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Secondary Task Survey and Driving Simulator for use in a Highly Automated Vehicle Takeover Study

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Abstract

In highly automated vehicles, a driver is required to takeover vehicle control from the automated system in the event of a situation that cannot be handled. However, it is possible the driver became occupied with an alternate, non-driving related task and no longer has the proper situational awareness to safely takeover driving before automation is disengaged. The purpose of this initial study is to determine common non-driving related tasks and to construct a realistic driving simulator. This will lead to a future study with the aim to understand how common non-driving related tasks affect a driver's takeover performance. The results of a questionnaire are being used to determine prevalent non-driving related tasks common among drivers today. Although previous studies have incorporated non-driving related tasks, there is a paucity in comparative studies that have investigated more than one task under the same conditions. Most recent autonomous vehicle takeover research has concentrated primarily on the takeover response time for single tasks, or focused on takeover modality (e.g., visual, auditory, haptic). In this future project, the ranking of non-driving related tasks by response time and performance will be evaluated. The time that participants take to disengage from the non-driving related task and takeover vehicle control after a takeover request is initiated is to be analyzed under an unplanned setting with a fixed time budget. For the experiment, a customized driving simulator was constructed and a simulated driving scenario is being meticulously designed. The study is based on the premise that longer takeover response times are indicative of low situational awareness. The anticipated result is that a non-driving related task that requires looking away from the road for an extended duration of time will contribute to slower response times and degrade takeover quality more than other non-driving related tasks. Identifying how users respond to takeover requests when previously engaged in different non-driving related tasks will assist designers in constructing vehicle takeovers that are likely to be successful.

Keywords: Transition of Control, Takeover Request, Highly Automated Vehicles

1. Introduction

Automated driving has the potential to cut costs, reduce traffic congestion, lower vehicle emissions, provide mobility for those who cannot drive, allow drivers more comfort, and drastically decrease traffic injuries and fatalities[1,2,3,4]. Given these benefits and recent technological breakthroughs, autonomy will continue to progress.

The Society of Automotive Engineers International has created a standard taxonomy of vehicle automation levels extending from no automation to full vehicle automation. With the progression of each level, the automated driving system takes on more of the driving responsibility from the human driver. The levels of driving automation are termed as no automation (level 0), driver assistance (level 1), partial automation (level 2), conditional automation (level 3), high automation (level 4), and full automation (level 5). At level 0, the human driver is responsible for monitoring the environment and all of the driving task. At level 1, the system can execute either longitudinal (acceleration, braking) or lateral (steering) tasks, while at level 2 the system can execute both of these tasks while the human driver monitors the environment. Level 3 introduces a switch from the previous levels of automation in that the environment is now monitored by the system while the automated driving system is activated. At level 3 and level 4, the human driver has to be prepared to takeover manual vehicle control within several seconds if there is a condition encountered that the automated system was not designed for. If the limits of automation are exceeded, the automated system will issue a takeover request (TOR) to the driver, requesting the driver to regain manual control of the vehicle. At level 5, the automated system performs all aspects of the driving task and a human driver is not necessary[5].

Since the driver does not have to monitor the environment while automation is engaged starting at level 3, the driver may focus their attention on non-driving related (NDR) tasks. The critical issue is that the driver is responsible for driving sometimes, which is more challenging than having the driver drive all of the time or not at all[6].

Studies have shown the activity that a driver is engaged in prior to a TOR from automation to the driver has an effect on takeover performance[7,8,9]. There is a need to study a large number of realistic NDR tasks on takeover performance. This will help provide insight on how to balance driver comfort and satisfaction while allowing the automated system to rely on the driver to takeover vehicle control in critical scenarios.

To study the effects of NDR tasks on takeover performance, key NDR tasks to test had to be determined and a realistic driving simulator had to be created. This paper will address the creation and analysis of a driver secondary task survey and the design and construction of a realistic driving simulator.

2. Methodology

2.1. Driver Secondary Task Survey

Prior to allowing participants to take part in the takeover study, the secondary tasks that are to be manipulated in the study have to be determined. For this, a driver secondary task survey was created through Google Forms to determine the most common secondary tasks that drivers currently engage in, as well as secondary tasks that drivers think they would engage in as vehicle automation progresses.

The driver secondary task survey begins by asking for consent, demographic information, and how often the participant drives. Since the driver secondary task survey is targeted towards those who actively drive, if the participant reports they never drive, the survey concludes at that point. The next set of questions ask about the top common secondary tasks the participant engages in today while driving. Another set of questions asks participants to imagine they are in a conditionally automated vehicle or a fully automated vehicle and report on the top secondary tasks they think they would engage in. It should be noted that these questions are open-ended, so participants are welcome to respond with whatever answers they would like. In the last set of questions, a list of secondary tasks is presented, and participants are asked to rate the frequency of their current engagement with each secondary task. By design, the list of secondary tasks is presented as the last set of questions so as not to hinder or bias any open-ended responses.

2.2. Driving Simulator

For the purposes of the takeover study, a medium fidelity simulator was constructed utilizing commercially available simulator components. Measurements were taken from a 2016 Buick Verano and used in the early design stages of the simulator. In order to create a simulator with accurate proportion to the measured vehicle, the simulator was first designed using Computer Aided Design software (CAD) to be constructed with the chosen parts and materials available from the average hardware store. CAD measurements were double checked against the observed measurements of the Buick Verano before the simulator was constructed to match the CAD model.

A significant factor in the design of the simulator was the final cost. Off the shelf components selected to construct the simulator were chosen to balance fidelity and cost. In cases where a parameter of the design increased fidelity without a clearly defined limit (e.g. screen area) the components were first chosen on the basis of cost and then the desired parameters were maximized in the design of the simulator. One such parameter chosen in this manner was the field of view of the monitors where cost was the primary determining factor.

3. Results

3.1. Driver Secondary Task Survey

There are 66 responses to the driver secondary task survey to date. Of those, the average age of participants was 38.01 years and 55% reported being a current college or university student. 80% of respondents said that they drive daily and the 5% who reported that they never drive are removed from further analysis. In addition, 65% said that their typical drive is 0.5 hours or less.

When asked about the most commonly engaged in secondary task today, the overwhelming majority of responses related to music/radio. Of the 33 participants saying that music/radio is their most common secondary task, 12 said they always engage and 13 said they almost always engage in this task.

Participants are provided a list of secondary tasks and asked to rate their current engagement with each task while driving. A few secondary tasks from the list are discussed here. 54 participants reported never reading while driving. 55 participants reported never watching television shows, movies, or clips while driving. 27 participants said they never send messages or emails using the keyboard, with another 20 saying they rarely do as depicted in Figure 1. Only one participant reported always sending messages or emails using the keyboard. The distribution for daydreaming or getting lost in thought appears to be normally distributed, with 24 participants reporting that they sometimes do this task while driving. For the task of getting drowsy, closing eyes, or sleeping, the counts of responses decrease with increasing engagement categories as seen in Figure 2.

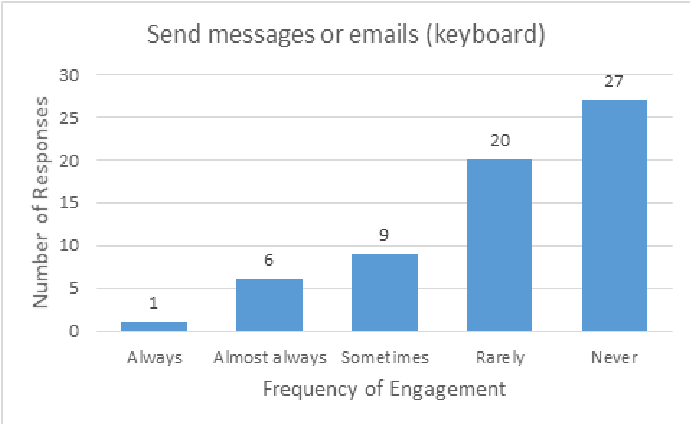

Figure 1. Current engagement reported by participants for the task of send messages or emails (keyboard).

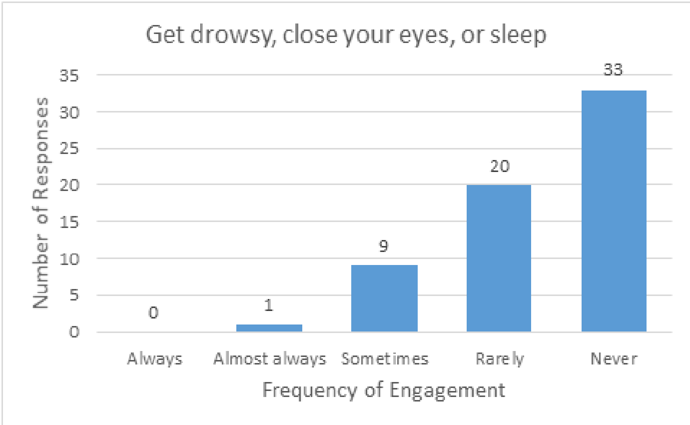

Figure 2. Current engagement reported by participants for the task of get drowsy, close your eyes, or sleep.

Participants are asked about the top three secondary tasks they would imagine engaging in a conditionally automated vehicle. Combining all responses for secondary tasks imagined to occur in a conditionally automated vehicle without a frequency ordering, the top responses are music/radio, messaging, and eat or drink as shown in Figure 3.

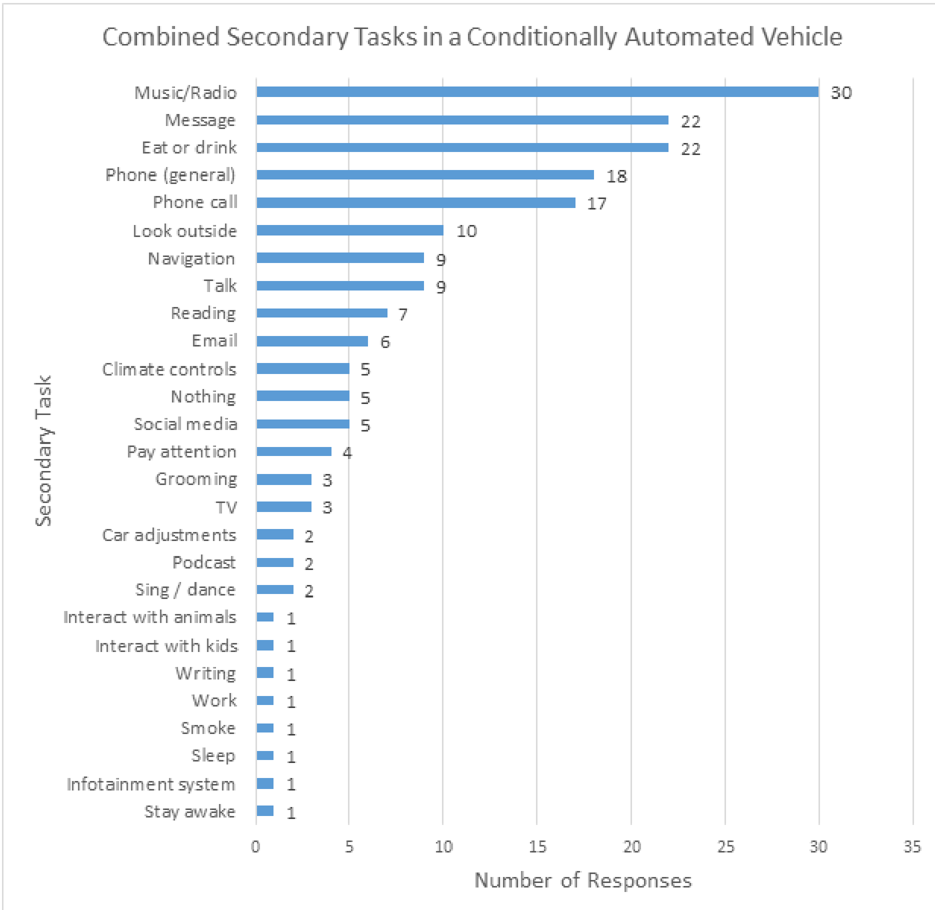

Figure 3. Combined common secondary tasks participants imagined to occur in a conditionally automated vehicle.

Participants are also asked about the top three secondary tasks they would imagine engaging in a fully automated vehicle. Combining all responses for secondary tasks imagined to occur in a fully automated vehicle without a frequency ordering, the top responses are general phone use, music/radio, messaging, eat or drink, and reading as shown in Figure 4.

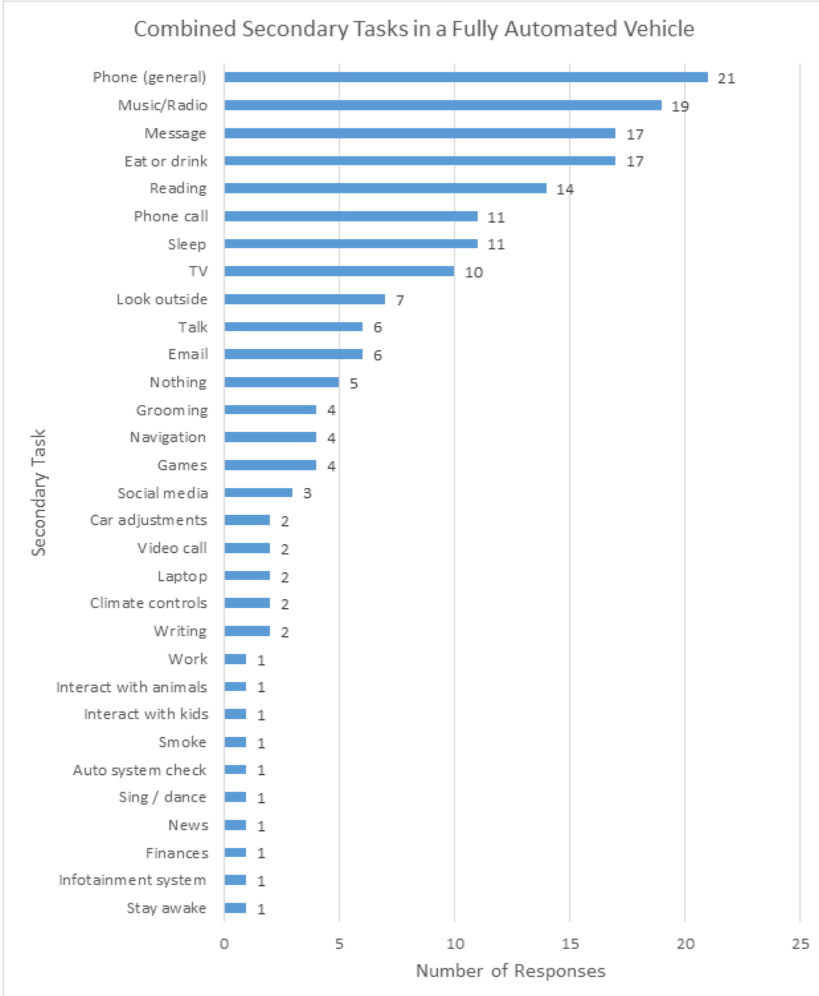

Figure 4. Combined common secondary tasks participants imagined to occur in a fully automated vehicle.

There is a difference that can be seen between the responses that participants give about what secondary tasks they would imagine engaging in a conditionally automated vehicle and in a fully automated vehicle. The non-driving related tasks of sleeping, reading, and watching television are more frequently reported for the fully automated vehicle scenario than the conditionally automated vehicle scenario. Furthermore, the responses for the secondary tasks in a fully automated vehicle are more spread out and creative than the conditionally automated vehicle responses. For example, the categories of using a laptop and playing games emerge in the fully automated vehicle scenario.

There are also differences between current engagement and projected engagement for various secondary tasks. The majority of participants said they never watch tv shows, movies, or clips, never send messages or emails (keyboard), never read, and never get drowsy, close their eyes, or sleep. However, these were among the more popular secondary tasks reported by participants for what they would imagine engaging in as vehicle automation progresses. Additionally, where there was report for current engagement in daydreaming and getting lost in thought, there are no responses along these lines for envisioned engagement in either a conditionally or fully automated vehicle.

3.2. Driving Simulator

The simulator designed for the takeover study was constructed to match the plans created in the CAD model. To save on cost, the construction of the simulator utilized 2x4 boards and medium-density fiberboard paneling. Figure 5 shows the constructed simulator next to the CAD model. The seat was taken from a *Next Level Racing F-GT* hobby racing simulator and adapted to be bolted to the designed simulator. Steering input is provided by a *Thrustmaster TMX Force Feedback Racing Wheel* which was modified to use a larger 12” steering wheel for a more realistic feel as shown in

Figure 6. Throttle and brake inputs are provided by the *VG T3PA-Pro* pedal set which offers strong counter-spring force as shown in Figure 7. In order to emulate the field of view out of the front of a vehicle a triple monitor solution was selected, utilizing three *Viotek GN27CB* curved 27-inch 1080P monitors mounted to a swivel mount. The maximum field of view was measured to be 140° with the participant 700mm from the central monitor and 170° with the participant 500mm from the central monitor. Vertical field of view was found to be 37° at 500mm and 27° at 700mm. The entire simulator rests on caster wheels.

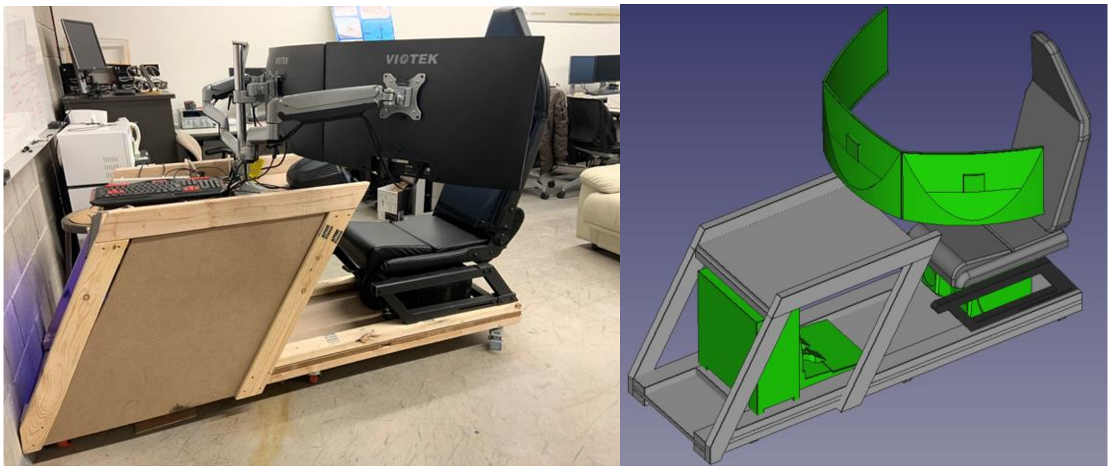

Figure 5. Constructed simulator next to CAD model of simulator designed to match the internal dimensions of a 2016 Buick Verano.

Figure 6. Modified steering wheel used in driving simulator.

Figure 7. Pedal set used in driving simulator.

4. Conclusion

The responses from the driver secondary task survey play a key role in helping to determine the secondary tasks that are to be implemented in the takeover study. In addition, a driving simulator that adheres to realistic vehicle dimensions was constructed. The next step in this project is to detail out the takeover study, run pilot subjects, and implement the takeover study on a larger number of participants. This will include creating a simulated driving scenario where a TOR is auditorily communicated and the software records the takeover response time and other takeover quality metrics.

5. Acknowledgements

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