Minimum Time to Situational Awareness During Transfer of Control Under Varying Levels of Task Load

SAFER SIM

SAFETY RESEARCH USING SIMULATION

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16. Abstract

Technology advancements in the past two decades have made the human-vehicle connection stronger than ever. Since 2009 there has been a boom in the development of autonomous vehicles (AVs) as an increasing number of manufacturers have begun to see immense potential in this area of artificial intelligence (AI). While the private sector is racing forward with the development of autonomous features, there is a need to understand how the human driver will interface with these features before Level 5 automation is finally achieved. This study sought to explore how distractions during automated driving impacted hazard anticipation upon re-taking control.

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Abstract

Technology advancements in the past two decades have made the human-vehicle connection stronger than ever. Since 2009 there has been a boom in the development of autonomous vehicles (AVs) as an increasing number of manufacturers have begun to see immense potential in this area of artificial intelligence (AI). While the private sector is racing forward with the development of autonomous features, there is a need to understand how the human driver will interface with these features before Level 5 automation is finally achieved. This study sought to explore how distractions during automated driving impacted hazard anticipation upon re-taking control.

Twenty-one participants drove in a simulated environment across eight different scenarios to compare how four different in-vehicle tasks that were performed during automated driving affected hazard anticipation after re-taking manual control of the vehicle. An alert of a potential hazard was provided to drivers 6 seconds in advance of the hazard materializing, and the participants were instructed to disengage automation and take back control of the vehicle. The visual and audible tasks elicited a much higher workload than the control group, as captured by the NASA-TLX questionnaire, and drivers who performed the visual task spent, on average, 30 more seconds glancing away from the road during automated driving. Despite all this, there was no statistically significant difference in the hazard anticipation between the groups who performed an in-vehicle task and the control groups, suggesting that a 6-second warning time is sufficient for drivers to regain spatial awareness after a period of automated driving.

1 Introduction

Technology advancements in the previous two decades have made the human-vehicle connection stronger than ever. Since 2009, there has been a rapid development of advanced driver assistance systems (ADAS) as an increasing number of manufacturers have explored the immense potential in this area of AI. While the private sector continues to race forward with the development of autonomous features, there exists a need understand how human drivers will interface with these features before Level 5 automation can be achieved [1].

With an increasing number of manufacturers for semi-automated vehicles, several new features are being added. However, these technologies are not perfect and still require driver attention at various moments to take over control. Samuel et al. found that the minimal ideal time for transfer of control from autonomous driving to manual driving was 8 seconds before a potential hazard scenario [2]. This meant that a driver would require a minimum of 8 seconds to be brought back into the loop and regain the amount of necessary situational awareness to navigate the car to safety. Samuel et al. in their study used a single in-vehicle task for all five treatment conditions.

Dogan et al. found that drivers try and anticipate a cue or alert from automated vehicles and that this could influence the monitoring behavior of drivers [3]. The experiment was conducted on a simulator which had traffic jam assist that controlled latitudinal and longitudinal movement of the vehicle. This study did not consider the three distinct time to situational awareness time barriers we have built into our experiment. Dogan et al. [4] discussed a similar situation as [3], which showed that anticipatory behavior was found in drivers in scenarios where the traffic assistance failed leading to loss of trust in the automation feature. In case of no such failure, acceptance of the traffic assist was clearly observed among the drivers.

Across 32 studies, De Winter et al. found that a driver in manual condition would feel an elevated level of workload as compared to a driver in a car with adaptive cruise control (ACC, controlled longitudinal movement) or highly automated driving (HAD, controls latitudinal and longitudinal movement) [5]. The data was found using a NASA TLX questionnaire which was given post study. They also found that drivers in ACC and HAD had reduced levels of situational awareness when performing a secondary task as compared to manual condition. We also used the NASA TLX index in our experiment to measure the workload on drivers and the impact on their situational awareness.

It remains difficult to generalize distraction, and hence having just one type of distraction is not completely representative of the various types of cognitive distraction that drivers experience today. In particular, we are interested in determining how situational awareness would be impacted under varying task loads.

1.1 Research Objectives and Hypotheses

This study seeks to examine whether the minimum transfer of control time found in previous literature is sufficient while the driver is partaking in potentially distracting, non-driving tasks. The results from this study could provide significant information into which issues can be further identified to make the implementation of automated driving features a safe and seamless experience for future generations. The authors hypothesized that the impacts of this project may be seen across all spectrums of users and manufacturers, in that vehicle manufacturers could take the findings from this experiment and add an alert system or provide cues to the driver as early as possible so that a distracted driver could be introduced back into the loop in enough time to avoid a collision. Overall, the research question is as follows: Does the presence of a distracting, non-driving task diminish a driver's ability to take back control of the vehicle in a timely fashion and quickly perceive potential hazards?

1.2 Scope

In an effort to measure the efficacy of these research objectives, this study was designed to evaluate the various task load on drivers while using vehicle automation. This research study focused on three main tasks: an active visual task, a passive visual task, and an active auditory task. These in-vehicle tasks were compared against a control scenario which lacked an in-vehicle task for drivers. The outcome measures were the workload placed upon the driver, their time spent glancing off the road, and their hazard perception shortly after re-taking control of the vehicle.

1.3 Report Structure

Chapter 2 outlines the methodology for the simulator study, as well as the specific questionnaires and analytical procedures adapted for this study. Chapter 3 summarizes the results of the driving simulator study and provides a discussion into the driver behavior evaluated in the various task-driven transfer of control simulator scenarios. Lastly, Chapter 4 outlines the conclusions of the study and provides recommendations for future adaptions of this research.

2 Methods

2.1 Participants

The use of human participants in the study was approved by the University of Massachusetts Amherst’s Institutional Review Board. All participants had valid U.S. driver’s licenses and were prescreened for any symptoms of motion sickness to prevent instances of simulator sickness. Minors and pregnant women were excluded from the study. The participants were not prescreened for any prior experience driving on the driving simulator.

Participants were recruited from the UMass Amherst campus via flyers and list servs. The average age of participants was intentionally low (20.6 years) as younger drivers are most susceptible to distracting in-vehicle behaviors [6, 7, 8, 9]. Additionally, younger drivers may have higher trust in automation, due to growing up with technology, and thus may be more willing to perform non-driving tasks when the vehicle is in automated mode. More so, just under half of the participants admitted to “texting and driving” within 3 months to participating in the study.

Table 2.1 - Participant demographics

Participant Sex	#	Number w/ prior Simulator Experience	Average Age	Avg Driving History
Male	14	7	20.4	3.6 years
Female	7	4	20.9	4.4 years
Total	21	11	20.6	3.9 years

2.2 Apparatus

A fixed-base full-cab driving simulator running Realtime Technologies (RTI) SimCreator was utilized in this study, located in the Arbella Insurance Human Performance Laboratory at the University of Massachusetts Amherst. The simulator consists of a vehicle cab and five screens with 330-degree field of view, two dynamic side-mirrors, and a rearview mirror. The front facing screens are presented in Figure 2.1 with an additional rear screen that present the view behind the driver.

Figure 2.1 - Driving simulator at UMass Amherst

The ASL Mobile Eye is an ultra-lightweight and portable head mounted eye tracking system and was used to monitor and record the eye movements of the driver. The eye tracker records the position of the eye point of gaze at 30 Hz. The eye tracker has a visual angle range of 50 degrees in the horizontal direction and 40 degrees in the vertical direction. The system's accuracy is 0.5 degrees of visual angle.

2.3 Scenarios and Experimental Design

The experiment was designed as a within-subject experiment with the independent variable being the in-vehicle tasks. There were four different tasks (Table 2.2), with each participant partaking in each task twice in their eight experimental drives. The participants were instructed to engage the automation, perform their task, and then alerted to disengage the automation, which occurred alongside a hazard warning (Figure 2.2) 6 seconds before the hazard materialized. It was after this disengagement of the automation that latent hazards were present. There were eight different hazard scenarios that were developed, as described Table 2.3, to assess the impact of task load on latent hazard anticipation.

Table 2.2 - Task labels and descriptions

#	Task Label	Description
1	Active – Visual Task	Playing solitaire on iPad
2	Passive – Visual Task	Reading on an iPad
3	Active – Auditory Task	Mock cell phone task
4	No Task	Control

Table 2.3 - Scenario and hazard descriptions

Scenario #	Hazard description
1	• Driver is traveling at ~35 mph on a one-lane undivided surface street. • Driver approaches a mid-block crosswalk with vegetation on both sides. A stationary pedestrian is present on the right but obscured by vegetation. • The hazard alert is provided to the driver 6 seconds before driver reaches the crosswalk – approximately 90 meters before the crosswalk.
2	• Driver is traveling at ~35 mph in the right travel lane on a two-lane road. • Approximately 150 meters ahead, a parked car pulls into the right travel lane with their left turn signal on and comes to an abrupt stop. • The hazard alert is provided to the driver 6 seconds before the stopped car – approximately 90 meters away from it.
3	• Driver is traveling at ~35 mph on a two-lane divided highway.

	• At a curved section on the roadway, a truck is parked on the side of the road. A pedestrian is standing in front of the truck but is obscured due to the road geometry and presence of the truck. • The hazard alert is provided to the driver 6 seconds before reaching the truck – approximately 90 meters from the rear of the truck.
4	• The driver is traveling at ~35 mph on a four-lane roadway (with two travel lanes in either direction), when approaching a stop sign controlled four-way intersection. • The hazard alert is provided to the driver 6 seconds before reaching the intersection – approximately 90 meters before reaching the intersection.
5	• Driver is traveling at ~35 mph on a four-lane undivided roadway (with two travel lanes in either direction). • A pedestrian crosswalk whose left side is obscured by a stopped truck in the left lane in the drivers' direction. • The hazard alert is provided to the driver 6 seconds before reaching the pedestrian crosswalk – approximately 90 meters before the crosswalk.
6	• Driver approaches a roundabout at ~35 mph. • The hazard alert is provided to the driver 6 seconds prior to reaching the roundabout – approximately 90 meters before the roundabout.
7	• Driver is traveling at ~35 mph on a divided highway with two travel lanes. • A construction zone on the right shoulder partially encroaches into the right travel lane. • The hazard alert is provided to the driver 6 seconds before the reaching the construction zone – approximately 90 meters before reaching the start of the construction zone.
8	• Driver is traveling at ~35 mph on a four-lane undivided roadway (with two travels lanes in either direction). • There are parked vehicles on the right side of the road, and a car is flashing their left turn signal to pull out into the right travel lane. • The hazard alert is provided to the driver 6 seconds before reaching the parked vehicles – approximately 90 meters before the first parked vehicle.

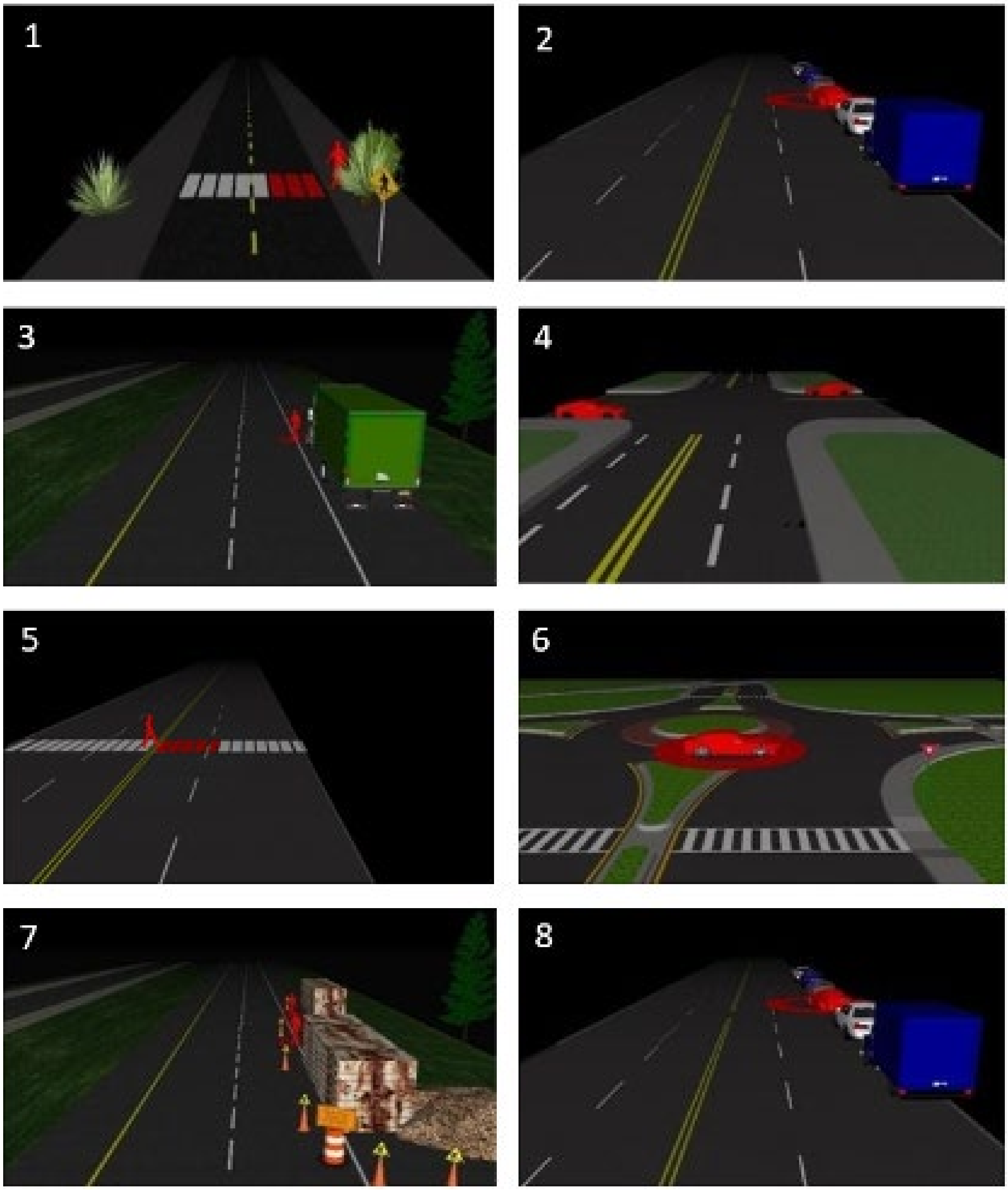

Figure 2.2 - Visual schematics of the eight hazard scenarios

2.4 Procedures

With the expectation of conducting a transfer of control between vehicle automation and manual driving, participants were prepared to conduct under both circumstances.

Participants were given alerts to engage the automation and alerts to disengage the automation, both controlled by scripted software algorithms. Upon entering the simulator vehicle, all participants were provided a practice drive to familiarize themselves with the vehicle interface, followed by a counterbalanced presentation of eight experimental scenarios. At the end of each experimental scenario, participants were asked to complete the NASA-TLX questionnaire, as explained in the following sections.

2.4.1 Demographic and SSQ Questionnaire

All participants were required to provide informed consent (Appendix A) and complete a brief demographic questionnaire at the beginning of the session, which captured their age, sex, driving history, and past texting. In addition, participants were asked to complete a brief simulator sickness questionnaire that assessed their potential outcome of simulator sickness symptoms (Appendix B).

2.4.2 NASA-TLX Questionnaire

The NASA task load index (TLX) was utilized in this study to assess the workload of each participants' experience during each experimental drive in the simulator. It was administered via an iPad after every drive for all of the participants in this study. The TLX questionnaire provided an array of subjective questions (as provided in Appendix C) that resulted in an overall weighted score of "workload." The questionnaire measured their mental, physical, and temporal demand, along with their performance, effort, and frustration. The six levels of workload ratings were developed to holistically evaluate the workload, while reducing the variability across all of the participants [10]. While a variety of other subjective workload assessments have been established in recent literature, the NASA TLX questionnaire was ultimately selected due to its favorability among subjects, as described in previous literature [11]. More so, the TLX has been utilized in several related fields of human factors research, and have reliably assessed driver performance against potential stress, situational awareness, and fatigue impacts [12, 13, 14].

2.5 Eye-Tracking Scoring

As previously mentioned, the ASL Mobile Eye tracker was used to measure the glance behavior of each participant throughout their experimental drives. Once the eye tracker videos were compiled, they were individually extracted and filed according to their respective participant ID number assigned by the researchers.

The videos were then imported into the BORIS video editing software, with several keyboard shortcuts created by the researchers in an effort to expedite the video scoring process. Each of the research scorers were instructed to watch the eye tracker videos from each participant, specifically marking the following points:

- Alert to Engage
    - The *Alert to Engage* was marked as the point in which a yellow dialog box appeared on the screen with the text "start task now," as well as an audio command that said, "transfer control now."
- Engagement
    - The *Engagement* was marked when the driver actively transferred the simulator vehicle into automation, via a switch on the steering wheel.
- Off-Road Glance
    - The *Off-Road Glances* were individually marked each time the participant took their eyes off of the roadway (e.g., looking at the sky, buildings, inside the cab, etc.), only while they were engaged in vehicle automation.
- Alert to Disengage

  - The *Alert to Disengage* was marked as the point in which an audio command stated "takeover control now" while the participants were simultaneously presented with a graphic of the upcoming hazard (Figure 2.3).
- Disengagement
  - The *Disengagement* was marked when the driver actively transferred the vehicle back to manual control, via a switch on the steering wheel.
- Hazard Detected
  - The *Hazard Detected* was marked as a binary variable, particularly when the participants glanced at the approaching hazard.

Figure 2.3 - Screenshot from the eye-tracking video showing hazard alert

Two researchers independently scored each video, with the mean values being taken. Before conducting the analysis, the intra-class correlation (ICC) was calculated between the two scorers to determine the interrater reliability. For total off-road glance duration during automated driving mode, the ICC was calculated as 0.99, which indicates high agreement in the two scores and gives confidence in the results. However, the ICC for the transfer of control time was calculated as less than 0.50, which indicates little to no agreement in the two scorer's values. Due to this low score, the transfer of control times were not considered further in our analyses.

3 Results and Discussion

The following sections discuss the results from the driving simulator study, including the driver workload analysis conducted from the NASA-TLX questionnaire, and the driver glance behavior from the eye-tracker analysis.

3.1 Driver Workload

The NASA-TLX questionnaire was administered after every drive to assess the workload placed on the driver as a result of the in-vehicle task. The full results are shown in Figure 3.1 and summarized in Table 3.1. The audible task had higher scores in five of the six categories as statistically compared to the no task group, meaning the audible task placed the highest workload on the driver. The solitaire task had higher scores in four of the six categories, and the reading task had higher scores than the control in three of the six.

Interestingly, the audible task had a significantly higher mental and temporal demand, along with effort and frustration, on the participant's workload as compared to the active task. From this, we could conclude that a cell phone conversation could be more mentally distracting than a touch-centric task such as texting.

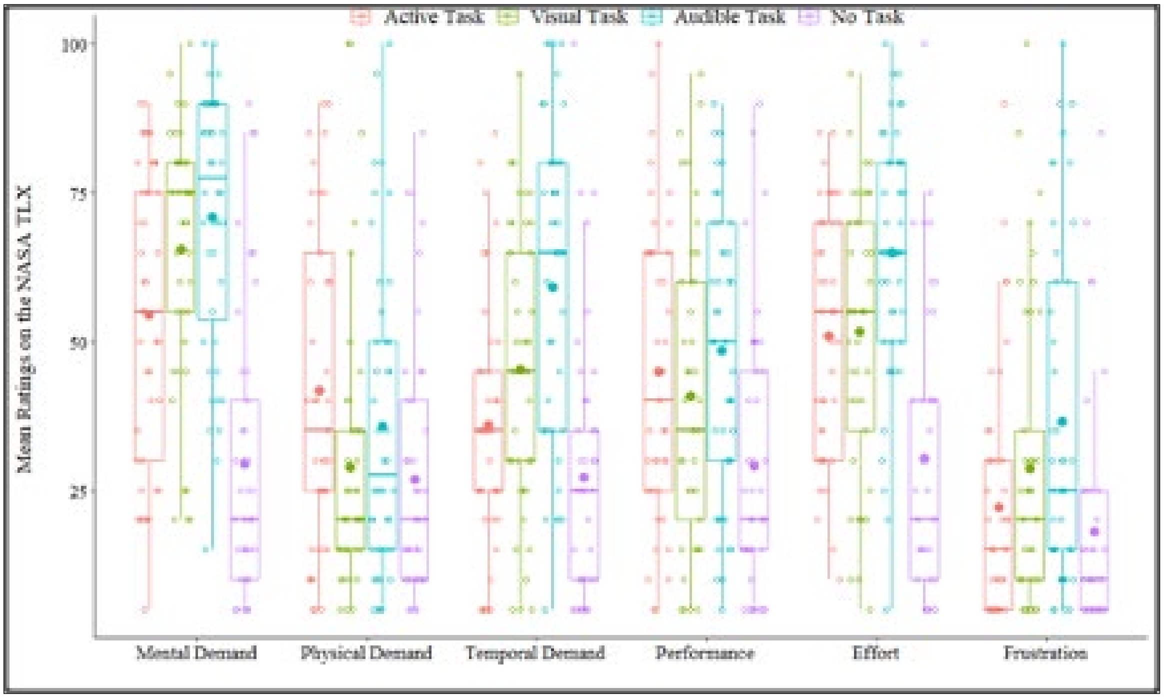

Figure 3.1 NASA-TLX scores for the four in-vehicle tasks

Table 3.1 Mean NASA-TLX scores by in-vehicle task

Metric	Mean (St. Dev.)			
	Active Task	Visual Task	Audible Task	No Task
Mental Demand	54.5* (24.8)	65.5* (21.7)	70.9* (21.8)	29.4 (24.3)
Physical Demand	41.7* (26.9)	28.8 (24.3)	37.8 (25.7)	26.8 (22.2)
Temporal Demand	35.9 (21.3)	45.2* (23.7)	59.2* (27.0)	27.2 (22.9)
Performance	45.0* (25.6)	40.9 (25.7)	48.4* (24.1)	29.0 (23.1)
Effort	50.9* (21.2)	51.7* (23.9)	64.9* (21.6)	30.2 (24.2)
Frustration	22.2 (20.6)	28.7 (25.1)	36.6* (28.3)	18.0 (19.6)

(*) indicated statistically significant difference compared to no-task scenarios

3.2 Off-Road Glances During Automated Driving

As shown below in Table 3.2, participants who performed the active and passive visual task spent the most amount of time, on average, glancing off the road during the automated driving mode with a mean off road glance time of 51.2 and 47.8 seconds, respectively.

By contrast, the mean off road glance time was much lower for the active auditory task (mock cell phone conversation) and the control (no task) groups, with mean off road glance times of 16.2 and 11.5 seconds, respectively.

Table 3.2 - Mean off road glance time by in-vehicle task

Task Label	Description	Mean Off Road Glance Time (sec)
Active – Visual Task	Playing solitaire on iPad	51.2
Passive – Visual Task	Reading on an iPad	47.8
Active – Auditory Task	Mock cell phone task	16.2
No Task	Control	11.5

3.3 Hazard Anticipation

Despite drivers in the visual task groups spending more time glancing off the road during the automated driving mode and requiring more mental and temporal demand and effort, there was no significant difference in their perception of the latent hazards as compared to the control group, as shown in Figure 3.2.

The audible task, despite eliciting a much higher workload than the control, also did not have a significant effect on hazard anticipation. These findings suggest that the 6-second alert was sufficient for the driver to re-engage with the driving environment, become spatially aware, and detect potential hazards.

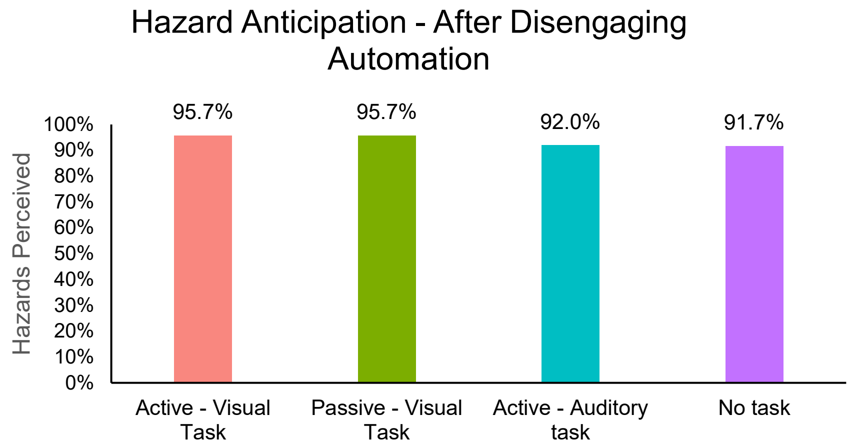

Figure 3.2 - Hazard anticipation by in-vehicle task type

4 Conclusions and Recommendations

Twenty-one participants drove in a simulated environment across eight different scenarios to compare how four different in-vehicle tasks that were performed during automated driving affected hazard anticipation after re-taking manual control of the vehicle. An alert of a potential hazard was provided to drivers 6 seconds in advance of the hazard materializing, and the participants were instructed to disengage automation and take back control of the vehicle.

The visual and audible tasks elicited a much higher workload than the control group, as captured by the NASA-TLX questionnaire, and drivers who performed the visual task spent, on average, 30 more seconds glancing away from the road during automated driving. Despite all this, there was no statistically significant difference in the hazard anticipation between the groups who performed an in-vehicle task and the control groups. In fact, drivers who performed in-vehicle tasks during the automated driving perceived more hazards than the control group, suggesting that the in-vehicle task may have kept them more mentally engaged. However, this difference was not statistically significant, and a larger sample of participants would be required to explore the interaction further.

The findings of this study suggest that a 6-second warning time is sufficient for drivers to re-take control of the vehicle and become spatially aware, even after being previously distracted by an in-vehicle task. However, this study provided a specific alert as to the upcoming hazard. Future studies should explore if this same finding is true without the specific alert and if drivers can quickly become re-engaged with the driving environment after previously being distracted.

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Appendix A: Participant Informed Consent Form

G1

PERFORMANCE EVALUATION STUDY
INFORMED CONSENT FORM

Principal Investigators: Dr. Michael Knodler, Dr. Cole Fitzpatrick, Ganesh Pai Mangalore and Francis Tainter

Sponsor: Mechanical & Industrial Engineering Department Funds

Project Title: Driver Behavior in Level 2 Automation

1. WHAT IS THIS FORM?

This is an Informed Consent Form. It will give you information about this study so you can make an informed decision about participating. You need to be 18 years of age or older to give informed *consent*.

2. WHO IS ELIGIBLE TO PARTICIPATE?

a) The subject populations will consist of adults ages 18 to 25, who have a valid U.S. driving license.
b) If you are prone to getting motion sickness, you should not participate in this study.

3. WHO IS SPONSORING THIS STUDY?

The University of Massachusetts Transportation Center is sponsoring this study.

4. WHAT IS THE PURPOSE OF THE STUDY?

The primary purpose of the study is to evaluate driver behavior when drivers are navigating virtual environments in a simulator cab. Participants are asked to navigate various virtual environments on a driving simulator while their eyes are tracked using an eye tracker.

5. WHERE WILL THE STUDY TAKE PACE AND HOW LONG WILL IT LAST?

You will take part in a 45 to 50-minute session, which includes time to complete questionnaires, time to perform the eye calibration procedure, and to drive on the driving simulator. The study sessions take place at the Human Performance Laboratory (Elab Building, Room 110) located in the College of Engineering at the University of Massachusetts in Amherst.

6. WHAT WILL I BE ASKED TO DO?

i) The experimenter will briefly explain the goals of the study and the session procedures.

ii) You will then drive on the driving simulator. Before the simulator drives begin, you will be fitted with a heart rate monitor on your chest under your clothing. It will remain for the entirety of the experiment. You will sit in the driving simulator and be fitted with a head-mounted eye tracking device that helps us better understand your eye behavior during the experiment. The eye tracker is essentially a pair of safety glasses with two miniature cameras mounted on it. The glasses are connected by a small cable to a video recorder. There will be an eye tracker calibration routine that will take place. For the calibration, the researcher will fit the glasses

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on you and then ask you to look at certain objects in your field of view. The calibration process takes approximately 5 minutes.

iii) Once the eye tracker has been calibrated, you will be given a short 2-3-minute practice drive to become used to the eye tracking device and the driving simulator (including the virtual environment and the simulator controls). Once you feel comfortable in the simulator, you will drive 8 experimental drives that will take 2-3 minutes each. During the simulator drives, you will either drive the simulation in a manual car or in an automated vehicle as determined by the experimenter. If manually controlling the car, you should operate the controls of the simulator car just as you would those of any other car and move through the simulated world accordingly. You should follow the speed limit and standard rules of the road and take care when braking. If at any time during the drives you feel discomfort or motion sickness, you should notify the experimenter so that they can stop the simulation. If navigating autonomously, you are expected to have your hands on the steering wheel even though the simulator will handle the maneuvering (steering, braking, acceleration and other vehicle control parameters) aspect of your driving throughout the entire simulation. You are also expected to pay attention to the forward roadway even though the vehicle handles your navigation in autonomous driving.

iv) At the end of each drive you will be asked to fill up a NASA TLX questionnaire asking you about the workload felt during the drive. The questionnaire will be given to you on an I-Pad by the student researcher and will take 2-3 minutes to complete it.

v) Once all the experimental drives are completed, you will be given a brief post-experiment questionnaire asking about your driving history, demographics, decision making, and any prescriptions that could affect your driving. You will also complete a payment voucher, and then receive payment for participating in this study. The entire study session is expected to average about 45-50 minutes.

7. ARE THERE ANY RISKS WITH PARTICIPATION?

In terms of risks, there is a slight risk of simulator sickness when you operate the driving simulators. A small percentage of participants who drive the simulator experience feelings of nausea. The lab typically runs up to or over 1,000 participants per year in simulator studies and the researchers are familiar with how to minimize the risk of participants feel ill on the simulator. Nonetheless, some participants may still not feel well while driving the simulator. Because of this risk, **any person who experiences motion sickness while in a real car should not participate in this study.** If during the simulator drives, you feel discomfort or nausea, you should inform the experimenter immediately so that the simulation can be stopped. Halting the simulation should quickly reduce the discomfort. If you do not feel better soon after the simulation is halted, we can arrange for someone to drive you home or help you seek medical care if necessary.

Due to the design of the simulation drives, some participants may feel that they are not driving to their full ability. Some participants might have the good feel of driving the simulator

No risks related to economic well-being will occur to the participants in this study. They receive compensation for their participation.

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There are "No Known" risks pertaining to social well-being

8. BENEFITS ASSOCIATED WITH PARTICIPATION?

Participants will not benefit directly from this study. The main benefit of participating in this study is that the simulation assessment may help you become a safer, better driver. More generally, the findings from this research will influence the understanding of safety and the training of safe behaviors for all drivers.

9. WHO WILL SEE THE RESULTS OF MY PERFORMANCE IN THE STUDY?

The results of this research may be published and submitted for presentation at professional society meetings. No participant will be identifiable from any presentation or publication discussing the research. The cross-references for participants and their randomly generated coded ID numbers will be contained in a password-protected Microsoft Excel file stored on the lab's storage drive, which is not connected to the internet and is only accessible by lab personnel. Only lab personnel working as researchers on the study will be authorized to access the participant ID cross-reference file. All data files, participant questionnaires, and simulator and eye tracker videos for the study, except the cross-reference file will contain only the participants randomly generated coded ID number and no identifying information. It is possible that your research record, including sensitive information and/or identifying information, may be inspected and/or copied by federal or state government agencies, in the course of carrying out their duties. If your record is inspected by any of these agencies, your confidentiality will be maintained to the extent permissible by law.

10. WILL I RECEIVE ANY PAYMENT FOR TAKING PART IN THIS STUDY?

Participants who complete the study will receive $20 compensation for your participation. If you decide to end your participation in the study before the end of your session either due to simulator sickness or other reasons, you will receive partial compensation of $10.

11. WHAT IF I HAVE A QUESTION?

Should you have any questions about the experiment or any other matter relative to your participation in this project, you may contact the primary student researchers for this study, Ganesh Pai Mangalore, at gpaimangalor@umass.edu, Francis Tainter, at ftainter@umass.edu or the professors in charge of this research, Dr. Cole Fitzpatrick, at cfitzpat@umass.edu, or Professor Dr. Michael Knodler, at mknodler@ecs.umass.edu. If, during the study or later, you wish to discuss your participation or concerns regarding it with a person not directly involved in the research, you can talk with the University of Massachusetts-Amherst's Human Subjects Research Administrator at 413-545-3428 or humansubjects@ora.umass.edu. A copy of this consent form will be given to you to keep for your records.

12. WHAT IF I REFUSE TO GIVE OR WITHDRAW MY PERMISSION?

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Your participation is voluntary and you may refuse to participate or may withdraw consent and discontinue participation in the study at any time without prejudice.

13. WHAT IF I AM INJURED?

The University of Massachusetts at Amherst does not have a program for compensating subjects for injury or complications related to human subjects' research, but the study personnel will assist you in getting treatment if you have sustained any injuries because of the study. You can contact Professor Dr. Michael Knodler, Dr. Cole Fitzpatrick or student researchers, Ganesh Pai Mangalore and Francis Tainter, for this assistance. Their contact information in included above in section 11, "What if I Have a Question?"

14. SUBJECT STATEMENT OF VOLUNTARY CONSENT

By signing below, I confirm that the experimenter has explained to me the purpose of the research, the study procedures that I will undergo and the benefits as well as the possible risks, including the possibility that I might feel queasy on the driving simulator. Alternatives to my participation in the study have also been discussed. I have read and I understand this consent form.

_____________________________________ ____________

Printed name and signature of participant Date

15. EXPERIMENTER STATEMENT

By signing below, I the experimenter, indicate that the participant has read and has had explained to them this study, and had any of their questions answered, and has signed the Informed Consent Form as required above.

_____________________________________ ____________

Signature of person obtaining informed consent Date

Appendix B: Participant Questionnaires

SIMULATOR SICKNESS QUESTIONNAIRE (SSQ)

Developed by Robert S. Kennedy & colleagues under various projects. For additional information contact:
Robert S. Kennedy, RSK Assessments, Inc., 1040 Woodcock Road, Suite 227, Orlando, FL 32803 (407) 894-5090.

INFORMATION PROVIDED ON THIS QUESTIONNAIRE IS STRICTLY CONFIDENTIAL. Your completion of this questionnaire is strictly voluntary and you can skip any questions that you do not want to answer.

Participant ID: __________ **Date:** ____________

THIS SECTION OF THE QUESTIONNAIRE IS COMPLETED BEFORE USING THE DRIVING SIMULATOR.

PRE-EXPOSURE BACKGROUND INFORMATION

1. How long has it been since your last exposure in a simulator? ______ days
   How long has it been since your last flight in an aircraft? ______ days
   How long has it been since your last voyage at sea? ______ days
   How long has it been since your last exposure in a virtual environment? ______ days
2. What other experience have you had recently in a device with unusual motion?

PRE-EXPOSURE PHYSIOLOGICAL STATUS INFORMATION

3. Are you in your usual state of fitness? (Circle one) YES NO
   If not, please indicate the reason:
4. Have you been ill in the past week? (Circle one) YES NO
   If "Yes", please indicate:
   a) The nature of the illness (flu, cold, etc.):
   b) Severity of the illness: Very Mild ________________ Very Severe
   c) Length of illness: ________________ Hours / Days
   d) Major symptoms:
   e) Are you fully recovered? YES NO
5. How much alcohol have you consumed during the past 24 hours?
   ____ 12 oz. cans/bottles of beer ____ ounces wine ____ ounces hard liquor
6. Please indicate all medications you have used in the past 24 hours. If none, check the first line:
   a) NONE ____________
   b) Sedatives or tranquilizers ____________
   c) Aspirin, Tylenol, other analgesics ____________
   d) Antihistamines ____________
   e) Decongestants ____________
   f) Other (specify): ____________________

7. a) How many hours of sleep did you get last night? _____ hours

   b) Was this amount sufficient? (Circle one) YES NO

8. Please list any other comments regarding your present physical state which might affect your performance on our test.

BASELINE (PRE) EXPOSURE SYMPTOM CHECKLIST

Instructions: Please fill this out BEFORE you go into the virtual environment. Circle how much each symptom below is affecting you right now.

#	Symptom	Severity			
1.	General discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Boredom	None	Slight	Moderate	Severe
4.	Drowsiness	None	Slight	Moderate	Severe
5.	Headache	None	Slight	Moderate	Severe
6.	Eye strain	None	Slight	Moderate	Severe
7.	Difficulty focusing	None	Slight	Moderate	Severe
8a.	Salivation increased	None	Slight	Moderate	Severe
8b.	Salivation decreased	None	Slight	Moderate	Severe
9.	Sweating	None	Slight	Moderate	Severe
10.	Nausea	None	Slight	Moderate	Severe
11.	Difficulty concentrating	None	Slight	Moderate	Severe
12.	Mental depression	None	Slight	Moderate	Severe
13.	"Fullness of the head"	None	Slight	Moderate	Severe
14.	Blurred Vision	None	Slight	Moderate	Severe
15a.	Dizziness with eyes open	None	Slight	Moderate	Severe
15b.	Dizziness with eyes closed	None	Slight	Moderate	Severe
16.	*Vertigo	None	Slight	Moderate	Severe
17.	**Visual flashbacks	None	Slight	Moderate	Severe
18.	Faintness	None	Slight	Moderate	Severe
19.	Aware of breathing	None	Slight	Moderate	Severe
20.	***Stomach awareness	None	Slight	Moderate	Severe
21.	Loss of appetite	None	Slight	Moderate	Severe
22.	Increased appetite	None	Slight	Moderate	Severe
23.	Desire to move bowels	None	Slight	Moderate	Severe
24.	Confusion	None	Slight	Moderate	Severe
25.	Burping	None	Slight	Moderate	Severe
26.	Vomiting	None	Slight	Moderate	Severe
27.	Other				

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Visual illusion of movement or false sensations of movement, when not in the simulator, car, or aircraft.

*** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

<u>THIS SECTION OF THE QUESTIONNAIRE IS COMPLETED AFTER USING THE DRIVING SIMULATOR.</u>

<u>**POST 00** MINUTES EXPOSURE SYMPTOMS CHECKLIST</u>

Instructions: Circle how much each symptom below is affecting you <u>right now</u>.

#	Symptom	Severity			
1.	General discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Boredom	None	Slight	Moderate	Severe
4.	Drowsiness	None	Slight	Moderate	Severe
5.	Headache	None	Slight	Moderate	Severe
6.	Eye strain	None	Slight	Moderate	Severe
7.	Difficulty focusing	None	Slight	Moderate	Severe
8a.	Salivation increased	None	Slight	Moderate	Severe
8b.	Salivation decreased	None	Slight	Moderate	Severe
9.	Sweating	None	Slight	Moderate	Severe
10.	Nausea	None	Slight	Moderate	Severe
11.	Difficulty concentrating	None	Slight	Moderate	Severe
12.	Mental depression	None	Slight	Moderate	Severe
13.	"Fullness of the head"	None	Slight	Moderate	Severe
14.	Blurred Vision	None	Slight	Moderate	Severe
15a.	Dizziness with eyes open	None	Slight	Moderate	Severe
15b.	Dizziness with eyes closed	None	Slight	Moderate	Severe
16.	*Vertigo	None	Slight	Moderate	Severe
17.	**Visual flashbacks	None	Slight	Moderate	Severe
18.	Faintness	None	Slight	Moderate	Severe
19.	Aware of breathing	None	Slight	Moderate	Severe
20.	***Stomach awareness	None	Slight	Moderate	Severe
21.	Loss of appetite	None	Slight	Moderate	Severe
22.	Increased appetite	None	Slight	Moderate	Severe
23.	Desire to move bowels	None	Slight	Moderate	Severe
24.	Confusion	None	Slight	Moderate	Severe
25.	Burping	None	Slight	Moderate	Severe
26.	Vomiting	None	Slight	Moderate	Severe
27.	Other				

* Vertigo is experienced as loss of orientation with respect to vertical upright.
** Visual illusion of movement or false sensations of movement, when <u>not</u> in the simulator, car or aircraft.
*** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

POST-EXPOSURE INFORMATION

1. While in the virtual environment, did you get the feeling of motion (i.e., did you experience a compelling sensation of self motion as though you were actually moving)? *(Circle one)*

   YES NO SOMEWHAT

2. On a scale of 1 (POOR) to 10 (EXCELLENT) rate your performance in the virtual environment: _______

3. a. Did any unusual events occur during your exposure? *(Circle one)* YES NO
   b. If YES, please describe:

Participant ID: ______________

(Research Admin. use only)

HUMAN PERFORMANCE LAB
POST-STUDY QUESTIONNAIRE

This is a ***strictly confidential*** questionnaire. Only a randomly generated participant ID number, assigned by the research administrator, will be on this questionnaire. No information reported by you here will be traced back to you personally in any way. **You can skip any questions you do not feel comfortable answering.**

Section 1: Demographics

Gender: ☐ Male ☐ Female

Age: __________

Race / Ethnicity: (check all that apply)
☐ Black / African American
☐ Caucasian
☐ Hispanic / Latino
☐ Asian
☐ American Indian / Native Alaskan
☐ Other

Have you participated in a study at this laboratory in the past? ☐ Yes ☐ No

Section 2: Driving History

Approximately how long have you had your driver's license? ______ years ______ months

About how many miles did you drive in the past 12 months?
☐ Less than 5,000 ☐ 5,000 to 10,000 ☐ 10,001 to 15,000 ☐More than 15,000

Does your license require you to wear glasses or contacts while driving? ☐ Yes, eyeglasses ☐ Yes, contacts ☐ No

Do you have any other restrictions on your driver's license? ☐ Yes ☐ No

If yes, please describe: ____

Are you currently on any over-the-counter or prescription medications that make it difficult to drive? ☐ Yes ☐ No

If yes, please describe: ____

In the past three months, have you text messaged while driving? ☐ Yes ☐ No
Note: Because of laws banning text messaging while driving in number of states, and a proposed law for such a ban in Massachusetts, this question may be asking you to divulge engagement in an illegal activity."

Appendix C: Sample NASA TLX Questionnaire

Task Questionnaire - Part 1

Click on each scale at the point that best indicates your experience of the task

Mental Demand

Low — High

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Physical Demand

Low — High

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand

Low — High

How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Performance

Good — Poor

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Effort

Low — High

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration

Low — High

How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Continue >>

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Physical Demand — How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

or

Frustration — How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Effort — How hard did you have to work (mentally and physically) to accomplish your level of performance?

or

Physical Demand — How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
or	
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
or	
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
or	
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
or	
Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Temporal Demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
or	
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
or	
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?
or	
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
or	
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
or	
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Performance

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

or

Temporal Demand

How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Physical Demand

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

or

Temporal Demand

How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Frustration

How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

or

Mental Demand

How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Physical Demand

How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

or

Performance

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?