SAVE-IT

SAfety VEhicles using adaptive Interface Technology (Task 4)

Experiments for Distraction Mitigation Strategies

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4.0 PROGRAM OVERVIEW

Driver distraction is a major contributing factor to automobile crashes. National Highway Traffic Safety Administration (NHTSA) has estimated that approximately 25% of crashes are attributed to driver distraction and inattention (Wang, Knipling, & Goodman, 1996). The issue of driver distraction may become worse in the next few years because more electronic devices (e.g., cell phones, navigation systems, wireless Internet and email devices) are brought into vehicles that can potentially create more distraction. In response to this situation, the John A. Volpe National Transportation Systems Center (VNTSC), in support of NHTSA's Office of Vehicle Safety Research, awarded a contract to Delphi Electronics & Safety to develop, demonstrate, and evaluate the potential safety benefits of adaptive interface technologies that manage the information from various in-vehicle systems based on real-time monitoring of the roadway conditions and the driver's capabilities. The contract, known as SAfety VEhicle(s) using adaptive Interface Technology (SAVE-IT), is designed to mitigate distraction with effective countermeasures and enhance the effectiveness of safety warning systems.

The SAVE-IT program serves several important objectives. Perhaps the most important objective is demonstrating a viable proof of concept that is capable of reducing distraction-related crashes and enhancing the effectiveness of safety warning systems. Program success is dependent on integrated closed-loop principles that, not only include sophisticated telematics, mobile office, entertainment and safety warning systems, but also incorporate the state of the driver. This revolutionary closed-loop vehicle environment will be achieved by measuring the driver’s state, assessing the situational threat, prioritizing information presentation, providing adaptive countermeasures to minimize distraction, and optimizing advanced collision warning.

To achieve the objective, Delphi Electronics & Safety has assembled a comprehensive team including researchers and engineers from the University of Iowa, University of Michigan Transportation Research Institute (UMTRI), General Motors, Ford Motor Company, and Seeing Machines, Inc. The SAVE-IT program is divided into two phases shown in Figure i. Phase I spans one year (March 2003--March 2004) and consists of nine human factors tasks (Tasks 1-9) and one technology development task (Task 10) for determination of diagnostic measures of driver distraction and workload, architecture concept development, technology development, and Phase II planning. Each of the Phase I tasks is further divided into two sub-tasks. In the first sub-tasks (Tasks 1, 2A-10A), the literature is reviewed, major findings are summarized, and research needs are identified. In the second sub-tasks (Tasks 1, 2B-10B), experiments will be performed and data will be analyzed to identify diagnostic measures of distraction and workload and determine effective and driver-friendly countermeasures. Phase II will span approximately two years (October 2004--October 2006) and consist of a continuation of seven Phase I tasks (Tasks 2C--

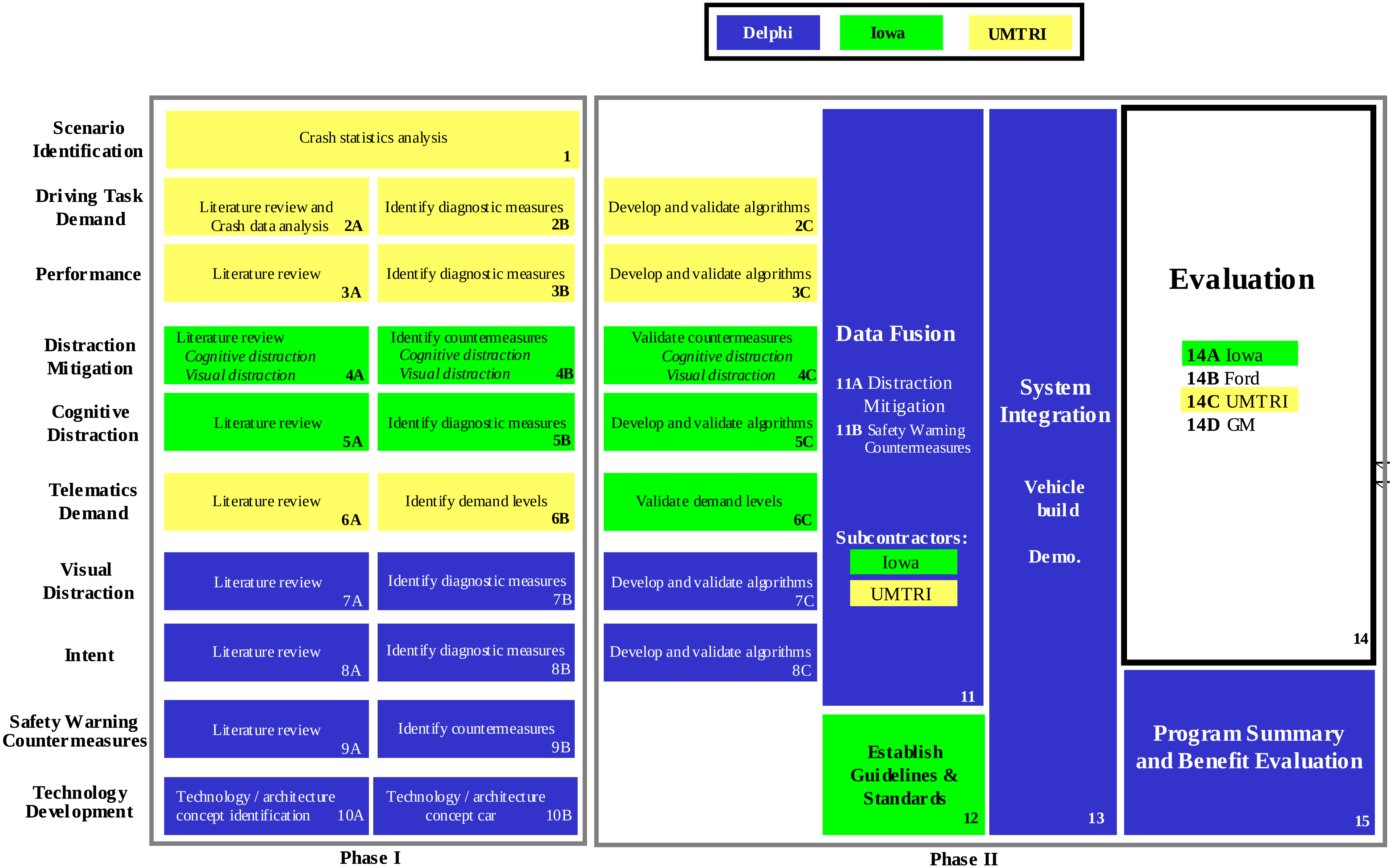


Figure i: SAVE-IT tasks

8C) and five additional tasks (Tasks 11-15) for algorithm and guideline development, data fusion, integrated countermeasure development, vehicle demonstration, and evaluation of benefits.

It is worthwhile to note the SAVE-IT tasks in Figure i are inter-related. They have been chosen to provide necessary human factors data for a two-pronged approach to address the driver distraction and adaptive safety warning countermeasure problems.

The first prong (Safety Warning Countermeasures sub-system) uses driver distraction, intent, and driving task demand information to adaptively adjust safety warning systems such as forward collision warning (FCW) systems in order to enhance system effectiveness and user acceptance. Task 1 is designed to determine which safety warning system(s) should be deployed in the SAVE-IT system. Safety warning systems will require the use of warnings about immediate traffic threats without an annoying rate of false alarms and nuisance alerts. Both false alarms and nuisance alerts will be reduced by system intelligence that integrates driver state, intent, and driving task demand information that is obtained from Tasks 2 (Driving Task Demand), 3 (Performance), 5 (Cognitive Distraction), 7 (Visual Distraction), and 8 (Intent).

The safety warning system will adapt to the needs of the driver. When a driver is cognitively and visually attending to the lead vehicle, for example, the warning thresholds can be altered to delay the onset of the FCW alarm or reduce the intrusiveness of the alerting stimuli. When a driver intends to pass a slow-moving lead vehicle and the passing lane is open, the auditory stimulus might be suppressed in order to reduce the alert annoyance of a FCW system. Decreasing the number of false positives may reduce the tendency for drivers to disregard safety system warnings. Task 9 (Safety Warning Countermeasures) will investigate how driver state and intent information can be used to adapt safety warning systems to enhance their effectiveness and user acceptance. Tasks 10 (Technology Development), 11 (Data Fusion), 12 (Establish Guidelines and Standards), 13 (System Integration), 14 (Evaluation), and 15 (Program Summary and Benefit Evaluation) will incorporate the research results gleaned from the other tasks to demonstrate the concept of adaptive safety warning systems and evaluate and document the effectiveness, user acceptance, driver understandability, and benefits and weaknesses of the adaptive systems. It should be pointed out that the SAVE-IT system is a relatively early step in bringing the driver into the loop and therefore, system weaknesses will be evaluated, in addition to the observed benefits.

The second prong of the SAVE-IT program (Distraction Mitigation sub-system) will develop adaptive interface technologies to minimize driver distraction to mitigate against a global increase in risk due to inadequate attention allocation to the driving task. Two examples of the distraction mitigation system include the delivery of a gentle warning and the lockout of certain telematics functions when the driver is more distracted than what the current driving environment allows. A major focus of the SAVE-IT program is the comparison of various mitigation methods in terms of their effectiveness, driver understandability, and user acceptance. It is important that the mitigation system does not introduce additional distraction or driver frustration. Because the lockout method has been shown to be problematic in the aviation domain and will likely cause similar problems for drivers, it should be carefully studied before implementation. If this method is not shown to be beneficial, it will not be implemented.

The distraction mitigation system will process the environmental demand (Task 2: Driving Task Demand), the level of driver distraction [Tasks 3 (Performance), 5 (Cognitive Distraction), 7 (Visual Distraction)], the intent of the driver (Task 8: Intent), and the telematics distraction potential (Task 6: Telematics Demand) to determine which functions should be advised against under a particular circumstance. Non-driving task information and functions will be prioritized based on how crucial the information is at a specific time relative to the level of driving task demand. Task 4 will investigate distraction mitigation strategies and methods that are very well accepted by the users (i.e., with a high level of user acceptance) and understandable to the drivers. Tasks 10 (Technology Development), 11 (Data Fusion), 12 (Establish Guidelines and Standards), 13 (System Integration), 14 (Evaluation), and 15 (Program Summary and Benefit Evaluation) will incorporate the research results gleaned from the other tasks to demonstrate the concept of using adaptive interface technologies in distraction mitigation and evaluate and document the effectiveness, driver understandability, user acceptance, and benefits and potential weaknesses of these technologies.

In particular, driving task demand and driver state (including driver distraction and impairment) form the major dimensions of a driver safety system. It has been argued that crashes are frequently caused by drivers paying insufficient attention when an unexpected event occurs, requiring a novel (non-automatic) response. As displayed in Figure ii, attention to the driving task may be depleted by driver impairment (due to drowsiness, substance use, or a low level of arousal) leading to diminished attentional resources, or allocation to non-driving tasks[1]. Because NHTSA is currently sponsoring other impairment-related studies, the assessment of driver impairment is not included in the SAVE-IT program at the present time. One assumption is that safe driving requires that attention be commensurate with the driving demand or unpredictability of the environment. Low demand situations

[1] The distinction between driving and non-driving tasks may become blurred sometimes. For example, reading street signs and numbers is necessary for determining the correct course of driving, but may momentarily divert visual attention away from the forward road and degrade a driver's responses to unpredictable danger evolving in the driving path. In the SAVE-IT program, any off-road glances, including those for reading street signs, will be assessed in terms of visual distraction and the information about distraction will be fed into adaptive safety warning countermeasures and distraction mitigation sub-systems.

(e.g., straight country road with no traffic at daytime) may require less attention because the driver can usually predict what will happen in the next few seconds while the driver is attending elsewhere. Conversely, high demand (e.g., multi-lane winding road with erratic traffic) situations may require more attention because during any time attention is diverted away, there is a high probability that a novel response may be required. It is likely that most intuitively drivers take the driving-task demand into account when deciding whether or not to engage in a non-driving task. Although this assumption is likely to be valid in a general sense, a counter argument is that problems may also arise when the situation appears to be relatively benign and drivers overestimate the predictability of the environment. Driving environments that appear to be predictable may therefore leave drivers less prepared to respond when an unexpected threat does arise.

A safety system that mitigates the use of in-vehicle information and entertainment system (telematics) must balance both attention allocated to the driving task that will be assessed in Tasks 3 (Performance), 5 (Cognitive Distraction), and 7 (Visual Distraction) and attention demanded by the environment that will be assessed in Task 2 (Driving Task Demand). The goal of the distraction mitigation system should be to keep the level of attention allocated to the driving task above the attentional requirements demanded by the current driving environment. For example, as shown in Figure ii, “routine” driving may suffice during low or moderate driving task demand, slightly distracted driving may be adequate during low driving task demand, but high driving task demand requires attentive driving.

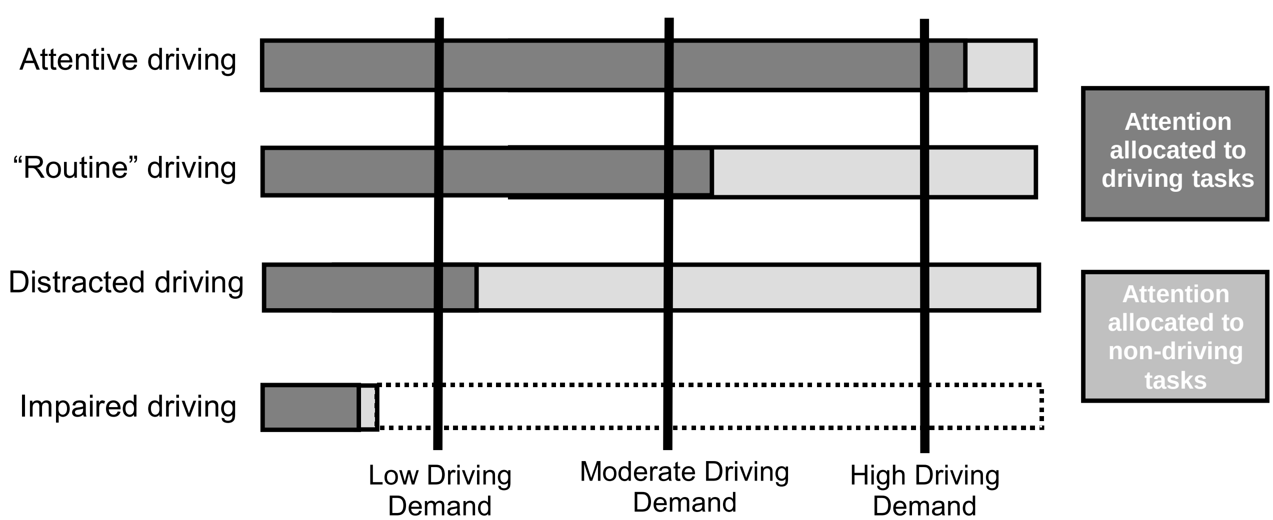


Figure ii. Attention allocation to driving and non-driving tasks

It is important to note that the SAVE-IT system addresses both high-demand and low-demand situations. With respect to the first prong (Safety Warning Countermeasures sub-system), the safety warning systems (e.g., the FCW system) will always be active, regardless of the demand. Sensors will always be assessing the driving environment and driver state. If traffic threats are detected, warnings will be issued that are commensurate with the real time attentiveness of the driver, even under low-demand situations. With respect to the second prong (Distraction Mitigation sub-system), driver state including driver distraction and intent will be continuously assessed under all circumstances. Warnings may be issued and telematics functions may be screened out under both high-demand and low-demand situations, although the threshold for distraction mitigation may be different for these situations.

It should be pointed out that drivers tend to adapt their driving, including distraction behavior and maintenance of speed and headway, based on driving (e.g., traffic and weather) and non-driving conditions (e.g., availability of telematics services), either consciously or unconsciously. For example, drivers may shed non-driving tasks (e.g., ending a cell phone conversation) when driving under unfavorable traffic and weather conditions. It is critical to understand this "driver adaptation" phenomenon. In principle, the "system adaptation" in the SAVE-IT program (i.e., adaptive safety warning countermeasures and adaptive distraction mitigation sub-systems) should be carefully implemented to ensure a fit between the two types of adaptation: "system adaptation" and "driver adaptation". One potential problem in a system that is inappropriately implemented is that the system and the driver may be reacting to each other in an unstable manner. If the system adaptation is on a shorter time scale than the driver adaptation, the driver may become confused and frustrated. Therefore, it is important to take the time scale into account. System adaptation should fit the driver's mental model in order to ensure driver understandability and user acceptance. Because of individual difference, it may also be important to tailor the system to individual drivers in order to maximize driver understandability and user acceptance. Due to resource constraints, however, a nominal driver model will be adopted in the initial SAVE-IT system. Driver profiling, machine learning of driver behavior, individual difference-based system tailoring may be investigated in future research programs.

Communication and Commonalities Among Tasks and Sites

In the SAVE-IT program, a "divide-and-conquer" approach has been taken. The program is first divided into different tasks so that a particular research question can be studied in a particular task. The research findings from the various tasks are then brought together to enable us to develop and evaluate integrated systems. Therefore, a sensible balance of commonality and diversity is crucial to the program success. Diversity is reflected by the fact that every task is designed to address a unique question to achieve a particular objective. As a matter of fact, no tasks are redundant or unnecessary. Diversity is clearly demonstrated in the respective task reports. Also documented in the task reports is the creativity of different task owners in attacking different research problems.

Task commonality is very important to the integration of the research results from the various tasks into a coherent system and is reflected in terms of the common methods across the various tasks. Because of the large number of tasks (a total of 15 tasks depicted in Figure i) and the participation of multiple sites (Delphi Electronics & Safety, University of Iowa, UMTRI, Ford Motor Company, and General Motors), close coordination and commonality among the tasks and sites are key to program success. Coordination mechanisms, task and site commonalities have been built into the program and are reinforced with the bi-weekly teleconference meetings and regular email and telephone communications. It should be pointed out that little time was wasted in meetings. Indeed, some bi-weekly meetings were brief when decisions can be made quickly, or canceled when issues can be resolved before the meetings. The level of coordination and commonality among multiple sites and tasks is un-precedented and has greatly contributed to program success. A selection of commonalities is described below.

Commonalities Among Driving Simulators and Eye Tracking Systems In Phase I
Although the Phase I tasks are performed at three sites (Delphi Electronics & Safety, University of Iowa, and UMTRI), the same driving simulator software, Drive Safety™ (formerly called GlobalSim™) from Drive Safety Inc., and the same eye tracking system, FaceLab™ from Seeing Machines, Inc. are used in Phase I tasks at all sites. The performance variables (e.g., steering angle, lane position, headway) and eye gaze measures (e.g., gaze coordinate) are defined in the same manner across tasks.

Common Dependent Variables An important activity of the driving task is tactical maneuvering such as speed and lane choice, navigation, and hazard monitoring. A key component of tactical maneuvering is responding to unpredictable and probabilistic events (e.g., lead vehicle braking, vehicles cutting in front) in a timely fashion. Timely responses are critical for collision avoidance. If a driver is distracted, attention is diverted from tactical maneuvering and vehicle control, and consequently, reaction time (RT) to probabilistic events increases. Because of the tight coupling between reaction time and attention allocation, RT is a useful metric for operationally defining the concept of driver distraction. Furthermore, brake RT can be readily measured in a driving simulator and is widely used as input to algorithms, such as the forward collision warning algorithm (Task 9: Safety Warning Countermeasures). In other words, RT is directly related to driver safety. Because of these reasons, RT to probabilistic events is chosen as a primary, “ground-truth” dependent variable in Tasks 2 (Driving Task Demand), 5 (Cognitive Distraction), 6 (Telematics Demand), 7 (Visual Distraction), and 9 (Safety Warning Countermeasures).

Because RT may not account for all of the variance in driver behavior, other measures such as steering entropy (Boer, 2001), headway, lane position and variance (e.g., standard deviation of lane position or SDLP), lane departures, and eye glance behavior (e.g., glance duration and frequency) are also be considered. Together these measures will provide a comprehensive picture about driver distraction, demand, and workload.

<u>Common Driving Scenarios</u> For the tasks that measure the brake RT, the "lead vehicle following" scenario is used. Because human factors and psychological research has indicated that RT may be influenced by many factors (e.g., headway), care has been taken to ensure a certain level of uniformity across different tasks. For instance, a common lead vehicle (a white passenger car) was used. The lead vehicle may brake infrequently (no more than 1 braking per minute) and at an unpredictable moment. The vehicle braking was non-imminent in all experiments (e.g., a low value of deceleration), except in Task 9 (Safety Warning Countermeasures) that requires an imminent braking. In addition, the lead vehicle speed and the time headway between the lead vehicle and the host vehicle are commonized across tasks to a large extent.

<u>Subject Demographics</u> It has been shown in the past that driver ages influence driving performance, user acceptance, and driver understandability. Because the age effect is not the focus of the SAVE-IT program, it is not possible to include all driver ages in every task with the budgetary and resource constraints. Rather than using different subject ages in different tasks, however, driver ages are commonized across tasks. Three age groups are defined: younger group (18-25 years old), middle group (35-55 years old), and older group (65-75 years old). Because not all age groups can be used in all tasks, one age group (the middle group) is chosen as the common age group that is used in every task. One reason for this choice is that drivers of 35-55 years old are the likely initial buyers and users of vehicles with advanced technologies such as the SAVE-IT systems. Although the age effect is not the focus of the program, it is examined in some tasks. In those tasks, multiple age groups were used.

The number of subjects per condition per task is based on the particular experimental design and condition, the effect size shown in the literature, and resource constraints. In order to ensure a reasonable level of uniformity across tasks and confidence in the research results, a minimum of eight subjects is used for each and every condition. The typical number of subjects is considerably larger than the minimum, frequently between 10-20.

<u>Other Commonalities</u> In addition to the commonalities across all tasks and all sites, there are additional common features between two or three tasks. For example, the simulator roadway environment and scripting events (e.g., the TCL scripts used in the driving simulator for the headway control and braking event onset) may be shared between experiments, the same distraction (non-driving) tasks may be used in different experiments, and the same research methods and

models (e.g., Hidden Markov Model) may be deployed in various tasks. These commonalities afford the consistency among the tasks that is needed to develop and demonstrate a coherent SAVE-IT system.

The Content and Structure of the Report

The report submitted herein is a report on the focus groups and experiments documenting the research progress to date (March 2003-March 2004) in Phase I. During the period of September 2003 to February 2004, the effort has been focused on the first Phase I sub-task: Experiments. The introduction section presents the major results from the literature review previously reported in Task 4-A. In this report, the focus group methodology, insights gained from the focus groups, the experimental method and resultant experimental data are described and research needs are identified. This experiment report serves to establish the research strategies of Phase II.

4.1 INTRODUCTION

Driver distraction mitigation strategies can be described based on levels of automation (high, medium and low) and type of automation (system initiated/driver initiated, and driver related/non-driver related initiated). High levels of automation in system initiated strategies will differ greatly from the high levels of automation with driver-initiated strategies. The majority of previous research has focused on driving-related strategies such as *intervening* (automatic braking systems), *warning* (collision warning systems), *informing* (speed indicator), *delegating* (adaptive cruise control), *warning tailoring* and *perception augmenting*. Of the non-driving related strategies, only *demand minimizing* has been investigated as a potential means of reducing distraction (Lee, Caven, Haake, & Brown, 2001). The strategies that clearly merit further investigation include the non-driving related strategies such as *locking & interrupting, place keeping, prioritizing & filtering*, *controls pre-setting* and *advising*. Therefore, it is crucial to investigate the impact of non-driving related issues as well because trade-offs exist with all mitigation strategies and it is important for designers and researchers to understand the impact of implementing each strategy and the effects of interactions between these strategies when used in combination.

The dimensions that define this taxonomy reveal general considerations for distraction mitigation strategies. Driver initiated strategies depend on the driver to recognize the degree of distraction and react appropriately. More importantly, these strategies may be susceptible to behavioral adaptation in which making the system easier to use increases the safety of individual transactions, but leads drivers to increase the number of transactions, resulting in an overall higher level of distraction.

System initiated strategies depend on the drivers' acceptance and appropriate reliance on the system. Potentially hazardous situations can occur if the driver relies too much on the system and the system fails to provide the necessary information or take the necessary actions. Moreover, over reliance on the system might amplify the risk taking behavior of the driver as the driver places more trust in the automation. In these situations of over reliance, the failure of high levels of automation might lead to more severe safety problems than lower levels of automation. High levels of automation may also lead to lower situation awareness (Endsley, 1995). However, situations with time critical elements (e.g. impending crash) would require higher levels of automation (Moray & Inagaki, 2003). If the system senses a near-fatal situation, the level of automation should be higher to take control immediately. That is, if the driver is going to crash regardless, the vehicle should take action.

Driving-related strategies that involve high levels of automation may also induce behavioral adaptation because drivers can become comfortable performing non-driving related tasks typically not performed in critical driving situations because the driver has grown accustom to the increased assistance of automation. This is an example of risk compensation defined by Peltzman (1975) which refers to the trade-off between the driving intensity (e.g. speed, thrills) and the perceived probability of death or injury from accident. There is also a level of uncertainty in the automation since the system may not always respond as expected. The potential impact of a false positive or false negative feedback depends on the level of automation. There is a greater safety risk if the *intervening* strategy does not perform as expected when compared to the *informing* strategy.

Another concern that may arise as system initiated options become more prevalent is workload transition (Huey & Wickens, 1993). When the previously automated function is assigned back to the driver by the system, the driver's workload may significantly increase very quickly. Therefore, the system should provide continual or periodic cues that keep the driver aware of the driving situation, so that the driver can step in quickly to resume control. Another issue related to an adaptive system that allocates tasks between the automation and the driver is the system's false adaptation to driver state and traffic condition. An example for false adaptation is the implementation of high automation level when the level of driver distraction is low, and an imminent danger does not exist.

Driver's acceptance of the system is also a key issue and dependent on ease of system use, ease of learning, perceived value, advocacy of the system, and driving performance (Stearns, Najm, & Boyle, 2002). Another factor that affects driver acceptance of a mitigation strategy is the age. A useful tool to predict driver acceptance of a strategy is Human-Computer Etiquette, in other words approaching the acceptance issue by keeping in mind that humans respond to technology socially, and their reactions to computers may be similar to their reactions to humans (Lee & See, in press). These key issues in combination with the previous concerns will influence the effectiveness of mitigation strategies. Therefore, future research should investigate potential functions that can be developed with each mitigation strategy and the most promising combination of strategies that would work best based on the driver's characteristics.

Table 4. 1. Mitigation strategies classified by level of automation and type of tasks.

LEVEL OF AUTOMATION	DRIVING RELATED STRATEGIES		NON DRIVING RELATED STRATEGIES	
	System Initiated	Driver Initiated	System Initiated	Driver Initiated
High	*Intervening*	*Delegating*	*Locking & Interrupting*	*Controls Pre-setting*
Moderate	*Warning*	*Warning Tailoring*	*Prioritizing & Filtering*	*Place-keeping*
Low	*Informing*	*Perception Augmenting*	*Advising*	*Demand Minimizing*

Each mitigation strategy has features that make it beneficial in some situations and not in others. In other words, a mitigation strategy may actually undermine rather than enhance safety. The following list of key dimensions can guide the selection and implementation of particular mitigation strategies.

- Degree and type of distraction confronting the driver
- Type of distraction confronting the driver; drivers may lack awareness regarding the degree of distraction
- Reliability of distraction estimate
- Criticality of the driving situation

4.1.1 Driving Related, System Initiated

Intervening

The perfect system that can help the driver to brake or steer under safety critical situations would enhance safety. However, uncertainty in the driving environment and sensor limits could lead to inappropriate and potentially dangerous responses. For example, system panic braking when there is no imminent danger may possibly create a dangerous response. When the driver is aware of a danger and can actually respond in an appropriate manner, automatic panic braking may also cause a hazard as well as annoyance to the driver. Therefore, it is essential for systems that intervene driving to maximize the rate of correct responses and minimize the rate of misses. In addition to these reliability issues, another problem associated with this strategy is that the driver may become too dependent on this function and be more likely to perform non-driving related tasks that the driver normally would not have performed otherwise and also potentially take more risks when driving. Moreover, drivers are usually critical of systems that intervene their driving whereas systems offering recommendations and providing information are accepted considerably more (Carsten & Fowkes, 1998; Gustafsson, 1997). We prefer to get information and recommendations from the passengers in our cars rather than giving the driver seat to them if we are uncertain about their driving skills. These issues may be resolved if *intervening* strategy can be dynamically adaptive to the driver and roadway state. For example, the threshold for the strategy to initiate (such as time to collision for panic braking or the amount of lane drifting) may change according to the level of driver distraction and/or roadway state (such as the presence of a car on the adjacent lane).

Warning

Warning systems use electronic sensors to detect the motion of a lead vehicle, determine if a collision is likely and warn the driver to move attention to the roadway (*warning*) or take vehicle control (*intervening*). The warning should be meaningful to the driver to promote immediate response. Otherwise, the confusion may elevate the level of cognitive distraction and hence increase the reaction time to the event.

Concern that can impact user acceptance and appropriate reliance on warning systems are false or nuisance alarms, both false positives (an alarm given, but no impending collision was present) and false negatives (an alarm not given, but impending collision was present). In these scenarios, distrust and disuse can result from high false alarm rates. High false alarm rates might also lead to driver frustration, which itself is a type of emotional distraction and might have a negative impact on the traffic safety (Burns & Lansdown, 2000). However, not all false positive alarms are harmful since false positive alarms can be used to train the novice drivers and are also needed to generate driver familiarity with the system. If the first time the driver receives a warning is in a true collision situation, the driver may not respond to it in the required amount of time. False positive alarms may also lead to more cautious driving and thereby result in reduced false alarm rates (Parasuraman, Hancock, & Olofinboba, 1997). Therefore, for the warning system to be effective, an acceptable false alarm rate should be provided.

One way to promote the driver acceptance to warning systems is to employ a graded warning, which would adapt the intensity of the warning according to the criticality of the situation, driver state and/or roadway demand. Goldman, Miller, Harp, Plocher (1995) proposed a driver adaptive warning system that has the ability to adapt the warning threshold to individual differences in driving style and warn the driver under an event that poses imminent danger and/or also when the driver's current behavior does not match his/her behavioral model learned by the system (e.g. when fatigued or distracted). This technique can also be implemented in systems that take vehicle control (*intervene*) to promote acceptance.

Informing

The dynamic model of stress and vigilance of Hancock & Warm (1989) suggests that the combination of information rate and information structure (meaning sought by the person) determines the attentional resource capacity in vigilance. Great deviations from the optimized combination of these two factors (either increase or decrease) sequentially result in discomfort, stress (when the deviations exceed the psychological adaptability of the individual), and performance deficits. Therefore, the information rate and structure presented to the driver should be optimized to promote driver acceptance of and high levels of attention for an informing system. Performance improves when the operator has control (information activating) on either one of these two factors or both (Hancock & Warm, 1989). In situations where the driver is thought to be too distracted, the system may fine-tune the messages based on the urgency of the situation and the roadway demand (i.e., a within strategy adaptation). As an example, if the driver was going over the speed limit, *informing* may provide speed information at some regular specified interval. If the driver is too distracted while driving over the speed limit, *informing* may change the interval of the speed information displayed by flickering with more urgency (Hoedemaeker, de Ridder, & Janssen, 2002).

Depending on the criticality of the distraction situation, the driver related, system initiated system would adapt to the most appropriate level of automation to mitigate distraction (i.e., a between strategy adaptation). For example, if the system decides that the driver engagement with IVIS is a distraction when approaching a stop sign, *informing* might be appropriate in order not to annoy the driver in case the driver actually noticed the sign. An example of *informing* can be an oncoming “STOP” on a HUD. If the system detects that the driver is not decelerating while approaching the stop sign, a *warning* might be more appropriate. In addition, if there is an oncoming vehicle and the system senses an impending collision, *intervening* might start braking smoothly for the driver and give the control back if the driver takes over braking. If the driver does not take any action or the system detects that the driver would not be able to stop in the required amount of time, the system might even start panic braking.

4.1.2 Driving Related, Driver Initiated

Delegating

This system can assist the driver in sharing the work load and therefore potentially reduce the attentional and biomechanical demands posed by the driving task. However, it might also transform interactive driving to a vigilant task of monitoring and potentially increase the level of distraction by encouraging the driver to engage in distracting activities. When the driver is engaged in other activities the detection of automation failures will be poor. If the automation fails to take the appropriate actions in driving and the driver can not act in a timely manner, the safety will be compromised (Parasuraman, Mouloua, & Molloy, 1996).

Warning tailoring

This strategy refers to the driver's adjustment of the sensitivity, or start-up and shut-down of the warning system depending on the distracting activities the driver expects to be engaged in. This differs from the warning strategy described in the previous section because driver input is now required. Allowing the driver to adjust or to activate the system can promote driver acceptance. However, the driver's responsiveness to and realization of the level of distraction will be important factors in the system effectiveness.

Perception augmenting

This strategy provides driver information at the driver's request. This will help reduce the driver's demand for locating necessary information (e.g. driver's speed, posted speed) while driving thereby decreasing the level of distraction. Similar to *warning tailoring* this strategy will also depend on the driver's realization of the need for the information. For example, if the driver is too distracted to be aware of how fast he or she is traveling, the driver may also be too distracted to activate an information system that can provide this information.

Driving related, driver initiated strategies are more promising to gain driver acceptance since the driver has control on these strategies. However, under safety critical situations of imminent danger the effectiveness of driver initiated strategies is in doubt compared to their system initiated counterparts. This shortcoming might be resolved by an adaptive system which can switch over to a system initiated strategy depending on the driver and roadway state as well as the hazardousness of the situation.

If there was a method to measure driver distraction, the driver related, driver initiated strategies would take into consideration the input by the driver, but adjust the information provided based on the perceived distraction level. For example, if the system perceived that the driver was not distracted, but would still prefer some level of roadway information, *perception augmenting* can provide posted speed information at the driver's request. If the system detects that the driver may be somewhat distracted (e.g., eyes were not on the road for an extended period of time), then *warning tailoring* would provide warning information at the sensitivity level placed in by the driver. Lastly, if the system detects an impending collision based on the headway setting of the driver, the system may switch to *delegating* and assist in braking if that was the preferred setting of the driver. Obviously, the effectiveness of these driver related, driver initiated systems are dependent on the settings placed in by the driver. Therefore, an extension to these strategies is to incorporate the driver related, *system initiated* strategies with the driver-related, *driver initiated* strategies. For example, if the driver set the forward collision warning system to activate at a specific headway and the system senses that the driver will not take action, the adaptive system can then switch to *intervening* and take over braking and steering (rather than merely assist in braking).

4.1.3 Non-driving Related, System Initiated

Locking & interrupting

This type of system can be classified as high levels of automation since *interrupting* discontinues the non-driving activities and *locking* locks out the system that is associated with these activities, at times when attention to the primary driving task is required. Ideally the system should be able to switch between *locking* and *interrupting* depending on the driver and roadway state in order to pick the best strategy since *interrupting* is a lower level of automation compared to *locking* and would have different effects on reducing distraction. The disadvantage of this strategy is the potential increased annoyance level of the driver, especially if the system unnecessarily takes action, as well as the potential for increasing the degree of distraction as the driver tries to continue the non-driving related task that was interrupted or locked, thereby, increasing driver distraction. In addition to the safety issues related to the driver distraction, with this strategy the productivity decrement associated with the in-vehicle task interruption also arises.

Prioritizing & filtering

This system minimizes the number of non-driving related tasks performed in high load situations by prioritizing and filtering information. This can be grouped as a moderate level of automation compared to interrupting and locking. For example, under high demand driving conditions, depending on the criticality of the situation, the incoming calls can either be filtered (not letting the phone ring) or prioritized (allowing only the calls that are listed by the driver as highly important). A potential downside of this strategy is that the driver's attention may be drawn to inappropriate elements of the driving task (e.g. notification of the next exit when the car ahead is braking).

Advising

Advising gives drivers feedback regarding the degree to which they are engaged in a non-driving task. A background sound on a cellular telephone conversation could remind both parties that one is driving. This sound could be modulated according to the driving situation and/or driver state (i.e., within strategy adaptation). For example, the *advising* of the background sound could become more intense as vehicle speed and traffic density increase. This strategy is considered a low level of automation since it informs the driver only without taking any action. However, such a strategy may increase driver annoyance as well as distraction if the demands of ignoring the "advice" become a burden such as a passenger constantly nagging the driver to watch out the traffic.

An example of how an adaptive system can be used with non-driving related, system-initiated strategies relates to in-vehicle text messages. If a driver was using e-mail in their car and the system perceived that the driver was not focused on the driving task, the system can provide an *advising* strategy to remind the driver that he or she is still driving. If the same person was approaching a more visually demanding roadway (e.g., a curve) and was still perceived to be distracted, the system would then activate the *prioritizing and filtering* strategy by either prioritizing the information that can be viewed at the moment (e.g., only messages from specific individuals can be received), or filtering the information presented (e.g., only messages that were four words or less). Lastly, if the driver has not had his or her eyes on the road for an extended period of time and was too close to a lead vehicle, the system can change to a *locking and interrupting* strategy that will stop anymore messages from appearing and lock you out of the system until the impending danger is over.

4.1.4 Non-driving Related, Driver Initiated

Controls pre-setting

This system is categorized as the highest level of automation for a driver initiated option for the non-driving related scenarios. For example, the driver can pre-set the radio or CD player or the destination on navigational devices and not modify it once in drive. However, the driver may still be tempted to manipulate the controls and therefore diminish the effect of this strategy.

Place keeping

This system minimizes the demand of switching between the driving and the non-driving related tasks. Task switching involves directing attention from one task to another (e.g. talking on the cell phone to braking and back to talking on the cell phone). As the number of tasks a person has to perform simultaneously increase, the more difficult it is for the driver to perform these tasks because task switching requires a certain amount of attention. For example, reading a map (either paper or display) significantly degrades driving performance (Dingus, Antin, & Hulse, 1989). If the visual demands on the road increases the drivers tendency to glance at an in-vehicle display more frequently, with shorter duration glance times and larger times between the glances to keep their driving safe (Tsimhoni & Green, 2001), the need for keeping the place of the driver at the non-driving related task also increases. If not helped, the driver might become distracted trying to relocate the point in the task he or she was performing, and may even have to start over if returning cues can not be easily identified. Alternatively, the driver may be more likely to persist and extend glances away from the road to a dangerous level. As stated for the *locking* and *interrupting* strategy, these issues may be resolved by designing IVIS which have clearly defined subtasks (especially for non-repetitive ones) that can be carried out in short attention switching intervals. The downside of this strategy is the potential encouragement of the driver to engage in more non-driving related tasks by making the task easier to carry out.

Demand minimizing

Lee et al. (2002) showed that given a collision scenario, a highly visual demanding interface generates only slightly higher reaction times, than a speech-based interface. This is supported by Verwey (2000) who showed that presenting information by speech versus maps does not have a significant difference on safety reduction. Moreover, speech recognition is more prone to errors. Another study by Lee et al. (2001) evaluated the effect of a speech-based email on driver's response to a lead vehicle's periodical braking. A 30% (310 ms) higher average reaction time was recorded for the treatment group which received the speech-based email than the control group which did not. Although the response data of the groups that received the complex e-mail versus a noncomplex one did not show differences, the subjective cognitive workload ratings were higher for the former group. Therefore, a poorly designed speech-based interaction with IVIS has many of the characteristics of a mobile phone communication, and would deteriorate driving performance (Lee, McGehee, Brown, & Reyes, 2002). For example, a poor quality synthetic voice would pose more cognitive distraction on the driver. Combined with the complexity of the driving task, this might deteriorate driving performance. Under high attention demanding situations, the use of such a system should be minimized. This may be accomplished by integrating the speech-based interaction system with the level of driver distraction and surrounding traffic information.

In contrast to the system initiated strategies that transform the non-driving related tasks into being more preventive to perform, the driver initiated strategies aim to ease these tasks. Therefore, these strategies would increase the level of IVIS use. Even if these strategies might decrease the level of distraction, as the time of IVIS usage accumulates the probability of a driver distraction rises. As the system can adapt between driving related, driver initiated & driving related, system initiated strategies to overcome the issues emerging from each strategy, the system can also adapt between non-driving related, driver initiated & non-driving related, system initiated strategies. The issues related to non-driving related and driving related strategies can similarly be resolved by system dynamically adapting between these strategies. However, these adaptations may generate issues of their own as the system starts behaving inconsistently, unsuitable for driver expectancies and therefore possibly creating new distractions to the driver as the system behaves in a way the driver may not anticipate.

Examples of adapting to non-driving related, driver initiated strategies can also be demonstrated with in-vehicle text messages. For these strategies, the driver will preset the settings before they begin their drive. However, it should be noted that the settings they preset may not actually help in a distracted situation, but perceived by the driver as a benefit while driving. For example, the driver may actually set what messages they want to see while they are driving (*controls pre-setting*). If they are approaching a curve, or in high demand traffic, they may put a place marker in the text until they are ready to read the messages again (*place-keeping*). The use of speech recognition to hear their messages rather then view their messages may also be incorporated by the driver (*demand minimizing*).

Based on issues discussed above, two promising strategies have been chosen for evaluation in a simulator experiment. These two strategies are *advising* and *locking* which represent the extreme ends of automation (low and high) under non-driving related, system initiated category. The logic under this decision is as follows:

- Non-driving related category has been chosen over the driving-related category since this category is in short of research compared to the latter one.
- The system initiated category has been chosen over the driver initiated category since driver initiated strategies depend highly on the subjective distraction level of the driver. Therefore, even if driver acceptance of system initiated strategies might be lower, these strategies are more promising in terms of their effectiveness in reducing distraction.
- Among the three non-driving related, system initiated strategies (i.e. locking, prioritizing and advising) the high and low levels of automation categories have been chosen in order to assess the effects of the level of automation in mitigating distraction.

The other strategies also merit further research, however due to the limited time and resources, elimination had to be done to pick up the strategies that are hypothesized to promise higher effectiveness.

These two strategies will be evaluated based on different driving scenarios and display type as it relates to driver safety, acceptance, and reliance.

4.2 FOCUS GROUP

Driver distraction is a major concern and has been shown to contribute to vehicular crashes. Therefore, investigating ways to mitigate distractions is very important. Driver acceptance of distraction mitigation strategies is crucial if these strategies are to be effective. Different driver distraction mitigation strategies were categorized in a taxonomy based on levels of automation, type of task being modulated by the strategy, and the strategy initiation. This taxonomy was further developed with focus groups that were conducted to investigate driver acceptance of the various mitigation strategies and is summarized in the previous section and is also described in detail in Task 4-A report. The taxonomy also guided a driving simulator experiment which evaluated how several mitigation strategies, presentation modalities, false system adaptation and driver age affect the system effectiveness and acceptance. The results of the focus group and its relevancy to the experiment are described in this section.

Focus groups have previously been used in transportation and other research to gain perspective and insights on an issue (Rogers, Meyer, Walker, & Fisk, 1998). Typically, focus groups are used as a part of large research programs and the data collected can be integrated with data from experiments, surveys, etc. However, the small number of participants limits the generalization to a larger population (Rogers et al., 1998; Stewart & Shamdasani, 1990). Nevertheless, the insight gained from this type of exploratory research is valuable in developing hypotheses and in formulating more precise research questions. Therefore, for this study, focus groups were performed to help develop the taxonomy which was then further investigated by a simulator experiment. 24 participants were recruited in two cities with different traffic conditions—Iowa City, IA (12 participants) and Seattle, WA (12 participants). Two focus groups were conducted in each city with participant age ranging from 22 to 64 ($\overline{X}$ =37.8, σ^2 =11.8). All participants were active drivers who drove daily.

All sessions were 4 hours long and followed a structured question path. The session began with introductions and explanations about why the group was assembled and what information was hoped to be garnered. To set the stage and educate participants about driver distraction, a brief overview of the different types of distraction were presented. Specifically, the visual only, visual manual, manual, and cognitive types of distraction were presented (Ranney, Mazzae, Garrott, & Goodman, 2000; Wierwille, 1993). In addition, the sources of distraction were also listed: vehicle (e.g., radio), driver/passenger (e.g., passengers), and external (e.g., billboards). Finally, a 12-minute video on driver distraction, which provided concrete examples of the types of distractions, was presented. The general structure of the focus group then proceeded along the sequence of topics presented in the results section.

4.2.1 Results

Distractions that participants had previously experienced

The three major groups of distractions discussed were in-vehicle, external, and cognitive distractions. In terms of in-vehicle distractions, cell phone, changing CD's and tuning the radio were considered the worst distractions. External distractions included trying to follow road signs in an unknown area, or observing an unplanned activity (e.g., crash) or planned activity (e.g., lawn mowing). Primarily, cognitive distractions included driving while thinking about a non-driving situation. Regardless of the distraction type, most drivers indicated that they would continue to use their in-vehicle devices and perform other types of distracting activities unless there is a law that tells them otherwise. This indicates that drivers are most interested in systems that will allow them to continue their non-driving related tasks, and mitigation strategies that interfere with drivers' ability to perform non-driving tasks may not be well-accepted. Therefore, these considerations need to be incorporated into the taxonomy.

Realization of the potential danger of the distraction activity

Participants also identified how systems could help increase their driving performance. Examples include another vehicle's horn, and passengers who alerted the driver to "look out" or of upcoming turns. Road markings such as rumble strips were beneficial in alerting of a roadway departure. Other techniques that were considered beneficial include having the driver of the lead vehicle depress the brakes intermittently to warn of a closing gap in the lead and following vehicles. These distraction indicators can be translated into mitigation strategies which are driving related. For example, auditory collision warnings, which implement the *warning* strategy, may emulate a vehicle's horn. Similarly, seat vibration for roadway departure warnings may help mitigate driver distraction by augmenting cues drivers currently use.

Technologies to mitigate distraction

Generic technologies (e.g., eye-tracker, directional seat vibration, etc.) were presented to the participants to generate ideas for innovative technology solutions. Participants appeared to favor systems that can adapt to the driver's needs such as eye tracking and seat vibration devices. They felt that employing a device that could track eye position relative to eyes-on-road time would be helpful and an automatic seat and mirror adjustment for each individual driver would reduce the need for small adjustments during driving. Some drivers even favored ideas such as a co-pilot that would take over when an eye-tracking system senses droopy eyelids relative to fatigue, while other drivers did not like the idea of high levels of automation. These comments showed the need to tailor driver distraction mitigation strategies based on the adaptive needs of each individual. These needs may be realized in different levels of automation (such as high, moderate and low) tailored based on individual differences and the particular distraction level.

Helpful passengers during distracted situations

Because people tend to respond socially to technology, reactions to technology can be similar to reactions to human collaborators (Lee & See, 2004). Therefore, if a system has characteristics of a helpful passenger, the driver may perceive the system to be more beneficial. Participants were asked to describe situations where passengers helped them drive better and what suggestions from passengers have been annoying. Focus group participants identified a helpful passenger as one who acts as 'a second set of eyes', who does not nag, who knows when to properly warn you of an impending danger. Offering conversation at the right times would classify a passenger as helpful, but talking constantly and during more visually demanding driving situations is not. The tone of a passenger's voice can also help the driver be more cautious in some situations. Recent research in the area of computer etiquette suggests that acceptance depends on more than the technical performance of the system (Miller, 2004). Distraction mitigating systems that carry these characteristics would have a higher likelihood of being accepted by the drivers.

Categorization, likes and dislikes of mitigation strategies

The mitigation strategies were categorized into levels of automation, initiation of the strategy, and type of task modulated by the strategy. The participants' perceptions and comments of these strategies within this preliminary taxonomy were requested. Drivers had different opinions regarding preferences for levels of automation. For example, some drivers preferred a high level of automation (i.e. *intervening*) because this would remove the driver from all responsibilities related to distracting situations as well as for those with impairments (e.g., medical condition, alcohol and drug related) that may impact their driving abilities under certain scenarios. Concerns that drivers had with this strategy include the possibility of suboptimal responses based on current technology as well as individual driver's experience. They felt that there are always unexpected situations that automatic control cannot account for. Moderate levels of automation for the driving related task (i.e., *warning*) was deemed helpful in the driving task by enabling drivers to make better decisions if the presentation of the information was not annoying. In terms of non-driving related tasks, a low level of automation (i.e., *advising*) was also perceived to be helpful by all drivers. Participants felt that an *advising* strategy would enable drivers to be more aware of their driving behavior and how it can impact others. Some drivers generally had negative attitudes towards interruptions of their non-driving related tasks such as the interruption of their cell-phone conversation. On the other hand, other drivers believed that rather than making the tasks easier to perform, the systems should prevent the drivers from engaging in non-driving activities. Clearly, acceptance of the system will play a key role in how drivers use the system as well as how satisfied they are in its performance. Therefore, the levels of trust and acceptance will need to be investigated in the next phase of the study.

4.2.2 Final Taxonomy

The focus group helped improve the taxonomy and identify an area (driving related strategies that are driver initiated) that was not typically identified as a category that would mitigate the effects of distraction. The majority of research in mitigation strategies has centered on the driving related strategies that are system initiated (such as forward collision warning system, run off the road). Previous research in driver initiated systems (e.g., conventional cruise control, speed information at driver's request) typically did not center on mitigation strategies, but were viewed as convenient systems for drivers (Bogard, Fancher, Ervin, Hagan, & Bareket, 1998). However, the focus group suggests that perhaps these types of systems can be tailored to reduce the effect of driver distraction. Moreover, titles of some mitigation strategies were changed to reduce the ambiguity and/or negative connotations relating to some of the mitigation groups (i.e., *nagging* to *advising*). Focus group discussions relating the categories of the taxonomy are presented below.

Driving related strategies, system initiated

The focus groups revealed that drivers have different preferences regarding this group of strategies. Some drivers liked the idea of high levels of automation whereas the rest preferred lower levels of automation. Regardless of preference all drivers were concerned about the system accuracy.

Driving Related Strategies, Driver Initiated

Based on the discussion of the focus group participants, some of the systems that were discussed did not fit into any of the existing categories. Therefore, the researchers developed this new category to facilitate other types of mitigation strategies as well as provide symmetry in taxonomy.

Non-Driving Related Strategies, System Initiated

These systems have not been studied as much as the other categories. However, findings from the focus group indicate that there are perceived benefits in further investigating these systems.

Non-Driving Related Strategies, Driver Initiated

Some focus group participants indicated that this group of strategies may lose their effectiveness if these systems were too easy to use. As an example, if they feel that hands free cell phones allows them to minimize task demands (*demand minimizing*), they may feel more comfortable using it more and therefore their likelihood to get distracted would increase. This issue should be considered in system design to ensure effectiveness of mitigation strategies.

4.3 EXPERIMENTAL METHODOLOGY

4.3.1 Experimental Objective

The primary objective of this experiment was to assess the effects of different driver distraction mitigation strategies on driver safety as well as the impact to In-Vehicle Information Systems (IVIS) while the mitigation strategy is activated. More particularly, the conducted experiments aimed to evaluate the effectiveness of a potential IVIS design which encompasses the capability of adaptation to roadway demands, in order to direct driver's attention to the driving task when necessary. The experiment specifically addressed the following issues:

- Assess the acceptability and effectiveness of different levels of automation implemented in IVIS (in particular, *advising* the driver to discontinue the IVIS interaction and completely *locking out* the interaction) to reduce distraction, enhance safety and increase IVIS productivity.
- Investigate whether the type of IVIS task demand (visual vs. auditory) influences the effectiveness of the mitigation strategies on enhancing safety or productivity.
- Assess the influence of system imperfections on the driver's acceptance of and response to the mitigation strategies.
- Assess the impacts of driver age on acceptance and effectiveness of the mitigation strategies.

4.3.2 Participants

Participants were recruited based on the following requirement (see APPENDIX A for screening script):

- Between the ages of 35-55 and between 65-75
- Possess a valid U.S. driver's license
- Have at least 5 years of driving experience
- Native English speaker
- Pass simulator sickness screening questions

The participants were monetarily compensated for their participation in this experiment.

Participants in pilot study

There were 8 participants solicited for the pilot study. However, 1 of the 8 dropped out – leaving 7 valid pilot data. The actual experiment was modified based on the outcome of this pilot study.

Participants in actual experiment

Of the 36 subjects solicited for the actual experiment, 8 subjects (5 older and 3 middle aged) dropped out due to simulator sickness and unwillingness to come back on day two. This resulted in a total of 28 valid drivers (16 middle aged and 12 older) used in the analysis.

4.3.3 Apparatus

<u>Fixed based simulator</u>

The experiments were conducted with a medium fidelity, fixed based simulator powered by Global Sim, Inc.'s DriveSafety™ Research Simulator, a fully integrated, high-performance driving simulation system designed for use in ground vehicle research and training applications (see Figure 4. 1). The simulator has a 1992 Mercury Sable vehicle cab with a 50-degree visual field. The cab is equipped with force feedback steering wheel, actual gauges, and a rich audio environment. A state-of-the-art PC Hardware is employed to generate fully textured graphics with 60 Hz frame rate at 1024 x 768 resolution. The driving scenarios are created by HyperDrive™ Authoring Suite. All graphics for roadway layouts, markings, and signage conform to American Association of State Highway and Transportation Officials (AASHTO) and Manual of Uniform Traffic Control Devices (MUTCD) design standards. Driving data was collected at 60 Hz.

Figure 4. 1. GlobalSim Drive Safety driving simulator

<u>In-vehicle visual display</u>

A 7 inch LCD (60 Hz frame rate at 640 x 480 resolution) mounted on the dashboard by a small stand was used in the experiment. The viewing angle from the driver's eye point is approximately 18 degrees.

Auditory display

Auditory messages used in the secondary task (IVIS task) were converted into .wav audio files through the Ultra Hal Text-to-Speech Reader, Version 1.0, created by Zabaware, Inc. (available at http://www.zabaware.com). This text to speech reader includes many high quality computerized voices. The voice used for conversion is "Sam," a Microsoft SAP14 Text-to-Speech Synthesis Machine. The "Sam" voice is described as an adult male, clear, low-accented North American English native voice.

Both of the message systems (for the visual and auditory component) were operated on a standard PC in Microsoft Visual Basic.

4.3.4 Driving Task

Each subject completed thirteen scenarios (including three practice drives) in two days. All scenarios took place on 2-lane rural roads without any oncoming traffic present. Due to the limited time of the project, the effects of oncoming traffic were not assessed. Constant level of fog was employed during each scenario to decrease the drivers' ability to anticipate an approaching curve or a lead vehicle braking event (the fog also decreased the likelihood of simulator sickness). The participant was instructed to drive at a comfortable speed which is not above the speed limit of 45 mph. The lead vehicle periodically braked at a mild rate of deceleration (0.2 g) for 5 seconds. Twelve of these braking events took place in each driving scenario. Half of these braking events were on curves and the other half were on the straight sections of the drive. Moreover, in order to make the scenario more realistic different radius curves were used; half of the curves were 400 meter radius (half left turn, half right turn) and the other half were 200 meter radius (half left turn, half right turn). An example of a driving scenario is shown in Figure 4. 2. The braking events and the radius of curves were randomized through the drives (APPENDIX B).

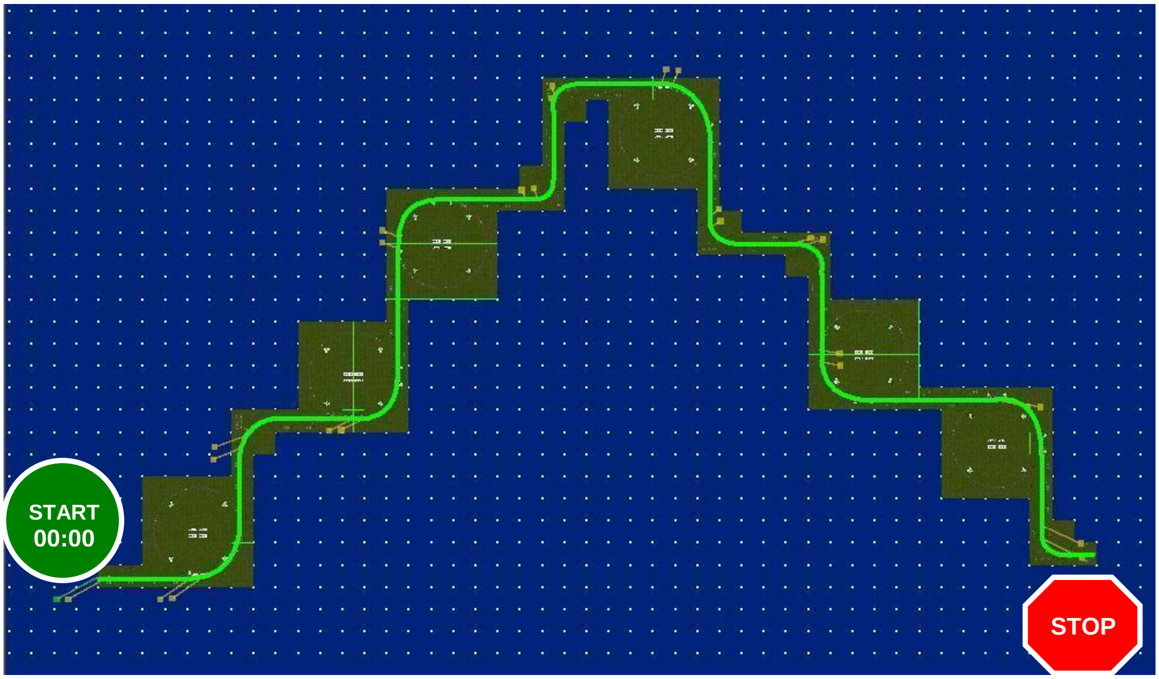


Figure 4. 2. The geometry of an example test road*[2]

4.3.5 IVIS Task

The IVIS tasks included visual and auditory demand tasks. These tasks, which were based on the working memory span task defined by Baddeley, Logie, & Nimmo-Smith (1985), was displayed to the subject via a peripheral display for the visual task and by a synthetic voice for the auditory task as described in the apparatus section. In both the visual and auditory conditions, the subject had to respond to the tasks through verbal responses and with button presses located on the steering wheel. Specifically, the secondary tasks required drivers to determine if a short sentence was meaningful or not (response by pushing steering wheel buttons) and then also recall the subjects of three consecutive sentences (verbal response). For example “the policeman ate the apple” is meaningful and its subject is “policeman”, whereas “the apple ate the policeman” is not meaningful and its subject is “apple”. For each set of three sentences, every new sentence was presented to the participant 5 seconds after the previous sentence presentation. A list of the sentences (with the number of syllables) and how they were balanced among the driving scenarios are provided in APPENDIX C.

The participants were provided with a 10 seconds pause time to verbally recall the subject words before a new set of three sentences were presented. The

[2] There were 10 scenarios used in the experiment. Figure 4. 1 shows one of the 10 test conditions.

tasks were presented to the participant in a game format and the participants were monetarily rewarded depending on their performance on the task (See APPENDIX D for the Interactive Game Instructions). Feedback regarding award during the drive was provided to the participant (verbal recall success after each three sentence set; button push success at the end of the drive). This enabled the experimental task to more realistically simulate driver's interaction with IVIS (i.e. performing the task was important to the driver). This in turn led to better assessment of driver acceptance of the strategies.

4.3.6 Experimental Design

There were initially two levels for each of the four factors: Age, Adaptation, Level of Automation, and IVIS demand (see Figure 4.3).

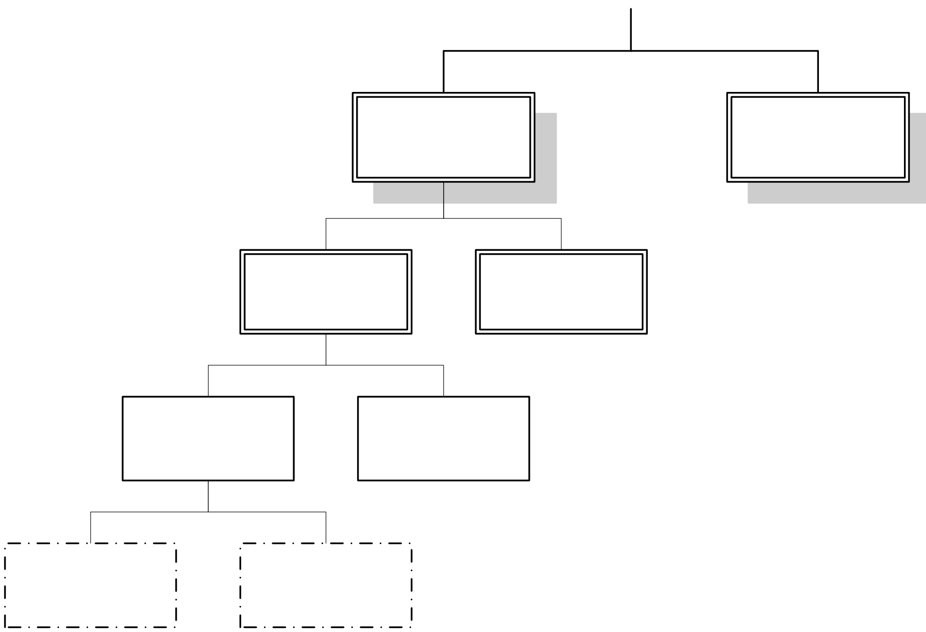


Figure 4.3. Experimental Design Factors

Independent variables

System adaptation

True system adaptation refers to the system properly adapting to the environmental or driver state. That is, the system takes action when it is supposed to and does not take action when it is not supposed to. *False system adaptation* occurs when the system fails to adapt appropriately, producing both false alarms as well as misses. That is, the system takes action when it should not and does not taking action when it should. These two types of imperfections might affect the driver acceptance, trust and use of the system, differently.

AGE
Young

SYSTEM
SYSTE

However, given the limited project and schedule, the effects of these imperfections were not differentiated. For the purpose of creating an unreliable system, both of these imperfection types were implemented together under the factor of false system adaptation to form a 50% reliability rate. In order to create different levels for the system adaptation factor, the signal detection theory has been employed (Green & Swets, 1998; Swets, 1996; Swets, Tanner, & Birdsall, 1961). This theory provided insights especially for the false system adaptation. As can be seen in Table 2, the conditions have been designed to provide equal number of hits, correct rejections, false alarms and misses (See APPENDIX B for randomization of false system adaptation through drives). This theory also provided an insight to design the experiment to generate equal number and duration of alarms (advising and locking) for each scenario drive. Providing unequal duration of alarms would have confounded the acceptance measures, since the acceptance, while depending on the system adaptation, also might depend on the duration of the warning presented to the driver.

Level of Automation

Two distraction mitigation strategies were implemented in the system to either advise the driver to discontinue the non-driving related task or to lock out the interaction with the system completely. Both of the strategies were mapped to the driving events that require appropriate response from the driver, independent of driver's IVIS task performance. These two events are lead vehicle braking and curve entry ahead. Curve entry ahead refers to the road section consisting of two seconds long drive straight section before the curve and the three seconds long drive section of the curve ahead. The subjects were told that the system would take these actions when the driver has to give attention to the roadway, specifically when the lead vehicle was braking or there was a curve ahead.

IVIS Demand

This factor is explained above under the heading of IVIS Task. The distraction mitigation strategies were implemented differently for the visual and the auditory task demands.

Visual IVIS Task: Advising was implemented with a red bezel around the screen that presented the IVIS task. The red bezel illuminated whenever there was a lead vehicle braking or curve entry ahead (5 seconds for both conditions) (Figure 4. 4). With the advising, the driver was still able to interact with the system. The lockout strategy blanked the screen and illuminated the red bezel. The red bezel and the lockout remained in effect until the triggering condition was over (i.e. lead vehicle braking or curve entry).

Figure 4. 4. IVIS Visual Display with an Advising Strategy

Auditory IVIS Task: For the auditory IVIS task, advising was implemented with a periodic clicking noise (1 Hz) whenever there was a lead vehicle braking or curve entry ahead (5 seconds for both conditions). As for the visual IVIS task condition, with the advising, the driver was still able to interact with the system. The lockout strategy stopped the task message presentation and presented the periodic clicking noise to the driver. The lockout remained in effect until the triggering condition was over.

The type of strategy and individual differences in lead vehicle following speeds had an impact on the number of IVIS messages received in each drive by the participants. However, the button-press and verbal recall tasks provided a controlled exposure to the visual, auditory, motor, and cognitive distraction associated with in-vehicle information system interaction and was similar to the tasks used in other driver distraction studies (Radeborg, Briem, & Hedman, 1999; Salvucci, 2002)

Between subject variable

Age was implemented between subjects. Each subject went through all the driving scenarios.

Within subject variables

For the purposes of analysis, the within subjects variables were collapsed into a Systems Category (Visual-Advising, Visual-Locking, Auditory-Advising, Auditory-Locking) due to the blocking of the randomization (blocking occurred for Days (1, 2), Adaptation per Day (True, False) and Task Baseline Condition per Day (Auditory, Visual).

All four system conditions plus one of the baselines were tested under both true and false adaptation (see Table 4. 2). There were two baseline drives. During the first half of both baseline conditions, there was no secondary task presented and no mitigation strategy (this is the no-task baseline condition). In the second half of the baseline condition, the driver was presented with either a visual or auditory secondary task (this is the task baseline condition). Given that each system condition with follow-on questionnaires took approximately 30 minutes to complete, the study was set up over two days with each of the adaptation level and each of the baseline condition completed on one of the two days. The order of adaptation was randomly assigned as was the baseline condition.

Table 4. 2. Experimental Setup of Within Subjects Variable

	Adaptation	
	TRUE	FALSE
Systems	Visual-Advising	Visual-Advising
	Visual-Locking	Visual-Locking
	Auditory-Advising	Auditory-Advising
	Auditory-Locking	Auditory-Locking
	Baseline (1) or (2)	Baseline (1) or (2)

Baseline conditions

The task baseline conditions (visual and auditory) were implemented to assess the effects of the strategies to mitigate distraction. Whereas, no-task baseline was implemented to assess the deteriorating affect of non-driving related tasks on driving performance.

4.3.7 Dependent Variables

The primary dependent measures collected from the driving tasks were the responses based on the lead vehicle braking event and the performance measures while on the curves. The primary measures collected from the IVIS task were the number of correct responses (both for the button push and the verbal recall). Subjective measures of mental effort, perceived risk, system acceptance, system trust, interpersonal trust were also assessed. Subjective measure questionnaires can be found in APPENDIX E. The dependent measures are further discussed in the Results section.

4.3.8 Procedure

Subject participation was over two days. On the first day, after signing an informed consent document, driving and game instructions are given to the subjects (APPENDIX D). A practice drive consisting of two 5 minute runs (in the auditory and visual condition) is given. The practice drives were designed to increase subject familiarity with the simulator, driving environment and the visual and audio secondary tasks. During the second half of the drive, the participants were familiarized with the game (or secondary task). On day two, the practice run consisted of normal driving only (without the game) to refamiliarize the participant to the simulator environment given that the participant have been driving in real traffic. A practice on the secondary task was not performed because during the pilot runs the experimenter did not observe any decrements on the secondary task performance. However, the participants were still given the secondary task instructions.

Experimental drive

The practice drive is followed by four 12-15 minute experimental drives and one baseline drive per day (for a total of five drives per day excluding the practice drives). After each of the non-baseline drives, four questionnaires were given that assessed mental effort, perceived risk, system acceptance, and system trust.

Questionnaires

At the end of day two, a set of questionnaires were also given to assess system acceptance after all drivers were completed and interpersonal trust. The subjects were also debriefed at the end of day two (APPENDIX F).

4.4 DATA REDUCTION

To perform the analysis, some data reduction had to be completed. The objective data from the driving simulator was reduced to the scenario level for analysis. The following describes the data reduction that was completed.
The following data was reduced to better understand how the drivers perform on a curve (during curve entry and on curves) and during a lead vehicle braking event.

4.4.1 Curves

The data was reduced based on curves to assess whether or not the strategy helped the drivers perform better on the curves. The curve variables provide insights on safety (steering entropy), and curve negotiation behavior (speed and acceleration).

1. *Steering Entropy*: This variable is the main safety measure used which determines the discontinuities in the steering behavior (Nakayama, Futami, Nakamura, & Boer, 1999).

2. *Maximum curvature speed:* Speed at the point of maximum curvature. Calculated only for curves with no lead vehicle braking events. This is to ensure that the speed maintained solely represents the driving performance on curves.

3. *Maximum curvature acceleration:* Acceleration at the point of maximum curvature. Calculated only for curves with no lead vehicle braking events.

Reduction was also performed on the curve entries (2 seconds before the curve and proceeding 3 seconds on the curve) to assess how well the drivers understood the information provided by the mitigation strategy. For each curve entry three different values were calculated:

1. *Average speed*: Average speed on the curve entry.
2. *Entrance speed:* Speed 2 seconds before the curve.
3. *Minimum acceleration:* Minimum acceleration on the curve entry.
4. *Average acceleration:* Average acceleration on the curve entry.

4.4.2 Lead Vehicle Braking Events

Lead vehicle braking event is defined in the time interval between the onset of the lead vehicle braking (LVB) to the lead vehicle reaching back to the desired speed of 45 mph (LV45). For each braking event, eight values were calculated (the following 7 variables and an additional variable which indicated if the participant was able to follow the lead vehicle). These variables helped assess lead vehicle following behavior, reaction times to a lead vehicle braking event, and intensity of the braking.

1. *Inverse headway distance*: The reciprocal distance between the participant and lead vehicles at the onset of the lead vehicle braking. Because visual angle is a factor that may affect the braking response, and inverse headway distance is proportional to the visual angle, inverse headway distance was added to the model as a covariate when the effect was significant. These covariate effects are considered throughout the analysis.

$$InvH = \frac{1}{H}$$

   Where *InvH* = inverse headway distance
   H = headway distance to the lead vehicle.

2. *Accelerator release time*: The time interval from the onset of the lead vehicle braking to the participant releasing the accelerator pedal. This should be followed by a participant braking. This variable is predictive of how fast the drivers release the accelerator pedal during lead vehicle following and is impacted by the lead vehicle following distance, the saliency of cues (visual angle) and the relative speeds between vehicles.

   Accelerator release time = t(accelerator release) – t(begin)

   Where t (begin) = time at onset of the lead vehicle braking
   t (accelerator release) = time the driver releases accelerator.

3. *Transition time*: The difference between the brake reaction and the accelerator release times.

   Transition time = t(brake onset) – t(accelerator release)

   Where *t(brake onset*) = time the driver depresses the brake pedal.

4. *Minimum time to collision*: The minimum time to collision (minimum TTC) if the participant was to continue in the same path with the same velocity (automatically calculated in DriveSafety software). This measure is dependent on the reaction times, relative speeds, distance between two vehicles and the intensity of braking.

5. *Minimum acceleration*: The highest deceleration (or lowest acceleration) value during a lead vehicle braking event. Minimum acceleration is also predictive of braking intensity.

$$a_{\min} = \min a_i \,|_{f(begin)}^{f(end)}$$

Where a=acceleration at frame i
f (begin)=frame when the participant starts braking
f (end) =frame when the participant starts accelerating.

Data is collected at 60 Hertz. Therefore, in one second, there are 60 frames.

In addition to the above criteria, the data was also limited by the factors defined below.

1. Data which indicated that both feet were used during the drive (one foot on the brake and one foot on the accelerator) were eliminated. This is defined as a brake pedal position value greater than 0.018 and an accelerator pedal position value greater than 0.001.
2. Participants had to be following the lead vehicle. Otherwise the braking event was invalid. The invalid braking events are defined as follows:
   - Brake reaction time greater than 9.01 (the time it takes for the lead vehicle to reach its full speed after braking),
   - Accelerator release time greater than 5.01 (the time it takes for the lead vehicle to start accelerating after braking).
   - Given that the minimum reaction time to visual stimulus is 0.2 seconds, brake reaction or accelerator release time less than 0.2 seconds (Woodworth, 1938),
   - Headway distance not recorded at the onset of lead vehicle braking (headway distance is recorded up to 100 meters).

The lead vehicle braking event data is aggregated for each of the drives completed by each subject. All eight variables (i.e. accelerator release time, brake reaction time, transition time, minimum time to collision, inverse headway distance, mean acceleration, minimum acceleration and lead vehicle following) were averaged for each drive. For example, if there were 8 valid lead vehicle braking events for a drive, the average of the 8 different values for minimum time to collision were obtained. Given that there were 12 braking events in each drive, lead vehicle following was calculated as 8/12. Similar to the lead vehicle braking data, the curve entry variables were averaged for each drive.

4.5 DATA ANALYSIS

4.5.1 Model

For this model, the day and run are repeated measures. That is, each participant had 2 days of 6 runs each (with the baseline drive divided into two runs: no-task baseline, and task baseline). Due to missing treatment combinations (e.g., there was no “No-Task Advising” since the baseline group cannot feasibly have this combination), the mitigation strategy and the IVIS demands were collapsed into one factor for the analysis called *Strategy-Task* that consisted of:

System (Mitigation Strategy, Secondary Task)

1. Visual-Advising
2. Visual-Locking
3. Auditory-Advising
4. Auditory-Locking

Task Baseline (No Mitigation Strategy, Secondary Task)

5. Auditory-Baseline
6. Visual-Baseline

No-Task Baseline (No Mitigation Strategy, No Secondary Task)

7. No Task-Baseline

This collapsing of the conditions for analysis is based on Milliken & Johnson (1992). Therefore, the resulting experiment is a 2x2x7 repeated measure design with Age (2 levels), Adaptation (2 levels), and Task - Strategy (7 levels). However, because the baseline conditions could not feasibly have any adaptation levels, there were missing treatment combinations (e.g. auditory-baseline and true adaptation). This was taken into consideration in the model specification.

The within subject variables include Adaptation (True, False), Task-Strategy (*System*: Visual-Advising, Visual-Locking, Auditory-Advising, Auditory Locking; *Baseline Secondary Task:* Visual-Baseline, Auditory-Baseline; *Baseline:* No Task-Baseline). The between subject variable is Age (Middle aged, Old).

The PROC MIXED procedure in SAS 9.0 was used to analyze the data. After the best covariance structure was chosen for the repeated measures design, estimates and the F tests for the main effects were calculated. Pair-wise comparisons between these effects were also performed between different levels of the independent factors using the Estimate statement in SAS 9.0.

4.6 RESULTS

4.6.1 Effects of distractions

Distractions had detrimental effects on driving performance for both curve negotiation and lead vehicle braking event response. Comparisons reported in this section are: visual baseline vs. no-task baseline; auditory baseline vs. no-task baseline; visual baseline vs. auditory baseline)

Curves

Drivers appeared to steer erratically on curves when they encountered distractions that were not mitigated by a system (Figure 4. 5). This effect was more profound with visual distractions than with auditory distractions ($t(268) = -4.09$, $p<0.0001$). Regardless of age and type of distraction, drivers approached the curves with lower speeds to compensate for the effect of distractions on their curve negotiation (visual vs. no-task: $t(256) = -3.67$, $p<0.005$; auditory vs. no-task: $t(244) = -3.17$, $p<0.005$) (Figure 4. 6). This compensatory behavior diminished at the point of maximum curvature ($F(2, 263) = 0.54$, $p=0.12$).

Drivers had to brake harder when entering a curve with auditory distractions but actually braked softer with visual distractions ($t(268) = 12.73$, $p<0.0001$). Given that drivers compensated for the auditory distraction effects by lowering their speeds while approaching a curve, they still perceived they were going too fast and braked harder. Therefore, when distracted, drivers slowed down at the curve entry and sped up later. Regardless of this compensatory behavior, drivers still had more erratic steering behavior when distracted; therefore a mitigation strategy is clearly needed for better curve negotiation performance.

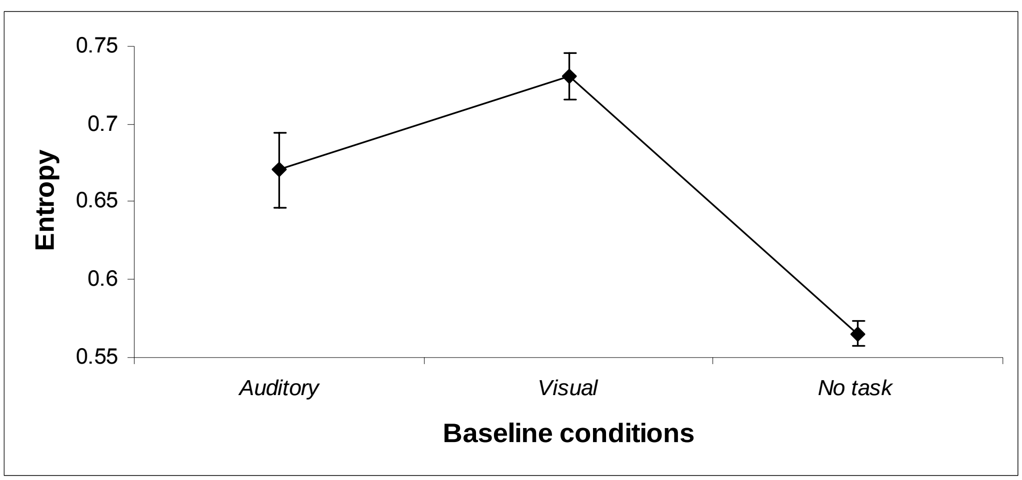
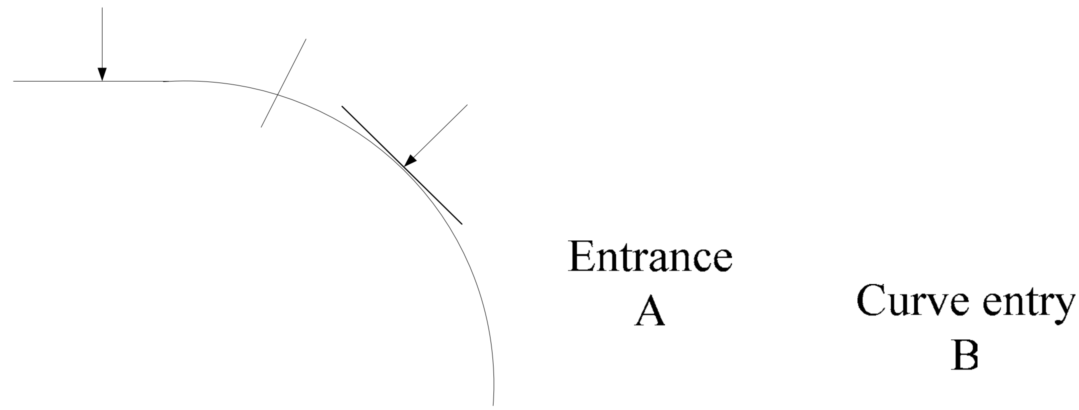


Figure 4. 5. Steering entropy on curves for baseline conditions



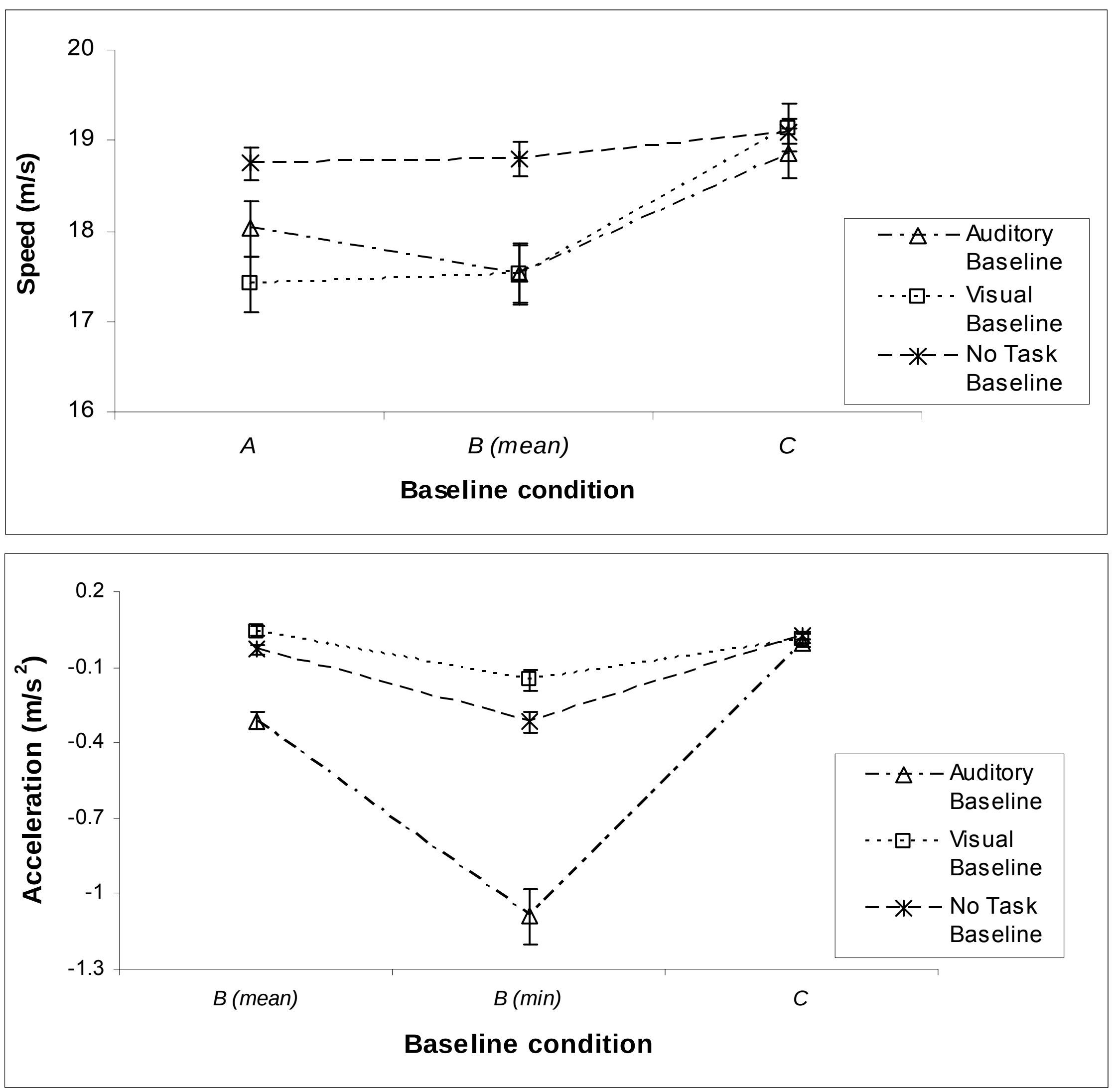


Figure 4. 6. Speed and acceleration on curves for baseline conditions

Braking Events

When drawing conclusions for driver response to a lead vehicle braking event, it is important not to concentrate on one variable but gain insights on the interaction among multiple variables because drivers modulate their braking behavior according to the evolving situation and the braking behavior is a closed-loop response (Lee et al., 2002). When distracted, drivers maintained slower speeds than they would have if not distracted (Table 4. 3). However, when visually distracted, the middle-aged drivers also released the accelerator pedal later than they would have if not distracted. Therefore, the initial cautious behavior was not maintained. Because accelerator release time may be affected by the velocity and following distance of the subject's vehicle, inverse time to collision at the point of accelerator release was also analyzed. Time to collision (TTC) is defined as the ratio of the distance between the subject and lead vehicle to the relative velocity. If the velocities are equal or the subject's vehicle velocity is greater than the lead vehicle velocity, then TTC is infinite, i.e. the collision will not occur based on the instantaneous data. In order to analyze this variable inverse TTC has been used. Therefore, data points representing a non-collision are mapped to 0 and a large inverse TTC represents the need for a quicker reaction time. Even if the drivers slowed down to mitigate the effects of distractions, they still had larger inverse TTC at the accelerator release. This is indicative of a lead vehicle following pattern that requires faster reaction. Drivers indeed compensated this lag by fast transition times from the accelerator to the brake pedal. Given the deteriorating effects of distractions, there is a need to mitigate the impacts of distractions on braking event response.

Table 4. 3. Effects of distractions on braking behavior

		Impact of distracting task	
Response variable	**Age group**	**Auditory vs. no-task**	**Visual vs. no-task**
Speed at lead vehicle brake onset	*Both*	-2.2 m/s t(239) = -3.45 p <0.001	-3.6 m/s t(234) = -5.63 p <0.001
Accelerator release time**	*Middle age*	*	0.4 s t(247) = 2.18 p <0.05
Inverse TTC at the accelerator release**	*Both*	0.040 t(252) = 2.31 p <0.05	0.039 t(248) = 2.21 p <0.05
Transition time from accelerator to brake**	*Both*	-0.8 s t(252) = -3.59 p <0.001	-0.7 s t(250) = -3.03 p <0.01
Maximum deceleration	*Both*	*	*
Minimum TTC	*Both*	*	*

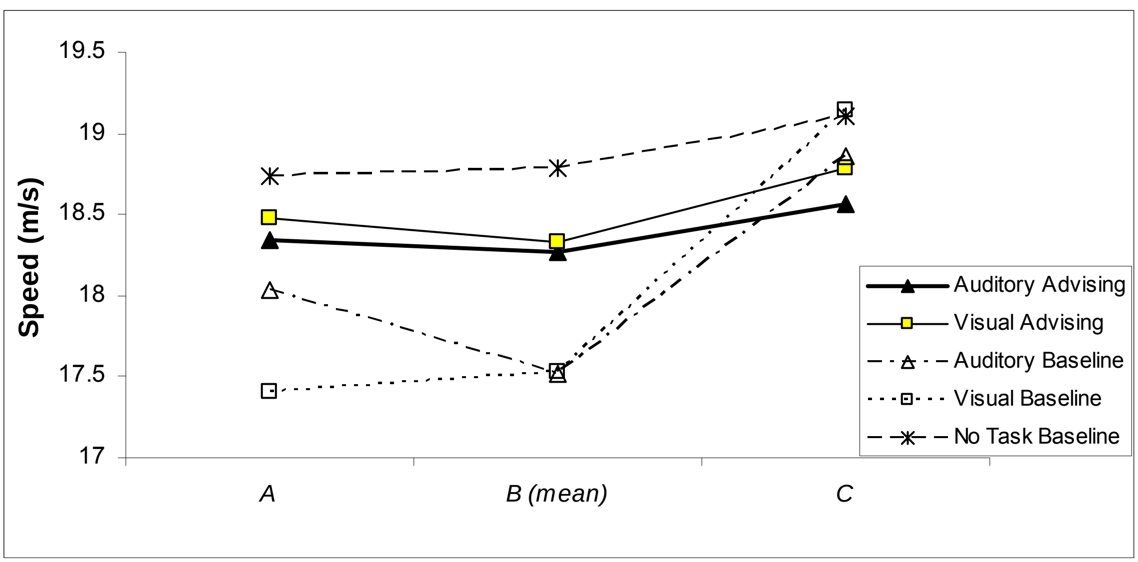
*p > 0.05
**The means for the braking event response variables are covariate adjusted.

4.6.2 Effect of mitigation strategies

There were differences in how drivers relate to the mitigation strategies depending on the event (lead vehicle braking, curve entry). In general, advising and locking strategies improved driver's performance while distracted, but the impact is different for each age group, and type of distraction. These differences are discussed below.

<u>Curves</u>

There were no overall benefits to an advising system in the visual format. Drivers approached the curves with higher speeds with the visual-advising when compared to the visual baseline ($t(252) = 5.17$, $p<0.0001$) (Figure 4. 7). Even though this shows that drivers had more confidence in their curve negotiation ability with a mitigation system, their steering behavior with visual-advising was similar to when they were visually distracted without an advising system ($t(257) = -0.9$, $p>0.05$). That is, their steering was actually quite erratic with or without a visual advising system. However, both age groups did benefit from an advising system in the auditory format. They did not have to brake as hard as they did when the auditory distraction was presented without a strategy ($t(268) = 12.16$, $p<0.0001$).



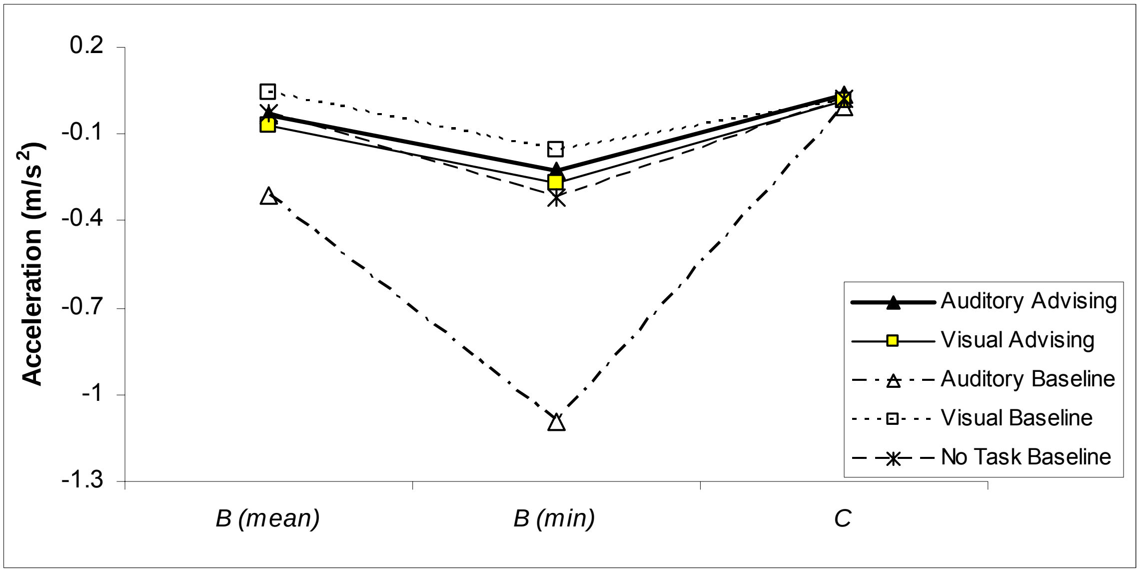


Figure 4. 7. Curve performance with advising

As mentioned, distractions generated more erratic steering behavior on the curves and this effect was quite strong for visual distractions and even with a visual-advising system. With a locking strategy, middle-aged drivers were able to reduce their steering errors on the curves as depicted by the steering entropy measures ($t(262) = -2.01$, $p<0.05$) while maintaining a speed similar to when they were not distracted ($t(255) = -1.28$, $p>0.05$) (Figure 4. 8). Given that visual locking also helped middle-aged drivers steer more consistently, locking strategy appears promising to mitigate the adverse effects of visual distractions on the performance of middle-aged drivers. Older driver's performance with a visual-locking strategy was similar to their performance with a visual-advising strategy and therefore, was not beneficial (Figure 4. 8). That is, older drivers steered more erratically with the locking strategy when compared to their non-distracted state ($t(268) = 6.12$, $p<0.0001$). Both advising and locking strategies were beneficial for auditory distractions. As reported before, auditory distractions resulted in abrupt braking when entering a curve as depicted by low minimum acceleration rates (Figure 4. 6). With the auditory-locking, drivers did not have to brake as hard when compared to their auditory baseline (Figure 4. 8) ($t(269) = 11.79$, $p<0.0001$). The results for the steering entropy ($F(1, 165) = 0.91$, $p > 0.05$) as well as the minimum acceleration on the curve entry ($F(1, 108) = 0.55$, $p > 0.05$) did not differ significantly between true and false adaptation. Whereas, with the false adapting visual-locking system, older drivers maintained lower entry speeds when compared to the true adapting visual-locking ($t(253)$ -2.91, $p<0.005$). Therefore, the benefits from the strategies on deceleration values and steering behavior were not rendered by false adaptation. However, with the false adapting visual-locking system, older drivers maintained more cautious speeds when entering a curve.

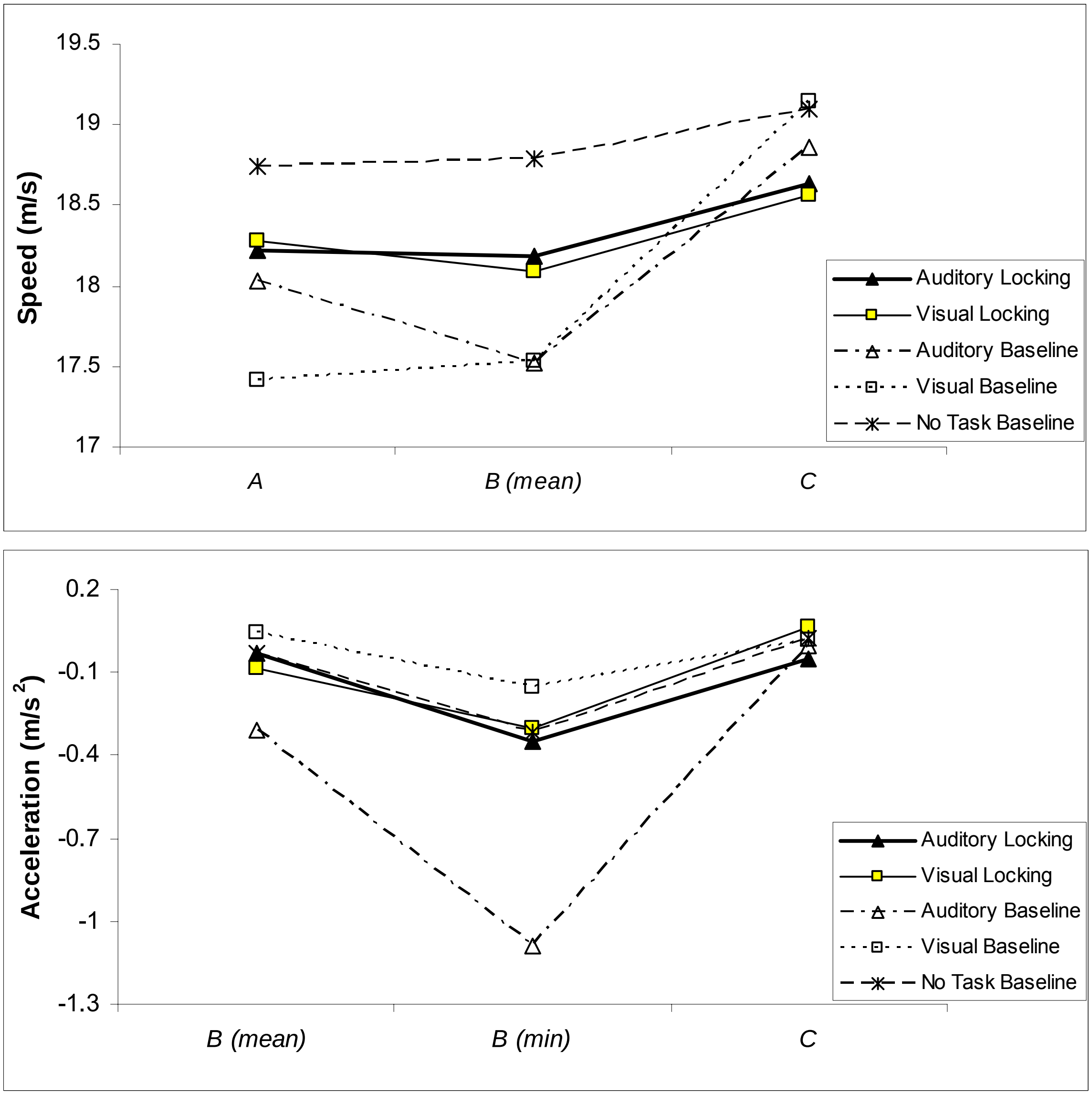


Figure 4. 8. Curve performance with locking

<u>Braking Events</u>

As previously mentioned, when distracted, drivers maintained slower speeds than they would have if not distracted. Advising during a visual distraction appears to mitigate this effect (Table 4. 4, Table 4. 5). However, because the driver does reach higher speeds with this strategy, there is a larger inverse TTC at the accelerator release when compared to the no-task baseline (Table 4. 4) and this actually requires a faster reaction time. The inverse TTC values at accelerator release for the older drivers are even larger than their visual baseline values (Table 4. 5). Moreover, older drivers have longer accelerator release times than their visual-baseline (Table 4. 4). Therefore, for visual distractions, presentation of the advising strategy exacerbates the distraction effects on older drivers. However, with the advising strategy during an auditory distraction, middle-aged drivers have lower inverse TTC at the accelerator release when compared to the auditory baseline (Table 4. 4). In line with this finding, advising during an auditory distraction helps middle-aged drivers to attain higher minimum time to collision values as well as lower their maximum deceleration value when compared to both their distracted and non-distracted case (Table 4. 4, Table 4. 5). Therefore, advising is promising to help avoid a rear end collision as well as a forward collision. The reason why this strategy does not help during a visual distraction may be because the drivers still need to take their eyes off the road to perform the secondary task.

Table 4. 4. Braking behavior: effects of mitigation strategies compared to baseline drive with secondary task

		Pairwise Comparisons			
Response variable	**Age group**	**Auditory advising vs. auditory baseline**	**Auditory locking vs. auditory baseline**	**Visual advising vs. visual baseline**	**Visual locking vs. visual baseline**
Speed at lead vehicle brake onset	*Both*	*	*	2.45 m/s t(248) = 3.31 p <0.01	*
Accelerator release time	*Older*	*	*	0.45 s t(256) = 2.02 p <0.05	*
Inverse TTC at the accelerator release	*Middle age*	-0.025 t(245) = -2.08 p <0.05	*	*	*
	Older	*	*	0.041 t(252) = 2.68 p <0.01	*
Transition time from accelerator to brake	*Both*	*	*	*	*
Minimum TTC	*Middle age*	2.89 s t(243) = 4.00 p <0.0001	1.80 s t(241) = 2.46 p <0.05	*	1.87 s t(237) = 2.48 p <0.05
	Older	*	2.48 s t(240) = 2.87 p <0.005	*	*

*p > 0.05

The locking strategy during a visual distraction provides much greater benefits during braking events compared to the advising strategy. This was particularly true for the middle-aged drivers who received the most benefit from this strategy. They have longer minimum time to collision when compared to their distracted and non-distracted conditions regardless of distraction type (Table 4. 4, Table 4. 5). There were, however, no improvements in performance for older drivers with the visual locking strategy when compared to the no-task and task baseline conditions.

However, older drivers as well as middle-aged drivers did perform better when the locking strategy was presented during an auditory distraction. All drivers had significantly longer minimum time to collisions when compared to the distracted and non-distracted conditions (Table 4. 4, Table 4. 5). Locking strategy for auditory distractions also resulted in higher minimum acceleration (or lower maximum deceleration) values for the middle aged. The improved performance under this strategy could be due to the fact that drivers, while able to maintain their eyes on the road, was no longer required to engage in a secondary task.

It should also be noted that the "transition from accelerator to brake" are still faster than the no-task baseline condition for many of the strategies. Even if there were no significant differences revealed when compared to the task-baselines (Table 4.4), the mean differences reported for the no-task baseline (Table 4. 5) are half that of the mean differences for the distraction effects (Table 4. 3). There is clearly a trend and the non-significance results in the task-baselines may be due to the statistical power of the experiment.

Table 4. 5. Braking behavior: effects of mitigation strategies compared to baseline drive with no secondary task

		Pairwise Comparisons			
Response variable	**Age group**	**Auditory advising vs. no-task baseline**	**Auditory locking vs. no-task baseline**	**Visual advising vs. no-task baseline**	**Visual locking vs. no-task baseline**
Speed at lead vehicle brake onset	*Both*	-2.12 m/s t(244) = -3.34 p <0.01	-3.19 m/s t(246) = -4.96 p <0.001	*	-3.15 m/s t(242) = -4.88 p <0.0001
Accelerator release time	*Both*	*	*	0.88 s t(248) = 3.43 p <0.001	*
Inverse TTC at the accelerator release	*Middle age*	*	*	0.029 t(246) = 2.45 p <0.05	*
Transition time from accelerator to brake	*Older*	*	*	0.055 t(248) = 4.12 p <0.001	0.035 t(238) = 2.57 p <0.05
	Middle age	-0.33 s t(247) = -2.33 p <0.05	-0.31 s t(246) = -2.16 p <0.05	*	-0.37 s t(247) = -2.55 p <0.05
Minimum acceleration	*Older*	-0.40 s t(244) = -2.55 p <0.05	*	-0.46 s t(247) = -2.81 p <0.01	-0.39 s t(246) = -2.30 p <0.05
	Middle age	0.53 m/s^2 t(245) = 2.18 p <0.05	0.61 m/s^2 t(237) = 2.43 p <0.05	*	*
Minimum TTC	*Middle age*	3.49 s t(229) = 5.32 p <0.0001	2.40 s t(225) = 3.61 p <0.0005	*	2.33 s t(230) = 3.41 p <0.001
	Older	*	2.24 s t(243) = 2.98 p <0.005	*	*

*p > 0.05

False adaptations rendered the effectiveness of the auditory strategies for the middle-aged drivers as depicted by shorter minimum TTC and lower minimum acceleration values reported in Table 4. 6. However, when compared to the auditory baseline, the advising strategy under false adaptation still resulted in longer minimum TTC (mean difference: 0.57 s, $t(226) = 2.20$, $p<0.05$).

Table 4. 6. Impact of false adaptation on strategy effectiveness for middle-aged drivers

	Auditory advising (False vs. True adaptation)	Auditory locking (False vs. True adaptation)	Visual advising (False vs. True adaptation)
Speed at lead vehicle brake onset	*	1.02 m/s t(244) = 2.01 p <0.05	*
Minimum acceleration	*	-0.81 m/s^2 t(199) = -2.85 p <0.005	-0.76 m/s^2 t(199) = -2.62 p <0.01
Minimum TTC	-1.86 s t(224) = -2.25 p <0.05	-2.19 s t(227) = -2.88 p <0.005	*

*p > 0.05

4.6.2 Subjective and Secondary Task Measures

Acceptance and Trust

An acceptance questionnaire based on Van Der Laan, Heino, & De Waard (1997) was given to the participants after each drive with a system. The questionnaire composed of nine questions investigating two dimensions of acceptance: usefulness and satisfying. Before analysis, the acceptance questionnaire was recoded to fall along a scale of -2 to +2 (-2 representing lowest level of acceptance and +2 representing the highest). These numbers were then averaged to obtain the usefulness score and the satisfying score. Additional acceptance questionnaires were also filled out by the participants. These questionnaires aimed to assess the acceptance of the *advising* and *locking* strategies if they were embedded in current IVIS features (radio, cell phone, email).

Because trust is an important attitude that may guide the reliance on a system (Lee & See, 2004), a system trust questionnaire was also given to the participants which was based on Wiese (2003). The questionnaire included the questions of ‘I trust the safety system’ and ‘The performance of the safety system enhanced my driving’. A -2 to +2 scale was used to code the responses (-2: strongly disagree, +2: strongly agree). The overall trust score was obtained by averaging the responses for these two questions. The trust put in the system may depend on the individual differences between the participants. In order to take this into account, the interpersonal trust score obtained from the Interpersonal Trust Questionnaire (Rotter, 1991) was included in the initial model. However, this covariate did not have a significant effect on the system trust ratings (F (1, 25.4) = 0.05, p < 0.8). Therefore the final model did not include the interpersonal trust score.

Acceptance with proposed mitigation strategies

There were some interesting differences between the middle-aged and older participants. Older participants perceived the systems to be more useful (t(26.5) = 3.07, p<0.005) and were more satisfied (t(26.7) = 3.35, p<0.005) with the system than the middle aged group (Figure 4. 9). These drivers tend to accept non-driving related, system initiated mitigation strategies more than middle aged drivers. However, regardless of age group, visual based strategies were perceived to be more satisfying ($t(159) = 6.39$, $p<0.0001$) and more useful ($t(157) = 4.63$, $p<0.0001$) than the auditory based strategies. These finding also support the insights gained by the focus group regarding the preferred display modality. Focus group participants preferred visual compared to auditory based strategies.

Van der Laan et al (1997) study found the two actions of a collision avoidance system (auditory and the haptic feedback) to be in the same region with our results. This is expected, since among the different systems compared in Van der Laan et al. (1997), the collision avoidance system was the closest to the strategies tested in this experiment. This system did not involve *intervening* or *warning* strategies like the intelligent cruise control system or *informing* strategy like the Tutoring and Enforcement System that were also used in their study. In addition, the auditory feedback that was mapped to headway time in the Van der Laan et al. (1997) study nicely fits with the background clicking sound employed in the auditory based strategies.

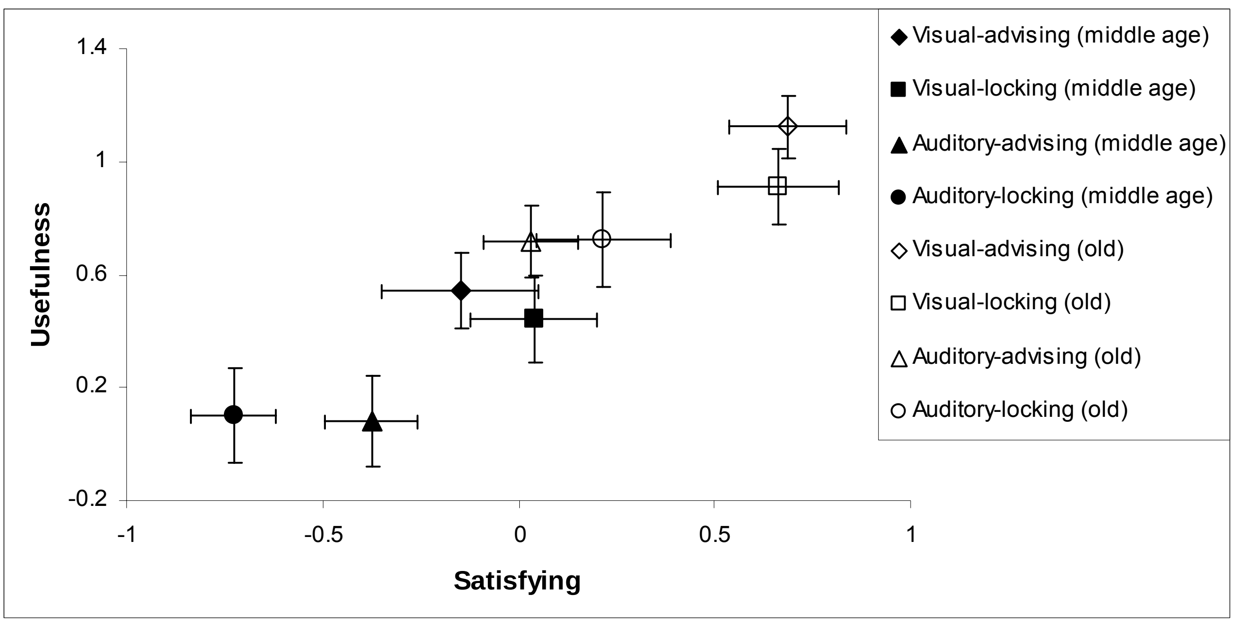


Figure 4. 9. Acceptance of Mitigation Strategies by Age Group and Presentation Modality

System Trust

Older participants trusted the systems more than the middle aged participants ($t(26.8) = 3.14$, $p<0.005$, $\overline{X}_{middle\ age}$: -0.028, $\overline{X}_{old\ age}$: 0.622). As expected, systems that were 100% reliable resulted in higher trust than the 50% reliable systems ($t(27.2) = 2.48$, $p<0.05$, $\overline{X}_{100\%\ reliable}$: 0.38, $\overline{X}_{50\%\ reliable}$: 0.11). The system accuracy was also revealed as an important issue from the focus group findings and the experimental data support that system accuracy would guide trust in the systems.

Predicting trust based on acceptance levels

Pearson correlation coefficients for three variables, level of trust in the driver distraction mitigation strategy, usefulness, and satisfying, were investigated. As the level of usefulness increased, so did the driver's level of trust ($p<0.0001$). This was also true for the level of satisfying. Drivers who were more satisfied with the strategy also perceived an increase in level of trust ($p<0.0001$). The relationship between usefulness and trust ($\rho= 0.731$) was stronger than the relationship between "satisfying and trust" ($\rho= 0.629$). This indicates that a useful system is more important with respect to trust than a system that provides immediate satisfaction. But because satisfaction is also strongly correlated with trust, this factor should not be dismissed.

Preferences for proposed mitigation strategies in the presence of various IVIS systems

After driving in the simulator and experiencing the various mitigation strategies, drivers rated their acceptance of these strategies as applied to current and likely in-vehicle information systems. Participants were asked to assess the preferences for these strategies given current technology including cellular phones, voice activated e-mail messages, and radio controls. These available in-vehicle systems were evaluated in order to allow participant to provide subjective preferences and relate what they observed in the simulator to something they were more familiar with. The older participants perceived the strategies embedded in IVIS to be more useful ($t(165) = 2.17$, $p<0.05$) and more satisfactory ($t(160) = 2.14$, $p<0.05$) than the middle aged group (Figure 4. 10). In general, all participants were more satisfied with the operation of a visual *advising* strategy (such as a red bezel) on their radio when compared to an auditory *locking* strategy in a cell phone ($t(160) = -3.35$, $p<0.001$) or email ($t(160) = -2.28$, $p<0.05$). Therefore, a visual based alert which does not lock the IVIS task appears to be more accepted by drivers than an auditory alert which does. This implies that driver's perceived importance in the secondary task plays a key role in the strategy acceptance.

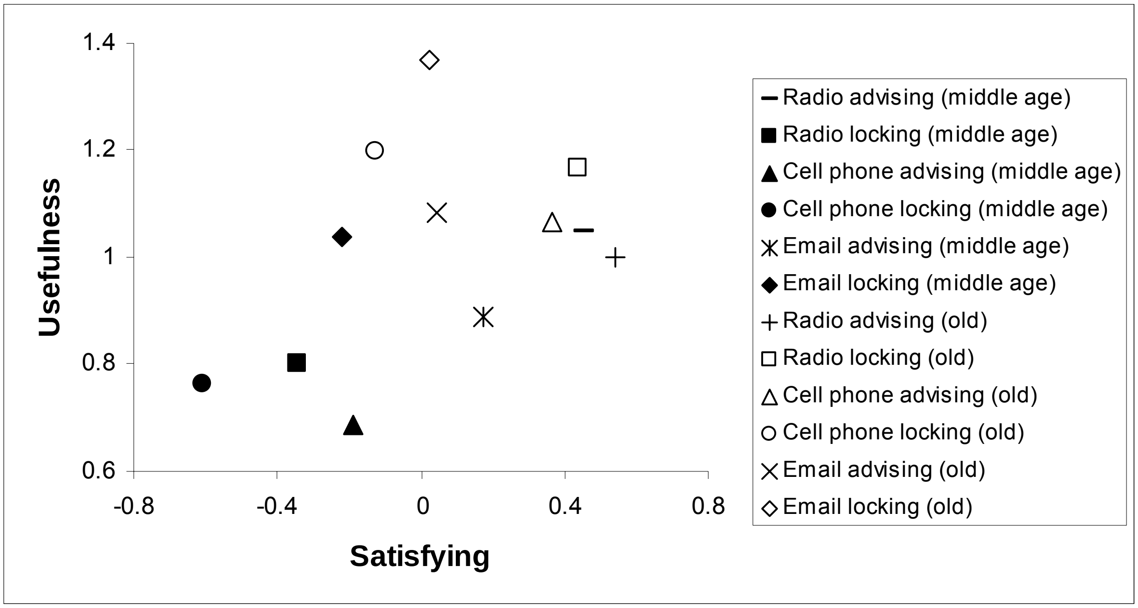


Figure 4. 10. Acceptance of Mitigation Strategies Embedded in Current IVIS

Relationship between the Focus Group and Simulator Results
The focus groups revealed that the level of automation had an impact on the acceptance of driving related strategies. More specifically, some drivers preferred the ability to maintain control of their vehicle and were not accepting of high level of automation. The experimental data did not show such an effect between the levels of automation for the non-driving related strategies. However, the experiment revealed that older drivers accepted the strategies more than middle aged drivers. The experimental data also supported the focus group finding on display modality. Auditory based systems were shown to be less accepted than the visual based systems. Therefore, designers may want to mitigate distractions by visual alerts when appropriate. Another focus group finding supported by the experiment was the concerns on system accuracy. Low levels of system reliability resulted in lower levels of trust. Trust was also found to be positively correlated with acceptance measures. Of the two acceptance measures usefulness had a greater impact on trust. This is an important issue because the trust in a system would guide the proper use by the drivers. Systems designers should aim to achieve high levels of reliability as well as acceptance before incorporating mitigation strategies in the vehicle.

<u>Mental Effort</u>

This measure was collected after each drive. Because the participants completed the no-task baseline and the task-baseline conditions (either visual or auditory) in the same scenario, there were only two questionnaires given for the baseline conditions. Therefore, comparisons between the baselines with the secondary task and the no-task can not be analyzed. Moreover, the differences between the system levels and the baseline conditions can not be truly assessed either. However, the differences between the visual and auditory distractions and different system levels can be investigated.

For the auditory baseline the middle-age participants had significantly lower mental effort values than the old age group (t (41.2) = -2.05, $p < 0.05$, mean difference: -20.488, 95% CI: -40.696, -0.281). This may be because the middle-age drivers' cognitive abilities are stronger than the older drivers' or the middle-age participants were more familiar with the synthetic voice technology. Given the mitigation strategies, middle-aged participants still perceived less mental effort than the older participants (t (26.5) = -2.06, $p < 0.05$) (Figure 4. 11). Middle-aged participants perceived less mental effort for visual-locking than both the visual-advising (t (203) = -2.85, $p < 0.005$, mean difference: -16.79, 95% CI: -28.403, -5.169) and the auditory-advising systems (t (203) = -2.11, $p < 0.05$, mean difference: -12.416, 95% CI: -24.04, -0.8). This may be because the locking strategy stopped the secondary task and gave time for the drivers to attend the road.

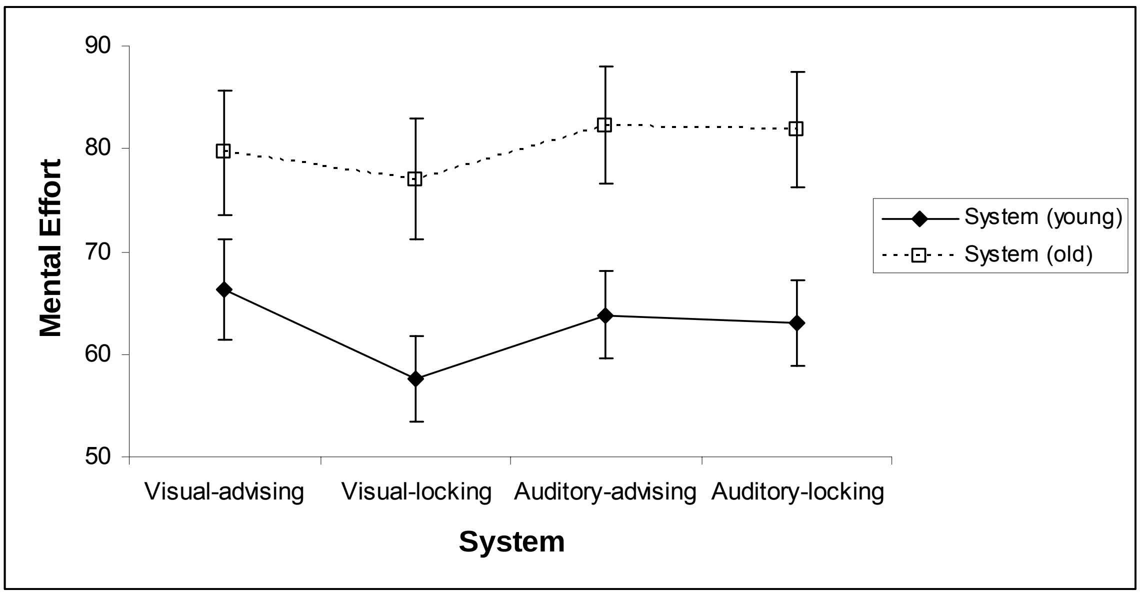


Figure 4. 11. Mental effort by system for different levels of age group

<u>Perceived Risk</u>

Because perceived risk was collected after each drive, comparisons between the baselines with the secondary task and the no-task cannot be analyzed because these baselines were part of the same drive. Along with that, differences between the system levels and each baseline conditions can not be truly assessed either for the same reason. However, the differences between the visual and auditory distractions and different system levels are as follows.

Both the auditory and the visual distractions were perceived to be equally risky. (F (1, 219) = 1.15, p = 0.3). However, system – adaptation interaction was significant (F (3, 193) = 3.18, p < 0.05) (Figure 4. 12). For the true adaptation, auditory-locking system resulted in higher perceived risk than the visual-locking system (t (193) = 2.2, p < 0.05, mean difference: 1.507, 95% CI: 0.158, 2.857). For the false adaptation, visual advising system had higher risk levels when compared to the auditory-advising system (t (193) = 2.73, p < 0.01, mean difference: 1.871, 95% CI: 0.522, 3.221).

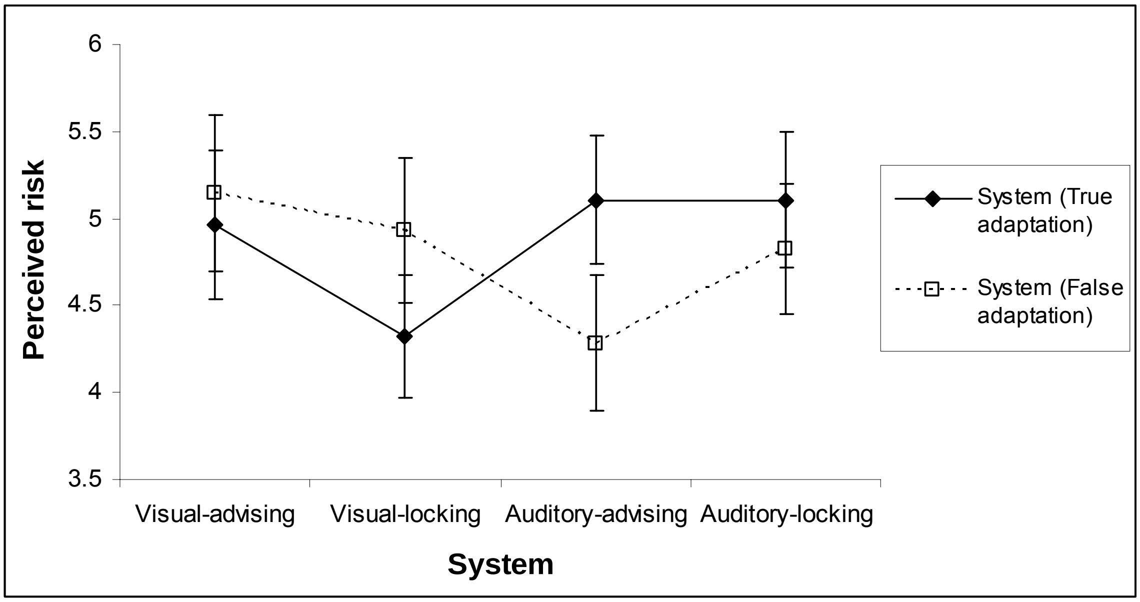


Figure 4. 12. Perceived risk by system for different levels of adaptation

<u>Productivity</u>

This variable is the average of the percent correct verbal and button push responses. Because the task was presented to the participants in the system conditions twice as longer than the baseline conditions, driver familiarity is an effect that may confound the comparisons between system and baseline conditions. Drivers did better when the secondary task was presented in an auditory format compared to a visual format (t(180) = 3.38, p<0.001). This may be due to the difficulty of comprehending the synthetic voice used in the experiment. Another potential reason is the longer availability of the visual task when compared to the auditory task (C. D. Wickens & Hollands, 1999). For true adaptation visual based systems resulted in higher productivity than the auditory based systems (t (174) = 4.52, p < 0.0001, mean difference: 16.59, 95% CI: 9.342, 23.847). The strategies did not have deteriorating effects on the productivity provided by the IVIS (Figure 4. 13).

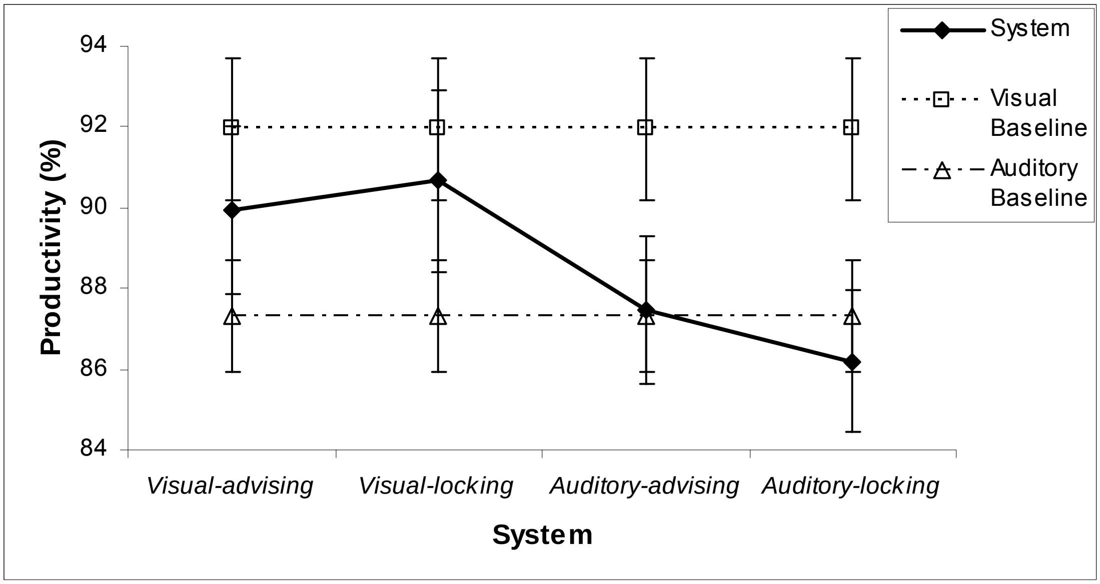


Figure 4. 13. Productivity with the secondary task

4.7 DISCUSSION

Summary

The primary objective of this experiment was to assess the effects of different driver distraction mitigation strategies on driver performance and acceptance. We compared the effect of In-Vehicle Information Systems (IVIS) on driver performance with and without the mitigation strategies. Two promising strategies were chosen to be tested for this experiment; advising and locking. An advising strategy gives drivers feedback regarding upcoming driving demands, such as braking lead vehicles and curves. A locking strategy locks out a system that is associated with non-driving activities, at times when attention to the primary driving task is required, such as during curves and when the lead vehicle is braking. The two strategies were also presented in visual and auditory format. Their performance with each as well as their acceptance of the system was compared to the baseline conditions with and without a secondary task. Two age groups were recruited for the experiments. The middle-aged group consisted of drivers between 35 and 55 years old, and older aged gorup consisted of drivers between 65 and 75 years old.

To summarize and frame the results relative to the goals of this task, we have divided the discussion into six central questions. These questions examine the effects of distractions; the most effective strategies; information accuracy; acceptance and trust in strategies; time-sharing between the driving and secondary tasks; and the constraints and limitations of this study.

Q1. How does distractions effect driving performance? Is an auditory or a visual system more distracting?

Distractions in general deteriorated the driving performance. Drivers tried to compensate the distraction effects by slowing down, both when following the lead vehicle and when entering a curve. With visual distractions, drivers maintained slower speeds when entering a curve whereas with the auditory distractions the drivers maintained relatively faster speeds resulting in more abrupt braking. Visually distracted drivers had to accelerate to reach to the desired speed. The opposite behavior was observed for the auditory distractions. These drivers had to decelerate when entering a curve since they had previously been driving at higher speeds and were uncomfortable maintaining a higher speed throughout the curve entry. Regardless of distraction type, distractions resulted in erratic steering and a need for a faster reaction to lead vehicle braking events. Visual distractions caused a more erratic steering when compared to the auditory distractions. This result is expected because previous studies have shown that visual tasks (particulary those that require extensive glances away from the roadway) are more distracting in the driving environment (Parkes & Coleman, 1990; C. Wickens, D., Sandry, & Vidulich, 1983).

Q2. Which mitigation strategy most improves driving performance and does its effect depend on whether the mode is visual or auditory?

Visual-advising was not found to be a good alternative for both age groups. Advising in a visual mode caused more distractions to the older drivers. In visual modality, locking provided benefits to middle-aged drivers by resulting in better steering and lower minimum time to collision. Given that middle-aged drivers are more likely to use visual in-vehicle devices such as e-mail or navigational displays, it is promising that a visual mitigation strategy can be used to reduce the impact of driver distraction.

Both the advising and locking strategies under auditory distractions showed significant benefits for the middle-aged drivers. The findings showed that the strategies for the auditory task resulted in longer minimum time-to-collision and lower maximum deceleration for the lead vehicle braking event response. Older drivers benefitted from a locking strategy for auditory distractions as depicted by improvements in both minimum time to collision and maximum deceleration values. The most probable mechanism that provided this benefit is the saliency of the auditory information.

As mentioned earlier, drivers had to brake harder during the auditory-based distraction when entering a curve since they had previously been driving at higher speeds. Visually distracted drivers had lower speeds at curve entry which led to a positive acceleration. Both of the mitigation strategies (advising, locking) worked very well for both types of distractions (auditory, visual) since they converged all the curve performance values toward the baseline conditions.

Q3. Are some mitigation strategies more susceptible to inaccurate information?

False adaptations rendered the effectiveness of the auditory strategies for the middle-aged drivers as depicted by shorter minimum TTC and lower minimum acceleration. However, even if falsely adapted, the auditory advising strategy still mitigated the adverse effects of distractions and therefore is more robust to false adaptation. Moreover, with the false adapting visual-locking system older drivers maintained lower entry speeds when compared to the true adapting visual-locking. Therefore, with the false adapting visual-locking system, older drivers maintained more cautious speeds when entering a curve.

Q4. Do drivers accept and/or trust these types of mitigation strategies?

The experimental data showed that there are some major differences among the old and middle aged drivers that may have an impact on the type of mitigation strategy that is designed. The older drivers perceive the non-driving related, system initiated mitigation strategies to be more useful and satisfying when compared to the middle aged drivers. Middle aged drivers accept such strategies less because they get annoyed with the interventions in their non-driving related activities. Moreover, previous research showed that drivers are usually critical of systems that intervene in their driving, whereas systems that offer recommendations and provide information are deemed considerably more acceptable (Carsten & Fowkes, 1998). Some focus group participants were more concerned about the ability to remain in control of their vehicle and were not as content with a high level of automation, while others liked the idea of complete automation. Therefore, when developing systems to reduce distraction, the acceptance of these systems by different driver groups should also be considered. For example, the drivers may have the ability to tailor the system based on their individual preferences. The experiment also showed that trust is positively correlated with perceived usefulness of the strategy as well as how satisfied the drivers are with the strategy. Usefulness is quantified to have a larger impact than satisfying and therefore plays a more important role in trust.

Focus groups suggested that mitigation strategies presented in the auditory format can be very annoying. The experiment verified this finding. The auditory based mitigation strategies were accepted less than the visual based strategies. Therefore, when appropriate, warnings should be conveyed visually rather than as a sound alert. However, in some situations an auditory warning may be more effective than a visual one, and a tradeoff between effectiveness and acceptance would develop. In an imminent danger the system should aim for higher effectiveness. Another point that was frequently pointed out in the focus group discussions was the system accuracy. Drivers believed that the mitigation strategies should be as accurate as possible. Experiments showed that the system trust depends on the accuracy. Low system reliability resulted in less trust. Because distrust undermines reliance and the benefits of a system (Lee & See, 2004), accuracy is very important for mitigation strategy effectiveness. However, not all false positive alarms are harmful. Such alarms can be used to train novice drivers, and are also needed to generate driver familiarity with the system. If the first time the driver receives a warning is in a true collision situation, the driver may not respond to it in the amount of time available. False positive alarms may also lead to more cautious driving and thereby result in reduced false alarm rates (Parasuraman et al., 1997). Thus, for a mitigation strategy to be effective, an acceptable false alarm rate should be established.

Q5. What is the impact of time-sharing between the driving and the secondary task & mental effort?

Middle-aged drivers perceived less mental effort in performing the secondary task than older drivers. This could be due to several factors. This age group is typically more cognitively aware than the older age group and therefore can switch attention from the driving task to the secondary task more easily, observe the driving environment more acutely, and can more comfortably adapt to a mitigation strategy if placed in their vehicle. Another explanation could be due to socioeconomic factors. Given that drivers in this age group are typically more familiar with in-vehicle devices and more comfortable with new technology, it would not be surprising that they can easily adapt to performing other non-driving related tasks. Older drivers typically are uncomfortable performing other tasks while driving and would therefore, greatly benefit from a mitigation strategy that would help reduce the distraction level in their car. They also appeared to trust and accept the system more so if designers can take the older drivers constraints into consideration, the mitigation strategies will be most helpful for this age group.

Q6. What were some of the contraints and limitations?

These findings depend on the compensatory strategies drivers adopted and the interaction of these strategies with the experimental conditions. For example, the visual task induced drivers to reduce their speed more than the auditory task. This effect would be observed not only during the braking event or curve entry, but for the entire scenario where the secondary task was continually presented. A more detailed analysis is needed to investigate the relationship between speed and the mitigation strategies during the braking events because the speed is likely to affect the drivers' braking response. Because the position of the lead vehicle at the time of the braking event was set to a constant time headway, a slower driver would receive a more salient braking event and as a consequence might brake more rapidly than a faster driver.

This experiment was at least 5 hours long and was performed over two days. This length of time was necessary to ensure sufficient data was collected on all independent variables. However, this impacted the number of subjects that were able to complete the study and therefore, may have biased the types of drivers obtained. This was particularly relevant in regards to older drivers where the drop out rate was 30%. Drivers that were able to complete this study were clearly more diligent and saw benefits to completing the study. The older drivers that completed this study were also less cognitively impaired than drivers in this age group. Therefore, these may not be the typical users of these types of systems. In future studies, it would be better to have a smaller study requiring less participant time. Of course, obtaining older drivers for simulator studies may still be a problem and this is a major concern in driving simulator research.

Further research Issues

The issues covered in this study are the impact of true and false system adaptation, type of distraction confronting the driver (auditory and visual), age, and advising and locking mitigation strategies. The other driver distraction mitigation strategies should also be explored since experimental data can provide further insights for these strategies, especially under different distracting scenarios and levels of situation criticality. For example, for high criticality and level of distraction an intervening strategy may provide more benefits for driving safety. Moreover, this experimental design does not take overlapping events into consideration; for example, a braking event that occurs on the curve entry. Such overlapping events might require a different combination of alerts, such as flashing of the red bezel or increasing the frequency of the background clicking sound.

Furthermore, it is unclear how drivers would adapt to these types of systems over prolonged use. If the system is currently effective, as the advising and locking system appears to be, will that effectiveness diminish over time? Other areas of research also needs to be explored to understand whether the mitigation strategies may be more effective if the system was initiatied by the driver rather than the system as it was in this experiment. As discussed in Task 4-A report driver initiation of a strategy promises to be more acceptable than system initiation. Because acceptance might have an impact on the effectiveness of a strategy it should be investigated if driver initiated strategies are more helpful in distracted situations than their system initiated counterparts.

The experiment conducted for this research only focused on non-driving related strategies. However, because the driving related strategies address a broader range of distraction situations, these strategies may be more effective and should also be investigated. Another area that should be explored is the effectiveness and acceptance of an adaptive system. A system that can dynamically adapt within and between mitigation strategies based on the driver and roadway state is promising to reduce distraction. There are also issues associated with adaptive systems that should also be considered. For example, reliability of an adaptive system and ramifications of workload transition may create setbacks for the effectiveness of an adaptive system. Last but not the least, the usability of the mitigation strategies should also be investigated. If a system is designed for ease of use, would people tend to use it more often and in turn would the probability of being distracted increase (overall increased distraction)? These future research issues combined with the discussions provided in Task 4-A review generate an extensive research space to be explored.

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APPENDIX A

SCREENING FOR PARTICIPATION IN THE EXPERIMENT

This study takes place in a driving simulator located in the Cognitive Systems Lab (CSL) at the University of Iowa. There will be no real on-road driving at all, eliminating the risk associated with on-road studies. The simulator uses a real car body and emulates real driving very closely.

This study will examine issues related to the use of In-Vehicle Information Systems. The information gathered will be used to answer academic research questions regarding the design of these devices. All data obtained are for research purposes only and will remain confidential. Names will not be associated with the questionnaires in any way and no data will be reported to licensing authorities or insurance companies.

Now I need to ask you a series of questions to verify your eligibility for the study.

1. What is your name?
2. How old are you?
3. Do you have normal or corrected-to-normal vision?
4. Do you have an active driver's license?
5. How many years have you driven?
6. How many times per week do you drive?
7. Have you ever participated in an experiment involving a driving simulator? If yes, what was the experiment like?
8. Is English your first language?

Some people tend to experience a type of motion sickness, called simulator sickness, when driving the simulator. The next few questions are asked to help us identify if you might be prone to simulator sickness.

9. Do you frequently experience migraine headaches?
10. Do you experience motion sickness?
11. Do you experience claustrophobia?
12. Are you pregnant?

APPENDIX B

RANDOMIZATION OF CURVES, BRAKING EVENTS AND FALSE WARNINGS THROUGH TEN DRIVES

(L: Left, R: Right, 200: 200m radius, 400: 400m radius, x: Event existing)

Visual Task / Advising Strategy / True Adaptation

	Curve Type	Braking Event
Straight 1		x
Curve 1	400L	x
Straight 2		x
Curve 2	200R	x
Straight 3		x
Curve 3	400L	
Straight 4		
Curve 4	400R	
Straight 5		
Curve 5	200L	x
Straight 6		
Curve 6	200R	
Straight 7		x
Curve 7	400R	
Straight 8		x
Curve 8	200L	
Straight 9		
Curve 9	200R	x
Straight 10		
Curve 10	400L	
Straight 11		
Curve 11	400R	x
Straight 12		x
Curve 12	200L	x

Auditory Task / Advising Strategy / True Adaptation

	Curve Type	Braking Event
Straight 1		
Curve 1	200L	x
Straight 2		
Curve 2	400L	
Straight 3		x
Curve 3	400L	x
Straight 4		x
Curve 4	400R	x
Straight 5		
Curve 5	200L	
Straight 6		x
Curve 6	200R	
Straight 7		x
Curve 7	200R	
Straight 8		
Curve 8	200L	
Straight 9		x
Curve 9	400R	
Straight 10		
Curve 10	400L	x
Straight 11		x
Curve 11	400R	x
Straight 12		
Curve 12	200R	x

Auditory Task / Locking Strategy / True Adaptation

	Curve Type	Braking Event
Straight 1		
Curve 1	400R	
Straight 2		x
Curve 2	400R	
Straight 3		
Curve 3	200R	x
Straight 4		x
Curve 4	400L	x
Straight 5		x
Curve 5	200L	x
Straight 6		x
Curve 6	200R	
Straight 7		
Curve 7	200R	
Straight 8		
Curve 8	400L	x
Straight 9		
Curve 9	400R	x
Straight 10		
Curve 10	400L	x
Straight 11		x
Curve 11	200L	
Straight 12		x
Curve 12	200L	

Visual Task / Locking Strategy / True Adaptation

	Curve Type	Braking Event
Straight 1		
Curve 1	400R	
Straight 2		x
Curve 2	400L	x
Straight 3		
Curve 3	400L	
Straight 4		
Curve 4	200R	
Straight 5		
Curve 5	400L	x
Straight 6		x
Curve 6	200L	x
Straight 7		x
Curve 7	400R	
Straight 8		
Curve 8	200L	
Straight 9		x
Curve 9	200L	x
Straight 10		
Curve 10	200R	x
Straight 11		x
Curve 11	400R	x
Straight 12		x
Curve 12	200R	

Visual Task / Control / No Adaptation

	Curve Type	Braking Event
Straight 1		x
Curve 1	400L	x
Straight 2		
Curve 2	400R	
Straight 3		x
Curve 3	200R	x
Straight 4		x
Curve 4	400L	
Straight 5		
Curve 5	200R	
Straight 6		
Curve 6	400R	x
Straight 7		
Curve 7	200L	x
Straight 8		
Curve 8	200R	x
Straight 9		x
Curve 9	400L	
Straight 10		
Curve 10	400R	
Straight 11		x
Curve 11	200L	x
Straight 12		x
Curve 12	200L	

Auditory Task / Control / No Adaptation

	Curve Type	Braking Event
Straight 1		x
Curve 1	200R	
Straight 2		
Curve 2	200R	
Straight 3		
Curve 3	400L	x
Straight 4		
Curve 4	400R	x
Straight 5		x
Curve 5	200L	
Straight 6		x
Curve 6	200R	x
Straight 7		x
Curve 7	400L	
Straight 8		
Curve 8	200L	x
Straight 9		x
Curve 9	400R	x
Straight 10		
Curve 10	200L	x
Straight 11		
Curve 11	400L	
Straight 12		x
Curve 12	400R	

Auditory Task / Advising Strategy / False Adaptation

	Curve Type	Braking Event	Braking Warning	Curve Entry Warning	Curve Warning	Straight Warning
Straight 1						
Curve 1	200R			x	x	
Straight 2		x	x			
Curve 2	400L	x			x	
Straight 3		x				x
Curve 3	400R	x	x		x	
Straight 4						
Curve 4	200L	x		x	x	
Straight 5		x	x			x
Curve 5	200R					
Straight 6						x
Curve 6	400L	x		x		
Straight 7		x				
Curve 7	200L	x	x	x	x	
Straight 8						
Curve 8	200R			x		
Straight 9		x	x			x
Curve 9	400L					
Straight 10		x				
Curve 10	400R			x		
Straight 11						x
Curve 11	200L	x	x			
Straight 12						x
Curve 12	400R				x	

Visual Task / Advising Strategy / False Adaptation

	Curve Type	Braking Event	Braking Warning	Curve Entry Warning	Curve Warning	Straight Warning
Straight 1						
Curve 1	200L	x		x	x	
Straight 2		x				x
Curve 2	400L				x	
Straight 3		x	x			
Curve 3	400R			x	x	
Straight 4						
Curve 4	400L				x	
Straight 5						x
Curve 5	200R			x		
Straight 6		x				
Curve 6	200L	x	x	x		
Straight 7		x				x
Curve 7	200L	x				
Straight 8						x
Curve 8	200R	x	x			
Straight 9						
Curve 9	400L				x	
Straight 10		x	x			x
Curve 10	400R	x		x	x	
Straight 11		x	x			
Curve 11	400R			x		
Straight 12						x
Curve 12	200R	x	x			

Visual Task / Locking Strategy / False Adaptation

	Curve Type	Braking Event	Braking Warning	Curve Entry Warning	Curve Warning	Straight Warning
Straight 1		x				x
Curve 1	200R			x		
Straight 2		x	x			
Curve 2	200R	x	x	x	x	
Straight 3						x
Curve 3	400R					
Straight 4		x	x			x
Curve 4	400L	x			x	
Straight 5		x	x			
Curve 5	400R	x	x		x	
Straight 6						x
Curve 6	200L	x		x	x	
Straight 7		x				x
Curve 7	200L			x		
Straight 8						x
Curve 8	200R					
Straight 9						
Curve 9	400R				x	
Straight 10						
Curve 10	200L	x	x	x	x	
Straight 11						
Curve 11	400L			x		
Straight 12		x				
Curve 12	400L	x				

Auditory Task / Locking Strategy / False Adaptation

	Curve Type	Braking Event	Braking Warning	Curve Entry Warning	Curve Warning	Straight Warning
Straight 1		x	x			
Curve 1	200L	x			x	
Straight 2						x
Curve 2	400L					
Straight 3						x
Curve 3	200L	x	x	x		
Straight 4		x				x
Curve 4	200R			x		
Straight 5						x
Curve 5	200R					
Straight 6						
Curve 6	400L			x	x	
Straight 7						
Curve 7	200R	x	x	x		
Straight 8						
Curve 8	400R			x	x	
Straight 9		x				x
Curve 9	200L	x			x	
Straight 10		x	x			
Curve 10	400R	x		x		
Straight 11		x	x			
Curve 11	400R				x	
Straight 12		x				x
Curve 12	400L	x	x		x	

APPENDIX C

WORKING MEMORY SENTENCES AND STRUCTURES

The number and percent rate of different structure sentences in each sentence set

Two sentence sets were prepared for visual and auditory practice drives which were similar in structure with the experimental (A- set and B-set) and baseline condition sets. The sentence features for each set is shown in table below.

	Practice set	A - set	Baseline set	B - set	
1 syllable subject 1 syllable verb 1 syllable object 5 words total	8 - meaningless 8 - meaningful	25 - meaningless 25 - meaningful	14 - meaningless 14 - meaningful	25 - meaningless 25 - meaningful	**46% - 53%**
1 syllable subject 1 syllable verb 1 syllable object 6 words total	2 - meaningless 2 - meaningful	6 - meaningless 6 - meaningful	4 - meaningless 4 - meaningful	6 - meaningless 6 - meaningful	**11% -13%**
2 syllable subject 1 syllable verb 1 syllable object 5 words total	3 - meaningless 3 - meaningful	10 - meaningless 10 - meaningful	6 - meaningless 6 - meaningful	10 - meaningless 10 - meaningful	**19% - 20%**
1 syllable subject 1 syllable verb 2 syllable object 5 words total	1 - meaningless 1 - meaningful	4 - meaningless 4 - meaningful	4 - meaningless 4 - meaningful	4 - meaningless 4 - meaningful	**7% -13%**
1 syllable subject 2 syllable verb 1 syllable object 5 words total	1 - meaningless 1 - meaningful	3 - meaningless 3 - meaningful	2 - meaningless 2 - meaningful	3 - meaningless 3 - meaningful	**6% - 7%**
1 syllable subject 1 syllable verb 1 syllable object 4 words total	0	3 - meaningless 3 - meaningful	0	3 - meaningless 3 - meaningful	**3% - 6%**
2 syllable subject 1 syllable verb 2 syllable object 5 words total	0	2 - meaningless 2 - meaningful	0	2 - meaningless 2 - meaningful	**0% - 4%**
2 syllable subject 2 syllable verb 1 syllable object 5 words total	0	1 - meaningless 1 - meaningful	0	1 - meaningless 1 - meaningful	**0% - 2%**

For randomization purposes, the sentence sets were mapped to drive order number. Because the experimental conditions were randomized with drive order for every participant, the set of sentences were not presented for a specific experimental condition. This ensured that there was no confounding effect with the experimental conditions and the sentences presented. However, the baseline sentence set could not be randomized with the other sets because the duration of baseline driving was shorter hence the number of sentences was less. Therefore, two different baseline sets were formed by random selections from the

A and B sets. There were 12 sets of sentences formed and these sets were randomized for each drive as in table below.

Randomization of sentence sets

Day 1	Visual Practice	
	Audio Practice	
	1st Visual drive	A set (order of sentences randomized)
	2nd Visual drive	B set (order of sentences randomized)
	1st Audio drive	A set (order of sentences randomized)
	2nd Audio drive	B set (order of sentences randomized)
	1st Control drive	Control set 1 (selected from both A and B sets)
Day 2	3rd Visual drive	A set (order of sentences randomized)
	4th Visual drive	B set (order of sentences randomized)
	3rd Audio drive	A set (order of sentences randomized)
	4th Audio drive	B set (order of sentences randomized)
	2nd Control drive	Control set 2 (selected from both A and B sets)

Visual Practice Drive
The spoon turned to the horse.
The prince yelled at the king.
The ground kissed the man.
The boy hit the ball.
The keys received the dog.
The banker paid the clerk.
The picture drew a boy.
The night cleaned the room.
The monkey hugged the man.
The mouse bought a dog.
The girl walked with the sea.
The cow smelled the grass.
The boy ate the orange.
The bird lost the worm.
The flower smelled the man.
The boy swept the floor.
The boy forgot the book.
The toy lost the mouse.
The horse knocked the morning.
The clock kissed the gum.
The apple jumped the fence.
The clerk walked the dog.
The clock showed the time.
The phone picked the fish.
The friend liked the place.
The boy took a bath.
The boy wore the bed.
The girl sat on the chair.
The pig typed the book.
The farmer drank the juice.

Audio Practice Drive
The boy hit the ball.
The night cleaned the room.
The horse knocked the morning.
The boy forgot the book.
The prince yelled at the king.
The picture drew a boy.
The farmer drank the juice.
The boy took a bath.
The boy ate the orange.
The spoon turned to the horse.
The pig typed the book.
The clock showed the time.
The keys received the dog.
The monkey hugged the man.
The boy wore the bed.
The apple jumped the fence.
The girl walked with the sea.
The flower smelled the man.
The phone picked the fish.
The cow smelled the grass.
The girl sat on the chair.
The friend liked the place.
The clock kissed the gum.
The clerk walked the dog.
The banker paid the clerk.
The ground kissed the man.
The toy lost the mouse.
The bird lost the worm.
The mouse bought a dog.
The boy swept the floor.

1st Control Drive
The girl closed the window.
The postman jumped the fence.
The king slept at night.

The moon threw the sea.
The cook fried the egg.
The girl baked a pie.
The house served the stone.
The food set the table.
The princess read the book.
The grass smelled the ring.
The girl drank the paper.
The man fixed the house.
The food knocked on the stone.
The pig read a king.
The frog ate the fly.
The girl ate the apple.
The bus drove the man.
The singer ate the bed.
The song laid on the floor.
The teacher ate the fish.
The baby kicked the toy.
The queen picked the orange.
The boy played the game.
The food is on the floor.
The dog drank the milk.
The book read the coat.
The boy sang on the milk.
The bracelet crossed the toy.
The pig saw the snow.
The moon forgot the snow.
The ball is on the beach.
The fence kicked the shark.
The fish is in the sea.
The man cleaned the windows.
The spoon approached the cat.
The girl walked to school.
The waiter served the cake.
The artist drank the soup.
The boy opened the book.
The man is on the moon.
The duck flew the door.
The coat drove the bird.
The snow stopped the frog.
The lake pushed the man.
The duck caught the fish.
The smoke saw the hallway.
The zebra ate the car.
The man hung the coat.
The song was on the stick.
The tea climbed the chair.
The balloon cleaned the shark.
The child played the game.
The fish baked a pie.
The king received the keys.
The man ate the rocks.
The man rode the garbage.
The prince saved the cat.
The chicken wrote the book.
The man mowed the lawn.
The basket jumped the king.

2nd Control Drive

The sister washed the car.
The woman saw the mouse.
The girl kept the sky.
The orange typed the school.
The mother drank the milk.
The queen loved the king.
The beach is on the nest.
The boy parked the car.
The girl read the book.
The floor is on the cook.
The boy ate the bread.
The ring took the girl.
The man walked the clouds.
The girl sat on the couch.
The girl wore a dress.
The bed shot the mouse.
The child missed the bus.
The girl kissed the boy.
The sheep ate the grass.
The girl chewed the gum.
The ham helped the fish.
The snow stopped the cup.
The egg is on the stove.
The dog barked at the boy.
The book took the apple.
The girl squeezed the lemon.
The man approached the car.
The dog closed the lemon.
The cowboy stopped the moon.
The glass burnt the water.
The carpet broke the pig.
The clock heard the egg.
The box broke the floor.
The cow ate the corn.
The queen wore a ring.
The man prepared the moon.
The boy purchased the toy.
The dog chased the cat.
The day hooked the fish.
The boy drew a picture.
The child kicked the ball.
The shark said the word.
The doll typed the farm.
The doll was on the floor.
The queen swam in the page.
The laundry poured the soup.
The girl loaded the milk.
The milk walked the dog.
The math took the shower.
The banker crossed the road.
The queen drank tea.
The bike chased the dog.
The dancer drank the soup.

The woman cooked the fish.
The movie ate the juice.
The clown had a balloon.
The fish healed the grass.
The sea pushed the keys.
The girl had a party.
The chimney taught the girl.

1st Visual Drive

The floor is on the cook.
The man hung the coat.
The bird was in the nest.
The couch is on the tree.
The ball kicked the child.
The milk drank the man.
The man hooked a fish.
The lemon drank the horse.
The fish healed the grass.
The house served the stone.
The girl sat on the couch.
The father helped the dog.
The pig saw the snow.
The boy jumped on the hill.
The girl ate the apple.
The dog drank the milk.
The hand paid the grass.
The garden walked the stick.
The child kicked the ball.
The egg is on the stove.
The police asked the girl.
The movie ate the juice.
The cowboy stopped the moon.
The baby kicked the toy.
The corn pulled the string.
The clerk saw the rain.
The girl wore a dress.
The girl loaded the milk.
The keys moved in the house.
The man ate the rocks.
The queen swam in the page.
The girl kept the sky.
The book took the apple.
The man cleaned the car.
The chair healed the food.
The song was on the stick.
The frog ate the fly.
The zebra crossed the street.
The mother drank the milk.
The glass burnt the water.
The boy parked the car.
The game played the child.
The duck flew the door.
The box broke the floor.
The girl turned the house.
The cat smelled the fish.
The cook fried the egg.
The milk walked the dog.
The boy brushed his teeth.
The postman jumped the fence.
The chicken wrote the book.
The mother fed the child.
The cookies drank the coffee.
The bike chased the dog.
The girl missed the bus.
The spoon approached the cat.
The balloon cleaned the shark.
The man is on the moon.
The dancer drank the soup.
The stone pushed the queen.
The bus drove the man.
The ring took the girl.
The bus approached the stop.
The coat drove the bird.
The girl chewed the gum.
The queen loved the king.
The food knocked on the stone.
The book read the coat.
The egg hugged the farm.
The smoke saw the hallway.
The day ate the clock.
The ball is on the beach.
The waiter served the cake.
The king kissed the queen.
The girl had a party.
The girl walked to school.
The man saw the dog.
The bracelet crossed the toy.
The food set the table.
The cow ate the corn.
The boy opened the book.
The dog helped the boy.
The book opened the corn.
The chimney taught the girl.
The boy read the book.
The corn fixed the door.
The boy ate the bread.
The grass parked the hat.
The girl squeezed the lemon.
The cook served the food.
The sugar burnt the chair.
The girl closed the window.
The day hooked the fish.
The king slept at night.
The boy purchased the toy.
The banker crossed the road.
The duck flew home.
The baby cried the coffee.
The disease killed the people.
The country signed a treaty.
The door drank fire.
The doctor entered the house.
The fish walked home.

The fish swam home.
The dog ran home.
The bracelet entered the house.
The cow flew home.
The garden jumped the candles.

2nd Visual Drive
The bread ate the ball.
The duck laid the egg.
The farmer cooked the egg.
The fish hooked the man.
The beach is on the nest.
The snow stopped the frog.
The shark said the word.
The garbage rang the milk.
The boat bought the book.
The man approached the car.
The cook lost the toy.
The father picked the car.
The dog chased the cat.
The boy played the game.
The grass smelled the ring.
The woman cooked the fish.
The carpet broke the pig.
The dog closed the lemon.
The zebra ate the car.
The song laid on the floor.
The sea pushed the keys.
The girl drank the paper.
The dog barked at the boy.
The man mowed the lawn.
The man rode the garbage.
The bed shot the mouse.
The boy closed his eyes.
The prince saved the cat.
The fish baked a pie.
The girl kissed the boy.
The doll hooked the farm.
The girl opened the door.
The man cleaned the windows.
The horse ate the grass.
The tree was in the park.
The basket jumped the king.
The boy sang on the milk.
The food is on the floor.
The child missed the bus.
The pig jumped the house.
The moon saw the sea.
The pig built a king.
The moon forgot the snow.
The tea climbed the chair.
The cow crossed the road.
The pig is on the farm.
The hallway paid the soup.
The queen drank tea.
The curtain jumped the fence.
The man prepared the moon.
The ham helped the fish.
The girl baked a pie.
The king received the keys.
The woman saw the mouse.
The king wore a shoe.
The man fixed the house.
The man drove on the clouds.
The clock heard the egg.
The boy kissed the girl.
The clouds called the duck.
The mouse fed the chair.
The fish is in the sea.
The beach ate the ball.
The orange typed the school.
The cowboy rode the horse.
The boy drew a picture.
The sister washed the car.
The girl read the book.
The chair talked to the boy.
The artist drank the soup.
The goat kicked the boy.
The corn opened the book.
The fence kicked the shark.
The queen picked the orange.
The princess read the book.
The child played the game.
The doll was on the floor.
The rain dropped the roof.
The singer sang the bed.
The feet built the keys.
The queen wore a ring.
The duck parked the car.
The rabbit swam the snow.
The man kissed the girl.
The clown had a balloon.
The duck caught the fish.
The horse sat on the chair.
The girl rode the bike.
The clerk knocked the door.
The sheep ate the grass.
The math took the shower.
The father walked the dog.
The lake pushed the man.
The fence climbed the cat.
The teacher ate the fish.
The laundry poured the soup.
The boy ran home.
The flower approached the girl.
The girl walked home.
The woman blew the candles.
The sister pushed the mountain.
The book brushed gum.
The police kicked the movie.
The mother drank the coffee.
The mother studied the book.

The leg saved milk.
The bird flew home.
The bike broke clouds.

3rd Visual Drive

The floor is on the cook.
The dog helped the boy.
The girl walked to school.
The game played the child.
The mother drank the milk.
The chimney taught the girl.
The egg hugged the farm.
The man ate the rocks.
The girl kept the sky.
The queen swam in the page.
The ball is on the beach.
The dancer drank the soup.
The glass burnt the water.
The banker crossed the road.
The stone pushed the queen.
The box broke the floor.
The cow ate the corn.
The ball kicked the child.
The girl closed the window.
The girl missed the bus.
The corn pulled the string.
The song was on the stick.
The hand paid the grass.
The man is on the moon.
The boy jumped on the hill.
The cookies drank the coffee.
The king kissed the queen.
The bus drove the man.
The milk walked the dog.
The movie ate the juice.
The milk drank the man.
The boy parked the car.
The duck flew the door.
The coat drove the bird.
The couch is on the tree.
The egg is on the stove.
The waiter served the cake.
The clerk saw the rain.
The day ate the clock.
The child kicked the ball.
The girl chewed the gum.
The man saw the dog.
The pig saw the snow.
The postman jumped the fence.
The man cleaned the car.
The bus approached the stop.
The fish healed the grass.
The cook fried the egg.
The boy ate the bread.
The man hung the coat.
The dog drank the milk.
The bike chased the dog.
The bird was in the nest.
The food set the table.
The girl loaded the milk.
The book opened the corn.
The man hooked a fish.
The baby kicked the toy.
The smoke saw the hallway.
The cook served the food.
The boy brushed his teeth.
The chicken wrote the book.
The book read the coat.
The cat smelled the fish.
The sugar burnt the chair.
The girl turned the house.
The book took the apple.
The girl wore a dress.
The girl had a party.
The police asked the girl.
The spoon approached the cat.
The house served the stone.
The corn fixed the door.
The ring took the girl.
The zebra crossed the street.
The queen loved the king.
The grass parked the hat.
The frog ate the fly.
The boy purchased the toy.
The food knocked on the stone.
The father helped the dog.
The boy read the book.
The girl squeezed the lemon.
The king slept at night.
The boy opened the book.
The lemon drank the horse.
The keys moved in the house.
The mother fed the child.
The balloon cleaned the shark.
The girl ate the apple.
The cowboy stopped the moon.
The chair healed the food.
The girl sat on the couch.
The garden walked the stick.
The bracelet crossed the toy.
The day hooked the fish.
The door drank fire.
The fish walked home.
The bracelet entered the house.
The baby cried the coffee.
The dog ran home.
The cow flew home.
The country signed a treaty.
The doctor entered the house.
The duck flew home.
The garden jumped the candles.
The disease killed the people.

The fish swam home.

4th Visual Drive

The ham helped the fish.
The boy closed his eyes.
The queen wore a ring.
The king wore a shoe.
The man rode the garbage.
The duck caught the fish.
The boy played the game.
The prince saved the cat.
The artist drank the soup.
The garbage rang the milk.
The pig read a king.
The laundry poured the soup.
The sound laid on the floor.
The boy kissed the girl.
The duck parked the car.
The feet read the keys.
The horse sat on the chair.
The clown had a balloon.
The girl baked a pie.
The cook lost the toy.
The fish hooked the man.
The cowboy rode the horse.
The mouse fed the chair.
The girl kissed the boy.
The rabbit swam the snow.
The queen drank tea.
The math took the shower.
The girl rode the bike.
The man walked the clouds.
The beach is on the nest.
The fish baked a pie.
The woman saw the mouse.
The rain dropped the roof.
The fence climbed the cat.
The basket jumped the king.
The sea pushed the book.
The girl opened the door.
The curtain jumped the fence.
The child missed the bus.
The man kissed the girl.
The duck laid the egg.
The child played the game.
The snow stopped the cup.
The father picked the car.
The queen picked the orange.
The singer ate the bed.
The princess read the book.
The farmer cooked the egg.
The lake pushed the man.
The doll typed the farm.
The bed shot the mouse.
The boy drew a picture.
The hallway paid the soup.
The king received the keys.
The cow crossed the road.
The sister washed the car.
The chair talked to the boy.
The horse ate the grass.
The goat kicked the boy.
The dog closed the lemon.
The clerk slept the door.
The man prepared the moon.
The tree was in the park
The grass smelled the ring.
The carpet broke the pig.
The father walked the dog.
The food is on the floor.
The doll was on the floor.
The orange typed the school.
The beach ate the ball.
The fish is in the sea.
The moon forgot the snow.
The pig jumped the house.
The boy sang on the milk.
The zebra ate the car.
The corn opened the book.
The dog barked at the boy.
The man fixed the house.
The pig is on the farm.
The clouds called the duck.
The moon threw the sea.
The man approached the car.
The dog chased the cat.
The man cleaned the windows.
The girl read the book.
The girl drank the paper.
The tea climbed the chair.
The bread ate the ball.
The woman cooked the fish.
The boat bought the book.
The man mowed the lawn.
The chair heard the egg.
The fence kicked the shark.
The teacher ate the fish.
The shark said the word.
The sheep ate the grass.
The leg saved milk.
The police kicked the movie.
The mother studied the book.
The boy ran home.
The woman blew the candles.
The mother drank the coffee.
The sister pushed the mountain.
The bike broke clouds.
The bird flew home.
The book brushed gum.
The flower approached the girl.
The girl walked home.

1st Audio Drive

The floor is on the cook.
The baby kicked the toy.
The smoke saw the hallway.
The boy opened the book.
The police asked the girl.
The clerk saw the rain.
The book took the apple.
The boy jumped on the hill.
The cook fried the egg.
The grass parked the hat.
The man cleaned the car.
The man is on the moon.
The chair healed the food.
The day hooked the fish.
The food set the table.
The song was on the stick.
The boy parked the car.
The girl ate the apple.
The milk drank the man.
The lemon drank the horse.
The bird was in the nest.
The dog drank the milk.
The garden walked the stick.
The chimney taught the girl.
The child kicked the ball.
The ball kicked the child.
The book read the coat.
The girl had a party.
The pig saw the snow.
The girl kept the sky.
The girl chewed the gum.
The glass burnt the water.
The boy read the book.
The keys moved in the house.
The banker crossed the road.
The waiter served the cake.
The day ate the clock.
The coat drove the bird.
The cow ate the corn.
The book opened the corn.
The duck flew the door.
The bracelet crossed the toy.
The girl missed the bus.
The postman jumped the fence.
The corn fixed the door.
The chicken wrote the book.
The bike chased the dog.
The box broke the floor.
The man saw the dog.
The food knocked on the stone.
The hand paid the grass.
The man ate the rocks.
The mother drank the milk.
The bus approached the stop.
The girl closed the window.
The game played the child.
The couch is on the tree.
The dancer drank the soup.
The girl wore a dress.
The girl walked to school.
The girl turned the house.
The fish healed the grass.
The corn pulled the string.
The queen loved the king.
The zebra crossed the street.
The king slept at night.
The girl loaded the milk.
The ring took the girl.
The man hooked a fish.
The king kissed the queen.
The boy purchased the toy.
The cat smelled the fish.
The boy ate the bread.
The movie ate the juice.
The snow stopped the frog.
The house served the stone.
The milk walked the dog.
The father helped the dog.
The egg is on the stove.
The dog helped the boy.
The girl squeezed the lemon.
The boy brushed his teeth.
The ball is on the beach.
The balloon cleaned the shark.
The mother fed the child.
The egg hugged the farm.
The cook served the food.
The cookies drank the coffee.
The frog ate the fly.
The bus drove the man.
The girl sat on the couch.
The man hung the coat.
The sugar burnt the chair.
The spoon approached the cat.
The cowboy stopped the moon.
The queen swam in the page.
The duck flew home.
The country signed a treaty.
The garden jumped the candles.
The fish walked home.
The bracelet entered the house.
The disease killed the people.
The doctor entered the house.
The door drank fire.
The dog ran home.
The cow flew home.
The fish swam home.
The baby cried the coffee.

2nd Audio Drive

The ham helped the fish.

The boy drew a picture.
The doll was on the floor.
The clouds called the duck.
The mouse fed the chair.
The cow crossed the road.
The rain dropped the roof.
The girl drank the paper.
The father walked the dog.
The tea climbed the chair.
The doll typed the farm.
The pig is on the farm.
The cook lost the toy.
The sea pushed the book.
The garbage rang the milk.
The man mowed the lawn.
The dog barked at the boy.
The lake pushed the man.
The girl jumped the fence.
The corn opened the book.
The pig read a king.
The teacher ate the fish.
The math took the shower.
The child missed the bus.
The man fixed the house.
The clown had a balloon.
The horse sat on the chair.
The basket jumped the king.
The fence kicked the shark.
The woman saw the mouse.
The goat kicked the boy.
The boy kissed the girl.
The dog chased the cat.
The girl opened the door.
The orange typed the school.
The bed shot the mouse.
The song laid on the floor.
The duck laid the egg.
The beach is on the nest.
The hallway paid the soup.
The beach ate the ball.
The tree was in the park.
The boy played the game.
The girl rode the bike.
The zebra ate the car.
The laundry poured the soup.
The man prepared the moon.
The boy kissed the girl.
The man approached the car.
The sister washed the car.
The girl baked a pie.
The king received the keys.
The bread ate the ball.
The feet read the keys.
The duck caught the fish.
The boy closed his eyes.
The chair talked to the boy.
The man cleaned the windows.
The boat bought the book.
The clerk slept the door.
The moon threw the sea.
The prince saved the cat.
The girl read the book.
The king wore a shoe.
The artist drank the soup.
The man walked on the clouds.
The cowboy rode the horse.
The food is on the floor.
The woman cooked the fish.
The man rode the garbage.
The chair heard the egg.
The sheep ate the grass.
The child played the game.
The boy sang on the milk.
The fence climbed the cat.
The singer ate the bed.
The queen drank tea.
The farmer cooked the egg.
The fish is in the sea.
The carpet broke the pig.
The queen wore a ring.
The queen picked the orange.
The moon forgot the snow.
The shark said the word.
The snow stopped the cup.
The horse ate the grass.
The duck parked the car.
The princess read the book.
The grass smelled the ring.
The fish baked a pie.
The pig jumped the house.
The rabbit swam the snow.
The father picked the car.
The dog closed the lemon.
The fish hooked the man.
The girl kissed the boy.
The leg saved milk.
The girl walked home.
The book brushed gum.
The mother studied the book.
The bird flew home.
The woman blew the candles.
The mother drank the coffee.
The boy ran home.
The bike broke clouds.
The police kicked the movie.
The flower approached the girl.
The sister pushed the mountain.

3rd Audio Drive

The floor is on the cook.
The cowboy stopped the moon.
The queen swam in the page.

The bike chased the dog.
The girl walked to school.
The girl wore a dress.
The coat drove the bird.
The duck flew the door.
The zebra crossed the street.
The baby kicked the toy.
The milk drank the man.
The balloon cleaned the shark.
The clerk saw the rain.
The police asked the girl.
The mother drank the milk.
The king kissed the queen.
The couch is on the tree.
The frog ate the fly.
The cow ate the corn.
The ball is on the beach.
The man hung the coat.
The glass burnt the water.
The grass parked the hat.
The food set the table.
The king slept at night.
The fish healed the grass.
The girl ate the apple.
The cook served the food.
The girl turned the house.
The book opened the corn.
The cookies drank the coffee.
The day ate the clock.
The chicken wrote the book.
The girl sat on the couch.
The boy brushed his teeth.
The father helped the dog.
The girl loaded the milk.
The queen loved the king.
The boy parked the car.
The cook fried the egg.
The boy ate the bread.
The sugar burnt the chair.
The movie ate the juice.
The man saw the dog.
The bus drove the man.
The waiter served the cake.
The chair healed the food.
The dancer drank the soup.
The boy jumped on the hill.
The bird was in the nest.
The child kicked the ball.
The cat smelled the fish.
The pig saw the snow.
The smoke saw the hallway.
The dog drank the milk.
The girl had a party.
The day hooked the fish.
The banker crossed the road.
The house served the stone.
The girl squeezed the lemon.
The ring took the girl.
The snow stopped the frog.
The egg hugged the farm.
The girl missed the bus.
The boy purchased the toy.
The spoon approached the cat.
The man cleaned the car.
The girl kept the sky.
The game played the child.
The boy read the book.
The garden walked the stick.
The milk walked the dog.
The mother fed the child.
The keys moved in the house.
The book read the coat.
The hand paid the grass.
The corn fixed the door.
The song was on the stick.
The bus approached the stop.
The bracelet crossed the toy.
The ball kicked the child.
The boy opened the book.
The box broke the floor.
The book took the apple.
The dog helped the boy.
The girl chewed the gum.
The postman jumped the fence.
The chimney taught the girl.
The man is on the moon.
The lemon drank the horse.
The girl closed the window.
The food knocked on the stone.
The corn pulled the string.
The man ate the rocks.
The man hooked a fish.
The egg is on the stove.
The dog went home.
The fish swam home.
The fish walked home.
The duck flew home.
The garden jumped the candles.
The country signed a treaty.
The baby cried the coffee.
The disease killed the people.
The bracelet entered the house.
The door drank fire.
The cow flew home.
The doctor entered the house.

4th Audio Drive

The ham helped the fish.
The bed shot the mouse.
The boy kissed the girl.
The doll was on the floor.
The princess read the book.

The king wore a shoe.
The lake pushed the man.
The cook lost the toy.
The fence kicked the shark.
The beach is on the nest.
The pig read a king.
The moon threw the sea.
The curtain jumped the fence.
The feet built the keys.
The queen picked the orange.
The woman saw the mouse.
The moon forgot the snow.
The horse ate the grass.
The man rode the garbage.
The woman cooked the fish.
The sea pushed the book.
The doll typed the farm.
The duck caught the fish.
The queen drank tea.
The singer ate the bed.
The duck laid the egg.
The man walked the clouds.
The tea climbed the chair.
The girl opened the door.
The chair heard the egg.
The cowboy rode the horse.
The man fixed the house.
The child missed the bus.
The tree was in the park.
The prince saved the cat.
The girl read the book.
The snow stopped the cup.
The boy closed his eyes.
The farmer cooked the egg.
The dog closed the lemon.
The zebra ate the car.
The man mowed the lawn.
The queen wore a ring.
The mouse fed the chair.
The girl drank the paper.
The fence climbed the cat.
The goat kicked the boy.
The man cleaned the windows.
The father picked the car.
The dog barked at the boy.
The rain dropped the roof.
The girl kissed the boy.
The duck parked the car.
The child played the game.
The carpet broke the pig.
The boy drew a picture.
The boat bought the book.
The boy sang on the milk.
The beach ate the ball.
The sound laid on the floor.
The man prepared the moon.
The teacher ate the fish.
The cow crossed the road.
The garbage rang the milk.
The corn opened the book.
The rabbit swam the snow.
The pig jumped the house.
The bread ate the ball.
The girl rode the bike.
The pig is on the farm.
The king received the keys.
The boy played the game.
The food is on the floor.
The grass smelled the ring.
The fish baked a pie.
The clerk slept the door.
The basket jumped the king.
The shark said the word.
The math took the shower.
The hallway paid the soup.
The chair talked to the boy.
The boy kissed the girl.
The fish is in the sea.
The orange typed the school.
The artist drank the soup.
The laundry poured the soup.
The sheep ate the grass.
The clown had a balloon.
The clouds called the duck.
The sister washed the car.
The man approached the car.
The fish hooked the man.
The horse sat on the chair.
The father walked the dog.
The girl baked a pie.
The dog chased the cat.
The leg saved milk.
The police kicked the movie.
The mother drank coffee.
The sister pushed the mountain.
The bird flew home.
The book brushed gum.
The boy went home.
The woman moved the candles.
The bike rode clouds.
The girl walked home.
The flower approached the girl.
The mother studied the book.

APPENDIX D

EXPERIMENTAL INSTRUCTIONS

Simulator Practice Instructions

The driving simulator you see is based on a 1992 Mercury Sable sedan. It operates just like a real car. The brake and the accelerator pedals work the same way as in a real car. We ask that you adjust the seat after getting in the car so that it is the most comfortable for you. The seat adjuster is located directly under the front of the driver seat. Pulling it up towards you will allow you to slide the seat backwards and forwards.

Although the driving simulator drives like a real car, it lacks the normal motion associated with driving in the real world. This can cause motion sickness in sensitive individuals. It is absolutely necessary to inform the experimenter if you experience ANY symptoms of motion sickness. These symptoms include headache, stomachache, dizziness, clamminess, and nausea. If you feel any of these symptoms, inform the experimenter and then pull over to the side of the road and stop the car. In the unlikely event that you become nauseated during the drive, please use the hygienic bag indicated by the experimenter.

The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. There is no need to turn the ignition on; the car is already started. When the experimenter tells you, push the YES button once and then put the vehicle into “Drive” and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph, while maintaining a constant safe following distance. This drive will take approximately 5 minutes. Drive as you would normally drive in the real world. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions? (Give the interactive game instructions.)

Interactive Game Rules - Visual

In the car of the future you might be able to play games in your car. With these games you might have the chance to make money depending on how well you do. In this drive, you will play an interactive game as you might in the future.

<u>The rules of the game are as follows;</u>

- When you hear a CLICK sound, check text-messages from the display placed to your right. Each message will consist of a sentence. Read these sentences while maintaining safe driving.
- After you read the sentence, immediately decide if the sentence is meaningful or not. For example, “the doctor saw the patient” is meaningful; “the man has a pen” is meaningful, while “the pen has a man” is not.

- Use the buttons on the steering wheel to answer (top for YES; bottom for NO). You should give your answer, before the next sentence appears on the screen.
- While doing this, remember the subject of the sentence. In the example, the subject in the first sentence “the doctor saw the patient” is doctor, in the second one “the man has a pen”: the subject is “man”; in the third sentence “the pen has a man”: the subject is “pen”. So it is “doctor, man, pen”.
- After the third sentence, you are going to hear a BEEP, recall the subjects of the sentences in the order you read them. Please wait for the beep before you recall the subjects.

The game will give you feedback on how well you do. (By % correct and accurate recall)

<u>Bonus;</u>

You can get additional money under the following conditions.

For each drive;
0% to 25% correct: $0.
25% to 50% correct: $0.5.
50% to 75% correct: $1.
75% to 100% correct: $2.
Do you have any questions?

Interactive Game Rules - Audio

Now you are going to play an audio version of the game. Depending on how well you play the game, you will receive a bonus.

<u>The rules of the game are as follows;</u>

- During this game you are going to hear sentences. Listen to these sentences while maintaining safe driving. The synthetic voice used to present the sentences is hard to understand. Try your best to understand all the sentences and respond with your best guess for those you can not completely hear.
- After you hear each sentence, immediately decide if the sentence is meaningful or not. For example, “the doctor saw the patient” is meaningful; “the man has a pen” is meaningful, while “the pen has a man” is not.
- Use the buttons on the steering wheel to answer (top for YES; bottom for NO). You should give your answer, before you hear the next sentence.
- While doing so, remember the subject of the sentence. In the example, the subject in the first sentence “the doctor saw the patient” is doctor, in

the second one “the man has a pen”: the subject is “man”; in the third sentence “the pen has a man”: the subject is “pen”. So it is “doctor, man, pen”.

- After the third sentence, you are going to hear a BEEP, recall the subjects of the sentences in the order you heard them. Please wait for the beep before you recall the subjects. If you could not hear a subject and can not make a guess say “unclear”. For example, in the above example if you could not hear the last two subjects say “doctor, unclear, unclear”.

The game will give you feedback on how well you do. (By % correct and accurate recall)

<u>Bonus;</u>

You can get additional money under the following conditions.
For each drive;
0% to 25% correct: $0.
25% to 50% correct: $0.5.
50% to 75% correct: $1.
75% to 100% correct: $2.
Do you have any questions?

Drive Instructions – Advising - Audio

During this drive, you will be playing the audio interactive game. There will also be a safety system to inform you of a roadway condition that requires appropriate action. A background clicking sound will warn you in case the lead vehicle is braking or there is a curve ahead. However, you will still be able to hear the sentences when the clicking sound is on.

The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, then put the vehicle into “Drive” and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

Drive Instructions - Advising - Visual

During this drive, you will still continue playing the visual interactive game. There will also be a safety system to inform you of a roadway condition that requires appropriate action. A red frame will come up around the display to warn you in case the lead vehicle is braking or there is a curve ahead. The presentation of the messages will not stop while the red frame is up.

The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, then put the vehicle into “Drive” and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

Drive Instructions – Control -Audio

During this drive, there is no safety system. However, you will still continue playing the audio interactive game at the second half of the drive. The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, put the vehicle into “Drive” and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph, while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

Drive Instructions – Control -Visual

During this drive, there is no safety system. However, you will still continue playing the visual interactive game at the second half of the drive. The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, put the vehicle into “Drive” and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph, while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

Drive Instructions - Locking - Audio

During this drive, you will still continue playing the audio interactive game. There will also be a safety system to inform you of a roadway condition that requires appropriate action. A background clicking sound will warn you in case the lead vehicle is braking or there is a curve ahead. However, you won't be able to hear the sentences when the clicking sound is on. The presentation of the sentences will resume after the click sound stops.

The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, then put the vehicle into "Drive" and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

Drive Instructions - Locking - Visual

During this drive, you will still continue playing the visual interactive game. There will also be a safety system to inform you of a roadway condition that requires appropriate action. A red frame will come up on the display to warn you in case the lead vehicle is braking or there is a curve ahead. However, you won't be able to see the sentences when the frame is on. The presentation of the messages will resume when the frame turns off.

The driving scene that will be presented to you begins with your vehicle stopped at the side of a road behind another vehicle. When the experimenter tells you, push the YES button once, then put the vehicle into "Drive" and proceed through the driving environment by following the car in front of you. At times, the lead vehicle may change its speed. Your task is to drive under 45 mph while maintaining a constant safe following distance. Drive as you would normally drive in the real world.

This drive will take approximately 10-12 minutes. When you see two flashing yellow arrow signs on both sides of the road, please slow down, stop, and put the car into PARK (P). This indicates the end of the drive.

Do you have any questions?

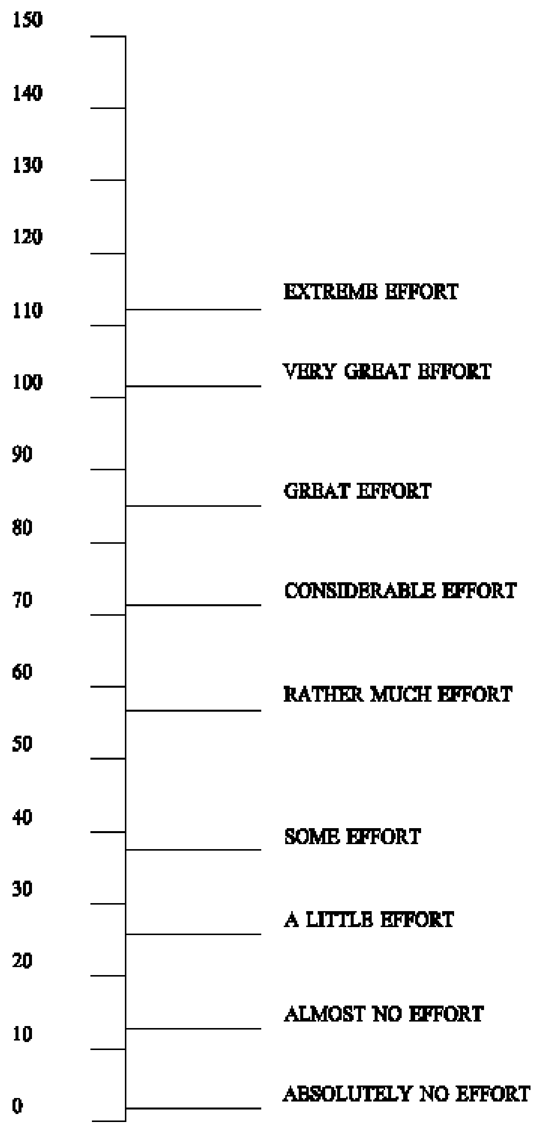
APPENDIX E

QUESTIONNAIRES

RATING SCALE MENTAL EFFORT (After Each Drive including / Control)

Rating Scale Mental Effort

Please indicate, by marking the vertical axis below, how much effort it took for you to complete the task you've just finished



PERCEIVED RISK (After Each Drive including / Control)

The scenario you just drove was As Risky As:

10: driving with my eyes closed; A crash is bound to occur every time I do this

9: passing a school bus that has its red lights flashing and the stop arm in full view

8: driving just under the legal alcohol limit with observed weaving in the lane

7: in between 6 & 8

6: driving 20 miles per hour faster than traffic on an expressway

5: in between 4 & 6

4: driving 10 miles an hour faster than traffic on an expressway

3: in between 2 & 4

2: driving on an average road under average conditions

1: driving on an easy road with no traffic, pedestrians, or animals while perfectly alert

IVIS ACCEPTANCE / VAN DER LAAN (After Each Drive / excluding Control)

What is your opinion about the safety system you just used? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system was very easy to use but required a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

SYSTEM TRUST QUESTIONNAIRE (After Each Drive / excluding Control)

Indicate how much you agree with the follow statements about the safety system you just experienced (circle only one response for each statement).

I am confident in my ability to drive the car safely without the safety system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The performance of the safety system enhanced my driving safety.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I am familiar with the operation of the safety system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I trust the safety system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The safety system is reliable.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The safety system is dependable.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The safety system has integrity.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I am comfortable with the intent of the safety system.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

Imagine that you are driving home from shopping and are talking on the cell-phone. Like you have encountered in this experiment, the system started to give a background clicking noise to inform you of a roadway condition you have to react.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

Imagine that you are driving home from shopping and are talking on the cell-phone. Like you have encountered in this experiment, the system started to give a background clicking noise to inform you of a roadway condition you have to react and cut out your conversation.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

In the future you might be able to check your email messages, in your car, with voice commands.

Imagine that you are driving home from shopping and checking your email messages. Like you have encountered in this experiment, the system started to give a background clicking noise to inform you of a roadway condition you have to react.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

In the future you might be able to check your email messages, in your car, with voice commands.

Imagine that you are driving home from shopping and checking your email messages. Like you have encountered in this experiment, the system started to give a background clicking noise to inform you of a roadway condition you have to react and would not let you check your messages.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

Imagine that you are driving home from shopping and are adjusting your radio. Like you have encountered in this experiment, the radio display started to flash red to inform you of a roadway condition you have to react.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

IVIS ACCEPTANCE / VAN DER LAAN (Once at the end of participation)

Imagine that you are driving home from shopping and are adjusting your radio. Like you have encountered in this experiment, the radio display started to flash red to inform you of a roadway condition you have to react and would not let you adjust your radio.

What will be your opinion about this safety system? Please rate your opinion for each descriptive item below (please tick one box for each item):

For example, if you thought the system will be very easy to use but will require a lot of effort to learn, you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

My judgments of the safety system I just used are:

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Good	☐	☐	☐	☐	☐	Bad
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting	☐	☐	☐	☐	☐	Worthless
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Thank you for completing this questionnaire.

Interpersonal Trust Scale (Once at the end of participation)

Please mark an 'X' in the box above the statement that best describes how you feel about that statement.

1. Hypocrisy is on the increase in our society.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

2. In dealing with strangers one is better off to be cautious until they have provided evidence that they are trustworthy.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

3. This country has a dark future unless we can attract better people into politics.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

4. Fear and social disgrace or punishment rather than conscience prevents most people from breaking the law.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

5. Using the honor system of *not* having a teacher present during exams would probably result in increased cheating.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

6. Parents usually can be relied on to keep their promises.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

7. The United Nations will never be an effective force in keeping world peace.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

8. The judiciary is a place where we can all get unbiased treatment.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

9. Most people would be horrified if they knew how much news that the public hears and sees is distorted.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

10. It is safe to believe that in spite of what people say most people are primarily interested in their own welfare.

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

11. Even though we have reports in newspaper, radio, and T.V., it is hard to get objective accounts of public events.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

12. The future seems very promising.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

13. If we really knew what was going on in international politics, the public would have reason to be more frightened than they now seem to be.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

14. Most elected officials are really sincere in their campaign promises.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

15. Many major national sports contests are fixed in one way or another.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

16. Most experts can be relied upon to tell the truth about the limits of their knowledge.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

17. Most parents can be relied upon to carry out their threats of punishment.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

18. Most people can be counted on to do what they say they will do.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

19. In these competitive times one has to be alert or someone is likely to take advantage of you.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

20. Most idealists are sincere and usually practice what they preach.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

21. Most salesmen are honest in describing their products.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

22. Most students in school would not cheat even if they were sure of getting away with it.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

23. Most repairmen will not overcharge even if they think you are ignorant of their specialty.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

24. A large share of accident claims filed against insurance companies, are phony.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

25. Most people answer public opinion polls honestly.

1	2	3	4	5
Strongly agree	Mildly agree	Agree and disagree equally	Mildly disagree	Strongly disagree

APPENDIX F

DEBRIEFING

DEBRIEFING

The purpose of the study you have just completed is to help answer questions related to the design and use of in-vehicle devices (such as radios, cell phones, navigation systems, etc.) that can increase the productivity of drivers but may also fatally distract them. More particularly, this study aims to evaluate an in-vehicle device design which can direct driver's attention to the roadway when necessary. The drives you completed investigated two different methods to inform the drivers when they have to give attention to the roadway. One method is to advise the driver; a red bezel for the display and a clicking background noise for the auditory messages. The other method locks out the driver interaction with the system; a blank screen for the display and interrupted messages and the clicking noise for the auditory messages. Four of the drives you completed in two days provided us with baseline driving information which allows us to compare your driving with the help of these safety features to how you might drive without any assistance.

The in-vehicle tasks that you completed during some of the drives was a secondary task aimed to distract you in the same manner that in-vehicle devices distract drivers in the real world. In order to better assess the driver acceptance of advising or locking-out methods, we have created a bonus structure for the in-vehicle tasks. The bonus structure was to assure that the task was important to you, as a real world use of the system would be. For example, you would be annoyed if the system locked-out your cell phone talk with your boss. We appreciate your hard work in completing this task appropriately.

One big factor that may affect the use of a distraction reducing system is the imperfections in the system. Driver's acceptance and use of the system may weaken if the system takes wrong actions. Therefore, we are also interested in how the reliability of this system affects your trust in the system. In one of the days you were given a %100 reliable system and in the other day you encountered a %50 reliable system.

Thank you for your participation. The results of this study will help us begin to answer questions regarding the design of in-vehicle systems that do not distract the drivers when they have to give attention to their driving. Any further questions regarding your participation can be directed to Birsen Donmez (graduate student) at (319) 335-5322 or Dr. John D. Lee (faculty advisor) at (319) 384-0810.