADATA

	Application	Application Subg	Subgroup	Messag	Message	Safety F	Safety Relevanc	Operati	Operational Relevance	Time Fr	POI	Audio	Presentation	Expira	ImageFile	AudioFile1	Text	MoreInformati	MoreInformationText	LagTi	Latitude	Longitude	Message
1	In-Vehicle Signage	Speed Limit	14	1	Speed Limit 45	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit45.jpg	SL45.wav	Speed Limit 45			3	38.87132	-77.16575	1
2	Advertisements	Promotion	25	2	Free Hotel	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_freenight.jpg	Earcon.wav	Hotel Special	FNH.wav	Free night at Star Hotel	3	38.87061	-77.17008	2
2	Advertisements	Gas	24	3	Cheap Gas	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_cheapgas.jpg	Earcon.wav	Cheap Gas	FOFG.wav	$5.00 off $50.00 gas purchase	3	38.87020	-77.17251	3
2	Advertisements	FoodBeverage	23	4	Deluxe Burger	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_burger_meal.jpg	Earcon.wav	Burger Special	DBFS.wav	Deluxe burger, fries and soda 3.99 at Big Burger	3	38.86967	-77.17568	4
8	Internet/Social Media	News	83	5	Breaking News	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	brkg-news-large-blk.jpg	Earcon.wav	Breaking News	GPE.wav	Gas pipeline explosion shuts down local highway	3	38.86912	-77.17877	5
1	In-Vehicle Signage	Pedestrian Crossing	11	6	Pedestrian Crossing	1	Directly Relevant	3	Little or No Relevance	4	20	Yes	CenterQuarter	60	sign_pedestrian.jpg	PCA.wav	Pedestrian Crossing			3	38.86884	-77.18035	6
8	Internet/Social Media	Text	85	7	New Text Message	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_guy3.jpg	Earcon.wav	Message from Uncle Mike	DYSP.wav	Did you see that play?	3	38.86787	-77.18608	7
8	Internet/Social Media	News	83	8	News Alert	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_news_alert_champs.jpg	Earcon.wav	News Alert	LNAHS.wav	Local high school team wins championship	3	38.86741	-77.18876	8
2	Advertisements	Automotive	21	9	Tire Sale	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale.jpg	Earcon.wav	Tire Sale	BTGF.wav	Buy 3 tires, get 4th free	3	38.86699	-77.19161	9
2	Advertisements	Promotion	25	10	Gym	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_gym.jpg	Earcon.wav	Gym Membership Special	OMFTMC.wav	One month free with 12 month contract	3	38.86637	-77.19525	10
8	Internet/Social Media	Email	82	12	New Email	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_girl3.jpg	Earcon.wav	Email from Tanya	MTLAF.wav	My train leaves at 4:00 p.m.	3	38.86621	-77.19797	11
1	In-Vehicle Signage	Pedestrian Crossing	11	11	Pedestrian Crossing	1	Directly Relevant	3	Little or No Relevance	4	20	Yes	CenterQuarter	60	sign_pedestrian.jpg	PCA.wav	Pedestrian Crossing			3	38.86623	-77.19891	12
8	Internet/Social Media	Calendar	81	13	Meeting Notice	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	alert_calendar.jpg	Earcon.wav	Meeting Cancelation Notice	TMWBR.wav	Team meeting will be rescheduled two weeks fro	3	38.86611	-77.20544	13
8	Internet/Social Media	Email	82	14	New Email	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	purchase-large-blk.jpg	Earcon.wav	Item has shipped	EDITTD.wav	Estimated delivery in 2-3 days	3	38.86614	-77.20835	14
1	In-Vehicle Signage	Speed Limit	14	15	Speed Limit 55	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit55.jpg	SL55.wav	Speed Limit 55			3	38.86908	-77.21972	15
1	In-Vehicle Signage	Sharp Curve	12	16	Sharp Curve	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sharp_curve.jpg	SCA.wav	Sharp Curve Ahead			3	38.88558	-77.21976	16
1	In-Vehicle Signage	Speed Limit	14	17	Speed Limit 55	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit55.jpg	SL55.wav	Speed Limit 55			3	38.88398	-77.22737	17
9	Vehicle	Maintenance	91	18	Vehicle Maintenanc	3	Not Relevant	1	Highly Relevant	5	39	Yes	CenterQuarter	30	maintenance_required.jpg	Earcon.wav	Vehicle Maintenance	VDFAFC.wav	Vehicle due for air filter change in 2,000 miles	3	38.88264	-77.23105	18
8	Internet/Social Media	Text	85	19	New Text Message	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_girl4.jpg	Earcon.wav	Message from Liz	WTMT.wav	What time is the meeting tomorrow?	3	38.88089	-77.23685	19
8	Internet/Social Media	Text	85	20	New Text Message	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_guy4.jpg	Earcon.wav	Message from Dad	DYSG.wav	Did you see the game last night?	3	38.87967	-77.24875	20
7	Public Transit	Metro	71	21	Metro Station	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	transportation_metro_03.jpg	Earcon.wav	Metro Station	VMSE.wav	Vienna Metro Station Exit 62	3	38.87962	-77.24957	21
8	Internet/Social Media	News	83	22	News Alert	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_news_alert_medical.jpg	Earcon.wav	News Alert	LNAV.wav	Volunteer organization raises $20,000 for medical	3	38.87915	-77.25816	22
8	Internet/Social Media	Text	85	23	New Text Message	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_guy2.jpg	Earcon.wav	Message from Grandpa	CTOT.wav	Come take out the trash.	3	38.87869	-77.26617	23
8	Internet/Social Media	Calendar	81	24	Meeting Notice	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	alert_calendar.jpg	Earcon.wav	New Meeting Notice	PMFAT.wav	Project meeting Friday at 3:00 p.m.	3	38.87808	-77.27209	24
8	Internet/Social Media	Social	84	25	New Social Media M	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_network.jpg	Earcon.wav	Friend Request	NFRFP.wav	New friend request from Paul	3	38.87625	-77.27933	25
8	Internet/Social Media	Social	84	26	New Social Media M	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_network.jpg	Earcon.wav	News Feed	GB.wav	#Gobucks	3	38.873961	-77.287203	26
1	In-Vehicle Signage	Speed Limit	14	27	Speed Limit 55	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit55.jpg	SL55.wav	Speed Limit 55			3	38.87377	-77.28796	27
5	Public Safety	Medical Care	51	28	Medical Care	2	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	hospital_02.jpg	Earcon.wav	Medical Care	EMCE.wav	Emergency Medical Care Exit 60	3	38.87171	-77.29501	28
1	In-Vehicle Signage	Speed Limit	14	29	Speed Limit 30	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit30.jpg	SL30.wav	Speed Limit 30			3	38.86541	-77.30885	29
2	Advertisements	Banking	22	30	Bank Mortgage	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_mortgage.jpg	Earcon.wav	Low Mortgage Rates	LMR.wav	Low mortgage rates - Apply today at Newman Ban	3	38.85844	-77.30684	30
2	Advertisements	Retail	26	31	Mattress Sale	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_mattress.jpg	Earcon.wav	Mattress Sale	BOGOM.wav	Mattress Sale - Buy one set, get 2nd half off at Ma	3	38.85918	-77.30495	31
2	Advertisements	FoodBeverage	23	32	Hot Wing Special	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_hotwings.jpg	Earcon.wav	Hot Wing Special	HWS.wav	$0.29 hot wing special at Wings, Wings, and More	3	38.86047	-77.30115	32
1	In-Vehicle Signage	Speed Limit	14	33	Speed Limit 35	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit35.jpg	SL35.wav	Speed Limit 35			3	38.86063	-77.30069	33
2	Advertisements	FoodBeverage	23	34	Lunch Special	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_pizza_special.jpg	Earcon.wav	Lunch Special	LS3T.wav	Lunch Special 3 toppings, & large drink for $5.99 a	3	38.86136	-77.29732	34
2	Advertisements	Retail	26	35	Pharmacy	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	pharmacy_02.jpg	Earcon.wav	Pharmacy Promotions	FFS.wav	Free flu shots	3	38.86187	-77.29468	35
1	In-Vehicle Signage	School Zone	13	36	School Zone	1	Directly Relevant	2	Little or No Relevance	3	7	Yes	CenterQuarter	45	sign_schoolzone.jpg	ESZ.wav	School Zone			3	38.86263	-77.29077	36
2	Advertisements	Automotive	21	37	Car Care	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_automotive.jpg	Earcon.wav	Car Care	FTRB.wav	Free tire rotation and balance	3	38.86315	-77.28748	37
2	Advertisements	Automotive	21	38	Motorcycle Sale	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale.jpg	Earcon.wav	Motorcycle Sale	SUM.wav	Sale on all used motorcycle	3	38.86365	-77.28295	38
2	Advertisements	FoodBeverage	23	39	Tailgate Special	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_chicken.jpg	Earcon.wav	Tailgate Special	TGS.wav	Tailgate special $34.99 at All Sports Restaurant	3	38.86393	-77.28057	39
2	Advertisements	Automotive	21	40	Auto parts	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_autosale.jpg	Earcon.wav	Auto Part Sale	10EP.wav	10% off entire purchase today only	3	38.86506	-77.27495	40
2	Advertisements	Banking	22	41	Free Checking	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_bank.jpg	Earcon.wav	Free Checking	FCB.wav	Free checking when you open an account today a	3	38.86771	-77.27248	41
1	In-Vehicle Signage	Speed Limit	14	42	Speed Limit 40	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit40.jpg	SL40.wav	Speed Limit 40			3	38.867989	-77.272022	42
2	Advertisements	Promotion	25	43	Now Leasing	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_leasing.jpg	Earcon.wav	Lease Special	NLR.wav	Now leasing, 1st month free rent at Best Apartme	3	38.87044	-77.26926	43
7	Public Transit	Metro	71	44	Metro Station	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	transportation_metro_03.jpg	Earcon.wav	Metro Station	VMSLNS.wav	Vienna Metro Station - Left Nutley Street	3	38.87173	-77.26518	44
2	Advertisements	FoodBeverage	23	45	Coffee Shop	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_coffee.jpg	Earcon.wav	Coffee Special	BTCGOF.wav	Buy 3 cups of coffee get 1 free	3	38.87226	-77.26283	45
8	Internet/Social Media	Email	82	46	New Email	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	purchase-large-blk.jpg	Earcon.wav	Item has shipped	EDIFSD.wav	Estimated delivery in 5 -7 days	3	38.87239	-77.25837	46
9	Vehicle	Maintenance	91	47	Vehicle Maintenanc	3	Not Relevant	1	Highly Relevant	5	39	Yes	CenterQuarter	30	maintenance_required.jpg	Earcon.wav	Vehicle Maintenance	VDFOC.wav	Vehicle due for oil change in 1,000 miles	3	38.87244	-77.25733	47
8	Internet/Social Media	Text	85	48	New Text Message	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_girl1.jpg	Earcon.wav	Message from Mom	CMWUGC.wav	Call me when you get a chance	3	38.87261	-77.25140	48
2	Advertisements	Gas	24	49	Cheap Gas	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_cheapgas.jpg	Earcon.wav	Cheap Gas	FOFG.wav	$5.00 off $50.00 gas purchase	3	38.87282	-77.24816	49
2	Advertisements	Promotion	25	50	Cleaners	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale.jpg	Earcon.wav	Dry Cleaning Special	AG199.wav	All garments $1.99 each	3	38.87302	-77.24549	50
2	Advertisements	Promotion	25	51	Storage	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_storage.jpg	Earcon.wav	Storage Special	OMFTMC.wav	One month free with 12 month contract	3	38.87327	-77.24207	51
2	Advertisements	Retail	26	52	Pharmacy	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	pharmacy_02.jpg	Earcon.wav	Pharmacy Promotions	FHS.wav	Free health screening	3	38.87348	-77.23883	52
2	Advertisements	Retail	26	53	Home Improvement	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_home_improveme	Earcon.wav	Home Improvement Sale	HIS.wav	Home improvement sale at Builder's Market	3	38.87375	-77.23477	53
2	Advertisements	Retail	26	54	Shopping Center	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale_25.jpg	Earcon.wav	25% off Sale	TOEP.wav	Today only, 25% off entire purchase at Daybreak K	3	38.87398	-77.23101	54
8	Internet/Social Media	Social	84	55	New Social Media M	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_network.jpg	Earcon.wav	Friend Request	NFRFE.wav	New friend request from Emma	3	38.87467	-77.22619	55
2	Advertisements	FoodBeverage	23	56	Kids Eat Free	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_mexican.jpg	Earcon.wav	Kids Eat Free	FKM.wav	1 free kids meal per adult entree purchase of at le	3	38.87509	-77.22415	56
8	Internet/Social Media	Email	82	57	New Email	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_girl2.jpg	Earcon.wav	Email from Melissa	PSYS.wav	Please send your schedule for next week	3	38.87574	-77.21880	57
2	Advertisements	FoodBeverage	23	59	Pizza Special	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_pizza.jpg	Earcon.wav	Pizza Special	2L2PMF.wav	2 large 2 toppings pizza for $12.99 Monday - Frida	3	38.87502	-77.21061	58
8	Internet/Social Media	Email	82	58	New Email	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	alert_payment.jpg	Earcon.wav	Bill Pay Notice	NBPN.wav	New bill pay notice due the 1st	3	38.8752	-77.20781	59
1	In-Vehicle Signage	Speed Limit	14	60	Speed Limit 40	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit40.jpg	SL40.wav	Speed Limit 40			3	38.87522	-77.20729	60
2	Advertisements	Automotive	21	61	Tire Sale	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale.jpg	Earcon.wav	Tire Sale	LFTRB.wav	Lifetime free tire rotation and balance with purch	3	38.87544	-77.20413	61
8	Internet/Social Media	Social	84	63	New Social Media M	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	social_network.jpg	Earcon.wav	News Feed	BF.wav	Basketball fever	3	38.87586	-77.19931	62
1	In-Vehicle Signage	Pedestrian Crossing	11	62	Pedestrian Crossing	1	Directly Relevant	3	Little or No Relevance	4	20	Yes	CenterQuarter	60	sign_pedestrian.jpg	PCA.wav	Pedestrian Crossing			3	38.87599	-77.19876	63
2	Advertisements	Promotion	25	64	Cleaners	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_sale.jpg	Earcon.wav	Dry Cleaning Special	TFOT.wav	Two for one Tuesdays	3	38.87717	-77.19324	64
1	In-Vehicle Signage	Speed Limit	14	65	Speed Limit 30	1	Directly Relevant	2	Moderately Relevant	3	7	Yes	CenterQuarter	60	sign_speedlimit30.jpg	SL30.wav	Speed Limit 30			3	38.87759	-77.19163	65
1	In-Vehicle Signage	Pedestrian Crossing	11	66	Pedestrian Crossing	1	Directly Relevant	3	Little or No Relevance	4	20	Yes	CenterQuarter	60	sign_pedestrian.jpg	PCA.wav	Pedestrian Crossing			3	38.87844	-77.18867	66
2	Advertisements	Automotive	21	67	Auto sales	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_cars.jpg	Earcon.wav	Auto Sale	ZISM.wav	0% interest for 60 months on select 2015 models	3	38.87889	-77.18441	67
2	Advertisements	Gas	24	68	Cheap Gas	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_cheapgas.jpg	Earcon.wav	Cheap Gas	FOFG.wav	$5.00 off $50.00 gas purchase	3	38.87905	-77.18160	68
2	Advertisements	Promotion	25	69	Free Hotel	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_freenight.jpg	Earcon.wav	Hotel Special	FNH.wav	Free Night at Star Hotel	3	38.87913	-77.17999	69
8	Internet/Social Media	News	83	70	News Alert	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	brkg-news-large-blk.jpg	Earcon.wav	News Alert	CASRF.wav	County animal shelter to hold rescue fund for dog	3	38.87965	-77.17639	70
2	Advertisements	FoodBeverage	23	71	Burger Special	3	Not Relevant	3	Little or No Relevance	5	45	Yes	BottomLine	30	marketing_burgers.jpg	Earcon.wav	Burger Special	J21B.wav	2 for 1 burgers at Joe's	3	38.88010	-77.17448	71

APPENDIX I. DISTRUBITION OF MESSAGES ALONG ROUTE



APPENDIX J. IN-VEHICLE QUESTIONNAIRE

Considering the messages you just received, how much do you agree/disagree with the following statements on a scale of 1-7 where 1 = Strongly Disagree, 4 = Neutral, and 7 = Strongly Agree.

1) I found the messages useful.

1	2	3	4	5	6	7
Strongly Disagree			Neutral			Strongly Agree

2) The frequency of message presentation is just right.

1	2	3	4	5	6	7
Strongly Disagree			Neutral			Strongly Agree

3) I would like to receive similar messages during my daily driving.

1	2	3	4	5	6	7
Strongly Disagree			Neutral			Strongly Agree

APPENDIX K. POST-DRIVE QUESTIONNAIRE

Note: The percentages in italics indicate the overall percentage breakdown of responses per question. All percentages are based off of N=32 unless documented otherwise

HFCV Post-Drive Questionnaire

Thank you for participating in this study today. The following questions will ask you about the connected vehicle system (CVS) you just experienced.

Please answer the following questions.

1) My immediate impression of the CVS is that it performed well and to my expectations?

1	2	3	4	5	6	7
0%	3%	3%	9%	31%	41%	13%

1	2	3	4	5	6	7
Strongly Disagree			Neutral			Strongly Agree

2) What aspects of the connected vehicle system did you like?

3) What aspects of the connected vehicle system did you dislike?

4) Is there anything about the connected vehicle system you would change?

5) The following is a list of messages that may have been presented during your drive today. Please select all messages you recall receiving.

❍ Automotive Advertisements

❍ Banking Advertisements

❍ Food and Beverage Advertisements

❍ Gas Advertisements

❍ Promotional Advertisements

❍ Retail Advertisements

❍ Calendar Notifications

❍ E-mail Notifications

❍ Text Messages

❍ News Updates

❍ Social Media Updates

❍ Speed Limit Notifications

❍ School Zone Notifications

❍ Public Transit Information

❍ Vehicle Maintenance Information

❍ Pedestrian Crossing Information

❍ Social Media Messages

❍ Roadway Information

❍ Weather Information

❍ Sports Information

❍ Rest Stop Information

❍ Road Work Information

❍ Environmental Awareness Information

❍ Road Condition Information

❍ Public Safety Information

How useful did you find the overall CVS, and the following CVS applications you just experienced?

	Not at all Useful (1)	(2)	(3)	Neutral (4)	(5)	(6)	Very Useful (7)
Overall (all Messages)	1 (0%)	2 (3%)	3 (6%)	4 (19%)	5 (32%)	6 (26%)	7 (13%)
E-mail	1 (19%)	2 (9%)	3 (9%)	4 (9%)	5 (13%)	6 (25%)	7 (16%)
Social Media	1 (50%)	2 (6%)	3 (9%)	4 (22%)	5 (3%)	6 (9%)	7 (0%)
Calendar	1 (9%)	2 (6%)	3 (6%)	4 (16%)	5 (16%)	6 (25%)	7 (22%)
News Updates	1 (19%)	2 (9%)	3 (6%)	4 (31%)	5 (16%)	6 (13%)	7 (6%)
Vehicle Information	1 (6%)	2 (0%)	3 (9%)	4 (13%)	5 (19%)	6 (25%)	7 (28%)
In-Vehicle Signage	1 (3%)	2 (0%)	3 (0%)	4 (13%)	5 (19%)	6 (28%)	7 (38%)
Advertisements	1 (34%)	2 (19%)	3 (6%)	4 (28%)	5 (6%)	6 (6%)	7 (0%)
Public Transit	1 (22%)	2 (16%)	3 (13%)	4 (28%)	5 (16%)	6 (3%)	7 (3%)
Public Safety	1 (3%)	2 (0%)	3 (0%)	4 (25%)	5 (25%)	6 (22%)	7 (25%)
Text Messages	1 (13%)	2 (6%)	3 (6%)	4 (16%)	5 (16%)	6 (31%)	7 (13%)

6) Did you request additional information from any of the messages presented?

❍ Yes

❍ No

Yes	78%
No	22%

If Yes, which messages did you request additional information and why?

If No, please explain why you did not request additional information?

7) After experiencing the CVS, what type of information do you think is appropriate to have access to while driving?

	1 (19%)	2 (16%)	3 (13%)	4 (0%)	5 (22%)	6 (13%)	7 (19%)
	1 (44%)	2 (16%)	3 (9%)	4 (13%)	5 (9%)	6 (3%)	7 (6%)
	1 (13%)	2 (6%)	3 (6%)	4 (16%)	5 (19%)	6 (19%)	7 (22%)
	1 (16%)	2 (16%)	3 (6%)	4 (22%)	5 (16%)	6 (6%)	7 (19%)
	1 (0%)	2 (0%)	3 (0%)	4 (13%)	5 (19%)	6 (25%)	7 (44%)
	1 (0%)	2 (0%)	3 (0%)	4 (9%)	5 (19%)	6 (19%)	7 (53%)
	1 (31%)	2 (9%)	3 (9%)	4 (19%)	5 (6%)	6 (3%)	7 (9%)
	1 (9%)	2 (9%)	3 (9%)	4 (31%)	5 (25%)	6 (6%)	7 (6%)
	1 (0%)	2 (0%)	3 (0%)	4 (19%)	5 (25%)	6 (22%)	7 (34%)
	1 (16%)	2 (0%)	3 (0%)	4 (25%)	5 (19%)	6 (22%)	7 (13%)

8) How would you rate the amount of information presented within the messages?

1	2	3	4	5	6	7
3%	3%	16%	31%	25%	19%	3%

1	2	3	4	5	6	7
Way Too Little			Just Right			Way Too Much

9) How would you rate the overall frequency of information presented during the drive?

1	2	3	4	5	6	7
6%	3%	9%	19%	22%	28%	13%

1	2	3	4	5	6	7
Much Too Infrequent			Just Right			Much Too Frequent

10) How would you rate the overall frequency of information presented during the drive based on message type?

	Much too infrequent (1)	(2)	(3)	Neutral (4)	(5)	(6)	Much too frequent (7)
E-mail	1 (0%)	2 (3%)	3 (16%)	4 (38%)	5 (25%)	6 (6%)	7 (13%)
Social Media	1 (0%)	2 (3%)	3 (16%)	4 (16%)	5 (25%)	6 (9%)	7 (31%)
Calendar	1 (0%)	2 (6%)	3 (9%)	4 (56%)	5 (13%)	6 (6%)	7 (9%)
News Updates	1 (3%)	2 (6%)	3 (6%)	4 (34%)	5 (28%)	6 (13%)	7 (9%)
Vehicle Information	1 (3%)	2 (3%)	3 (3%)	4 (69%)	5 (3%)	6 (13%)	7 (6%)
In-Vehicle Signage	1 (3%)	2 (9%)	3 (6%)	4 (59%)	5 (6%)	6 (13%)	7 (3%)
Advertisements	1 (3%)	2 (6%)	3 (0%)	4 (9%)	5 (13%)	6 (28%)	7 (41%)
Public Transit	1 (3%)	2 (6%)	3 (3%)	4 (66%)	5 (3%)	6 (9%)	7 (13%)
Public Safety	1 (3%)	2 (6%)	3 (13%)	4 (63%)	5 (3%)	6 (13%)	7 (3%)
Text Messages	1 (0%)	2 (6%)	3 (6%)	4 (53%)	5 (19%)	6 (3%)	7 (16%)

11) Would you like the ability to control which types of notifications you receive?

- ❍ Yes
- ❍ No
- ❍ Undecided

Yes	*100%*
No	*0%*
Undecided	*0%*

12) Would you like the ability to prioritize what messages you receive by message type?

- ❍ Yes
- ❍ No

Yes	*91%*
No	*0%*
Undecided	*3%*

❍ Undecided

13) Please rank order the message types listed below based on your preference and what you would most likely access in a vehicle (1 = very likely, 12 = not very likely).

___ E-mail

___ Social Media

___ Calendar

___ News Updates

___ Sports Scores

___ Weather

___ Vehicle Information

___ In-Vehicle Signage

___ Advertisements

___ Public Transit

___ Public Safety

___ Text Messages

Rank	***Email***	***Social Media***	***Calendar***	***News Updates***	***Sports Scores***	***Weather***	***Vehicle Information***	***In-Vehicle Signage***	***Advertisements***	***Public Transit***	***Public Safety***	***Text Messages***
1	15%	0%	0%	0%	0%	4%	26%	30%	0%	0%	26%	0%
2	0%	4%	15%	0%	0%	4%	33%	26%	0%	0%	4%	15%
3	7%	0%	7%	4%	4%	11%	11%	15%	0%	4%	22%	15%
4	11%	7%	4%	11%	0%	22%	11%	4%	0%	4%	4%	22%
5	11%	0%	11%	11%	4%	22%	4%	11%	0%	7%	11%	7%
6	15%	4%	26%	15%	4%	7%	0%	4%	4%	4%	4%	15%
7	7%	15%	19%	0%	4%	4%	7%	4%	11%	11%	11%	7%
8	11%	4%	11%	15%	7%	11%	4%	4%	4%	22%	4%	4%
9	4%	11%	7%	26%	7%	7%	0%	4%	4%	26%	4%	0%
10	11%	11%	0%	19%	19%	0%	4%	0%	15%	7%	11%	4%
11	7%	19%	0%	0%	33%	7%	0%	0%	19%	11%	0%	4%
12	0%	26%	0%	0%	19%	0%	0%	0%	44%	4%	0%	7%

14) After experiencing the CVS, how would you like the information to be presented? Select all that apply.

	Text	Speech	Tone	No Preference	None
E-mail	Text	Speech	Tone	No Preference	None
Social Media	Text	Speech	Tone	No Preference	None
Calendar	Text	Speech	Tone	No Preference	None
News Updates	Text	Speech	Tone	No Preference	None
Vehicle Information	Text	Speech	Tone	No Preference	None
In-Vehicle Signage	Text	Speech	Tone	No Preference	None
Advertisements	Text	Speech	Tone	No Preference	None
Public Transit	Text	Speech	Tone	No Preference	None
Public Safety	Text	Speech	Tone	No Preference	None
Text Messages	Text	Speech	Tone	No Preference	None

	Modality								
Message Category	***Text***	***Speech***	***Tone***	***Text + Speech***	***Text + Tone***	***Speech + Tone***	***Text+Speech+ Tone***	***No Preference***	***None***
Email	0%	47%	3%	6%	3%	9%	13%	3%	16%
Social Media	6%	19%	9%	3%	0%	3%	6%	9%	44%
Calendar	3%	38%	13%	3%	3%	22%	13%	3%	3%
News Updates	13%	28%	13%	0%	3%	9%	3%	3%	28%
Vehicle Information	6%	41%	13%	9%	3%	13%	16%	0%	0%
In-Vehicle Signage	9%	44%	9%	3%	3%	13%	19%	0%	0%
Advertisements	22%	13%	9%	0%	3%	3%	0%	16%	34%
Public Transit	13%	25%	16%	0%	3%	13%	0%	6%	25%
Public Safety	13%	34%	13%	3%	3%	16%	13%	6%	0%
Text Messages	3%	34%	13%	6%	6%	13%	9%	6%	9%

15) Please provide any additional thoughts you may have regarding the CVS.

APPENDIX L. ACTUAL MESSAGES PRESENTED BY PARTICIPANT

Group	ID	Messages Presented (out of 71 total)	Messages not Presented		
			Messages Filtered Out	Messages Expired	Other
A	300	71			
	301	71			
	302	71			
	303	71			
	304	69		#21, #49	
	305	71			
	306	71			
	307	71			
B	308	34	37 messages		
	309	42	29 messages		
	311	38	33 messages		
	312	64	7 messages		
	313	49	22 messages		
	314	57	14 messages		
	315	50	21 messages		
C	317	71			
	318	71			
	319	71			
	320	57		14 messages	
	321	70		#61	
	322	71			
	324	71			
	325	71			
D	327	71			
	328	68			#28, #29, #61
	329	71			
	330	68			#61, #62, #63
	331	71			
	332	71			
	333	71			
	334	71			

APPENDIX M. DETAILED CONTENT ANALYSIS

Comment Category	Frequency	Percentage
Context	15	94%
Context - Traffic	9	56%
Context - Limit to Driving Related Only	1	6%
Context - Display Messages When Stopped	8	50%
Context - Only Display News that Affects Driving/Safety	5	31%
Context - Have Gas Ads/Alerts Tied to Gas Tanks	6	38%
Context - Food Ads Limited to Lunch Hours	5	31%
Context - Food Ads for Favorite Restaurants	1	6%
Context - Differentiate Messages for Local vs Travel Driving	6	38%
Context - Signage Speed Limit	11	69%
Context - Signage Pedestrian Crossing	2	13%
Context - Vehicle Maintenance	10	63%
Timing	9	56%
Timing - Display Time Too Long	5	31%
Timing - Display Time Too Short	1	6%
Timing - Display Time Appropriate	3	19%
Frequency	12	75%
Frequency - Bottom Line Beep/Tone Too Frequent	3	19%
Frequency - Potential Frequency of Real Time Events	3	19%
Frequency - All Messages Too Frequent	6	38%
Frequency - Advertisements Too Frequent	3	19%
Presentation	14	88%
Presentation - Differentiate	10	63%
Presentation - Limit Modality to Speech Only	12	75%
Presentation - Move Center Location	5	31%
System Architecture	12	75%
System Architecture - Message Log	9	56%
System Architecture - Emergency Vehicles	3	19%
System Architecture - Express Lane	6	38%
System Architecture - Like Pedestrian Crossing Interrupt	3	19%
System Architecture - Like Speed Limit Interrupt	1	6%
System Architecture - Don't Replay Message after Interruption	1	6%
System Architecture - Interrupt through Audio Only	1	6%
System Architecture - No Interrupt for Vehicle Maintenance	1	6%
System Architecture - Limit Speed Limit Interruption when Speeding Only	1	6%
System Architecture - No Messages over NAV Directions	2	13%
System Architecture - No Messages during Turning	1	6%
System Architecture - Rerouting Available	2	13%
Add Steering Wheel Button	2	13%

APPENDIX N. EYE GLANCE LOCATION DEFINITIONS AND CODES

F	Forward (Center)	Any glance out the forward windshield directed towards the direction of the vehicle's travel. Note that when the vehicle is turning, these glances may not be directed directly forward but towards the vehicle's heading. Count these as forward glances.
D	Left Forward	Any glance out the forward windshield where the driver appears to be looking specifically out the left margin of the windshield (e.g., as if scanning for traffic before turning or glancing at oncoming traffic). This glance location includes anytime the driver is looking out the windshield, but clearly not in the direction of travel (e.g., at road signs or buildings)
G	Right Forward	Any glance out the forward windshield where the driver appears to be looking specifically out the right side of the windshield (e.g., as if scanning for traffic before turning, at a vehicle ahead in an adjacent lane, or reading a road sign). This is often preceded or followed by Left Forward. This glance location includes anytime the driver is looking out the windshield, but clearly not in the direction of travel (e.g., at road signs or buildings)
M	Rearview Mirror	Any glance to the rear view mirror or equipment located around it. This glance generally involves

		movement of the eyes to the right and up to the mirror. This includes glances that may be made to the rearview mirror in order to look at or interact with back seat passengers.
L	Left Window/Mirror	Any glance to the left side mirror or window.
R	Right Window/Mirror	Any glance to the right side mirror or window
S	Over-The-Shoulder (left or right)	Any glance over either of the participant's shoulders. In general, this will require the eyes to pass the B-pillar. If over the left shoulder, the eyes may not be visible, but this glance location can be inferred from context. NOTE: If it is clear from context that an over-the-shoulder glance is being made NOT to check a blind spot but instead to interact with a rear seat passenger (e.g., food/toy is being handed back), then code the glance as Passenger. If context cannot be known with a high level of certainty, then code as Over-the-Shoulder.
I	Instrument Cluster	Any glance to the instrument cluster underneath the dashboard. This includes glances to the speedometer, control stalks, and steering wheel.
T	Message Display/Tablet	Any glance to the tablet display above the center stack.
C	Center Stack	Any glance to the vehicle's center stack below the tablet. This includes infotainment system, climate control, and/or attached questionnaire scale sheet. Not to be confused with center console (cup holder area between driver and passenger), which is discussed under

		"Interior Object".
W	Interior Object	Any glance to an identifiable object in the vehicle. These objects include personal items brought in by the participant (e.g., purse, food, papers), any part of their body that may look at (e.g., hand, ends of hair), electronic devices (e.g., cell phone, iPod, laptop, PDA), and also OEM installed devices that don't fall into other categories (e.g., door lock, window and seat controls). Glances to the center console (cup holder area between passenger seat and driver seat) will also be included in this category. The object does not need to be in the camera view for a specific frame to be coded with this category. If it is clear from surrounding video that the participant is looking at the object, this category may be used. This category can be used regardless of whether the participant's hands are/aren't visible. NOTE: If the driver is looking at something that the passenger is handing to them, code the eye-glance as Passenger, until the object is fully in the drivers hand, then code as Interior Object (unless it's a cell phone, code as Cell Phone). Also, if the driver is looking at something that the passenger is holding (but never hands to the driver), code as passenger

		glance (not interior object).
A	Passenger	Any glance to a passenger, whether in front seat or rear seat of vehicle. You will need to use context (e.g., they’re talking, or handing something) in order to determine this in some situations. NOTE: This does NOT include glances made to rear seat passenger via the rearview mirror. Such glances should be coded as Rearview Mirror. NOTE: If the driver is looking at something that the passenger is handing to them, code the eyeglance as Passenger, until the object is fully in the drivers hand, then code as Interior Object (unless it’s a cell phone, code as Cell Phone). Also, if the driver is looking at something that the passenger is holding (but never hands to the driver), code as passenger glance (not interior object).
V	No Video	Unable to complete glance analysis because the face video view is temporarily unavailable. NOTE: this sometimes occurs for 1-2 syncs at a time, and a “video not available” message may appear. If the glance location is the same before and after this occurs and the period is only 1-2 syncs long, then code through this period as the glance location present before and after. If the “video not available” period is longer than 2 syncs OR it occurs during a transition, use the “No Video” option.

E	No Eyes Visible- Glance Location Unknown	Unable to complete glance analysis due to an inability to see the driver's eyes/face. Video data is present, but the driver's eyes and face are not visible due to an obstruction (e.g. visor, hand,), or due to glare. Use this category when there is no way to tell whether the participant's eyes are on or off the road. This is the default and most often used "unknown" option, but there may be times with the "off road" option listed below may be appropriate.
N	No Eyes Visible. Eyes Are Off-Road	Unable to enter in specific glance location due to an inability to see the driver's eyes/face. However, it is clear that the participant is not looking at the roadway. Video is present, but the driver's eyes and face are not visible due to an obstruction (e.g. visor, hand), head position, or due to glare. Use this category when the eyes are not visible, you are not sure what the participant is looking at, but it is obvious that the eyes are not on the roadway.
Z	Eyes Closed	Any time that BOTH the participant's eyes are closed outside of normal blinking (e.g., the subject is falling asleep or rubbing eyes). As a rule of thumb, if the eyes are closed for five or more syncs (1/2 a second) during a slow blink, code it as Eyes Closed. Otherwise, code it as the glance location present before the eyes closed. If one eye remains open, code the location according to the open eye. If only one eye is visible, code according to the visible eye.
O	Other	Any glance that cannot be categorized using the above codes. If you come across anything that could fall under this category, please inform the

		Lab Manager for appropriate follow-up. Some pre-approved uses of the "other" option are listed below: • When the driver is looking forward, and then looks straight up at the sky as if watching a plane fly by. • When the driver is tilting head back to drink and the eyes leave the forward glance but do not really focus on anything at all.

DOT HS 812 310
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U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

NHTSA

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