

Evaluation of Common Secondary Tasks in Highly Automated Vehicles

Submitted by

Arsha Ali

Electrical and Computer Engineering

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Mentor: Dr. Osamah Rawashdeh

Department of Electrical and Computer Engineering

Oakland University

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Table of Contents

| | |
|---|-----------|
| Abstract | 3 |
| Introduction | 4 |
| Levels of Automation..... | 4 |
| How Autonomous Vehicles Work | 6 |
| Benefits of Automation | 7 |
| Literature Review | 10 |
| Transition Time Required for a Successful Takeover..... | 10 |
| Transition Modality..... | 11 |
| Non-Driving Related Tasks Before Takeover..... | 13 |
| Conclusions | 16 |
| Methods and Materials | 20 |
| Driver Secondary Task Survey | 20 |
| Driving Simulator..... | 38 |
| Simulated Course | 41 |
| Secondary Tasks..... | 43 |
| Procedure..... | 43 |
| Experimental Design | 44 |
| Results and Discussion | 44 |
| Outcomes, Future Directions, and Conclusions | 46 |
| References | 47 |
| Appendix (Driver Secondary Task Survey) | 54 |

Abstract

In highly automated vehicles, a driver is required to takeover control from the automated system and manually drive in the event of a situation automation cannot handle. Until autonomy is perfected, a driver's input is mission critical. 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 study is 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 that are common among drivers today and projected to be engaged in as vehicle automation progresses. 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 project, the comparison of non-driving related tasks by response time and performance are being evaluated. The time that participants take to takeover vehicle control after a takeover request is initiated is being analyzed under a non-scheduled system initiated handover with a fixed time-to-collision of 6 seconds. For this experiment, a customized driving simulator was constructed and a simulated driving scenario was meticulously designed. This study is based on the premise that longer takeover response times are indicative of low situational awareness. The pilot study results show that a fast takeover time does not mean safer driving behavior. 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.

Introduction

Levels of Automation

The Society of Automotive Engineers (SAE) 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. The difference between level 3 and level 4 is that at level 4, the automated system can make a decision such as pulling over to the side of the road and stopping the vehicle should the human driver not respond to a takeover request (TOR). At level 5, the automated system performs all aspects of the driving task and a human driver is not necessary [1]. A visual summary of the automation levels is provided in Figure 1.

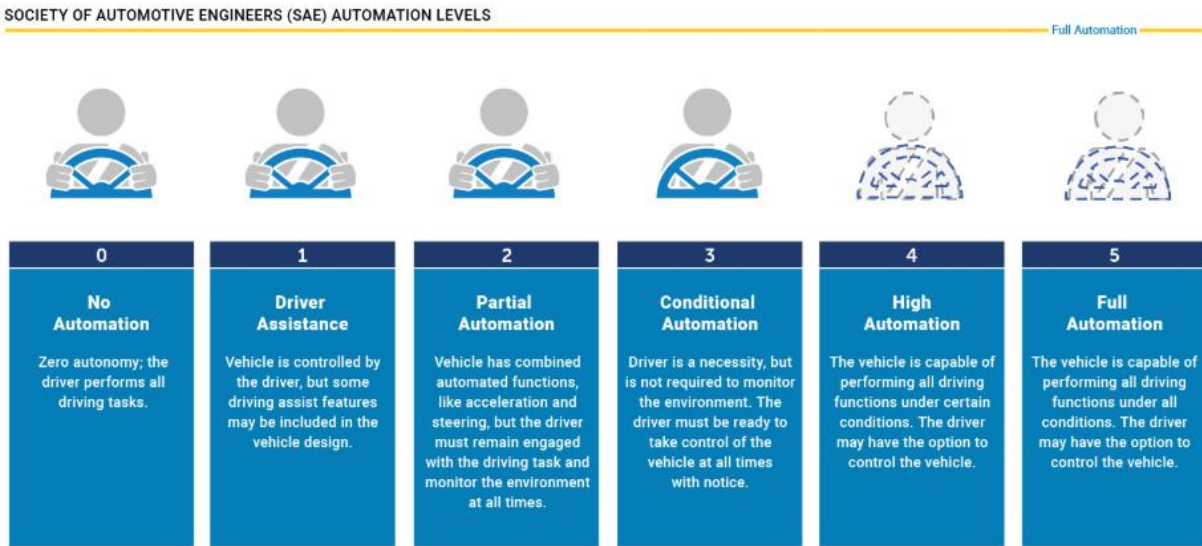


Figure 1: Society of Automotive Engineers Levels of Automation [2].

Some automated driving features such as cruise control, blind spot detection, lane departure warning, automatic emergency braking, lane keeping assist, adaptive cruise control, traffic jam assist, and self-park are already available in vehicles on the market today [2, 7]. While there has been significant progress made in the field of autonomous driving, a momentous challenge arises with conquering level 3 vehicles. In a level 3 vehicle, the human driver is tasked with responding “appropriately to a request to intervene” vehicle control where the system alerts the driver with “sufficient time for a typical human driver to respond appropriately” [1]. However, SAE International does not define what a “sufficient time” would consist of. Issuing a TOR with seconds for the driver to takeover can be dangerous since the driver may not have enough time to respond safely, and issuing a TOR too far in advance can cause confusion and lack of trust in the automated system. Furthermore, since the driver does not have to monitor the environment while the automated system is engaged, the driver may choose to become occupied with an alternate, non-driving related (NDR) task. When the driver is suddenly asked to takeover

vehicle control, the driver may not have the situational awareness to do so in a safe manner before the automated system is disengaged. The critical issue with level 3 driving 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 [3]. Due to this, many automotive companies have attempted to bypass level 3 automation, but until automated driving is perfected, a human driver will be needed to handle situations that the automated system cannot.

How Autonomous Vehicles Work

For an autonomous vehicle to perform the driving task, it has to be able to “see” the surrounding environment and make a decision based on that information just like a human driver would. In order for an automated vehicle to be aware of its surroundings, a number of sensors are positioned in various parts of the vehicle. These sensors are mainly comprised from lidar, radar, cameras, and global positioning system (GPS) antennas, allowing for “superhuman, 360-degree perception and much faster reaction times” [4, 5, 15]. Lidar, or light detection and ranging, sensors send out pulses of light and use the reflected pulses to measure distances to other cars, pedestrians, or other objects. Radar and cameras are also used to recognize traffic lights, street signs, or other information, and a GPS antenna can let the vehicle know its exact location. The information from the sensors is then processed by software, compared with pre-existing maps, and instructions are sent to control the car’s longitudinal and lateral driving [4, 5]. A diagram shows the main sensors and their responsibilities in Figure 2.

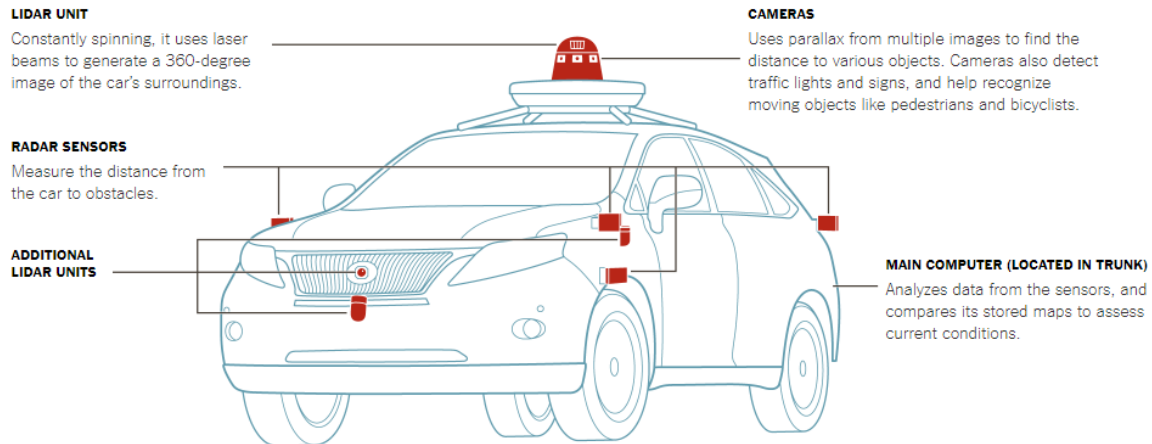


Figure 2: Main sensors used by an automated vehicle to navigate its surroundings [5].

Benefits of Automation

Automated driving has the potential to cut costs, reduce traffic congestion, lower vehicle emissions, provide mobility for those who cannot drive, and allow drivers more comfort [2, 4, 7, 13]. Providing transportation to those who cannot drive can include those with a temporary injury, the disabled, the elderly, children, and those that are intoxicated. In addition, others would not have to be troubled or asked to go out of their way to provide transportation for these individuals. With automated driving, these individuals could gain a greater sense of freedom and independence.

Furthermore, drivers can make efficient use of their time when relieved of the driving task, without creating unsafe driving conditions due to multitasking. “[Autonomous vehicles] would free drivers to engage in other productive or enjoyable activities— working, reading, watching a movie, or even sleeping—during a trip, thus reducing the opportunity cost of time spent in the car” [9].

In addition, a fully autonomous vehicle could reduce the amount of time that drivers waste doing mundane driving tasks such as sitting in traffic or searching for a parking space.

“Motorists across the US will begin to take back 30 billion hours per year lost to traffic” [16]. Not having to search for a parking space will reduce time that would be wasted and also reduce traffic congestion as “the car drops you off at the front door, then drives away to find a parking place on its own. When you’re ready to leave, you call for the car and [the car] comes to fetch you” [17]. “In 2007, University of California, Los Angeles (UCLA) urban planner Donald Shoup estimated that as much as 30 percent of central business district congestion arises from drivers cruising around in search of a parking space; that would be largely eliminated with driverless cars” [13]. Since drivers would no longer have to search for a parking space or sit in traffic, drivers will have more time put back in their day and traffic overcrowding for others would also be decreased.

Additionally, many individuals who regularly drive do not have a favorable view of driving. “Almost 90 percent of American workers commute by car, most of them alone, with a median trip duration of just under half an hour each way” [17]. Undoubtedly, cars are a major form of transportation for many individuals. “Commuting is an important aspect of our lives that demands a lot of our valuable time....For most people, commuting is a mental and physical burden, giving cause for various complaints” [19]. However, with autonomous vehicles handling the majority of the driving task, drivers can take advantage of the fewer restrictions that they have on what they can and cannot do.

One of the greatest benefits and motivations for automated driving systems is improvement in safety. The lack of safety in non-automated vehicles is evident as “Traffic fatalities are by far the most important contributor to the danger of leaving home” [18]. According to the National Motor Vehicle Crash Causation Survey (MNVCCS) conducted from 2005 to 2007, drivers were responsible for about 94% of crashes, with vehicles, the environment,

and unknown reasons comprising the remainder of crashes. In the category of crashes due to driver error, recognition error, which included driver inattention, internal and external distractions, and inadequate surveillance, was the largest cause, accounting for approximately 41% of crashes [6]. A number of other sources also document driver error accounting for upwards of 90% of crashes [7, 10, 11]. In the United States alone, car accidents deaths each year are approximately 1.25 million, and another 20 to 50 million people are injured [7, 8, 12]. Deaths and injuries extend beyond those inside the vehicle. 69,000 pedestrians and 48,000 cyclists comprised the more than 2 million roadway injuries in 2011 [9]. It is clear that vehicle safety improvements are necessary given the volume of people affected by car accidents. Although new technologies are designed with the intention of improving safety, traffic fatalities have been on the rise because human behavior has not changed [8, 11]. Currently ranking as the 9th leading cause of death, traffic injuries are predicted to become the 5th leading cause of death by 2030 if action is not taken [12].

Automated driving has the ability to drastically reduce the number of vehicle crashes since human recognition error would be decreased. Whereas humans can be subjected to mental lapses and distractions, an automated driving system is more focused and predictable.

“Autonomous vehicles are never drunk, distracted, or tired; these factors are involved in 41 percent, 10 percent, and 2.5 percent of all fatal crashes, respectively” [14]. Furthermore, an autonomous vehicle can slam on the brakes in less than a millisecond, whereas a human driver would require more than a second [8]. Although fractions of a second may not initially seem to be significant, this could prevent a potential collision. Thus, automated driving can protect drivers, passengers, bicyclists, and pedestrians [2]. The amount of lives lost to car crashes that could be saved with an automated driving system is immense. Given the recent technological

breakthroughs in autonomy, it is not unrealistic to reach a state wherein very few to no accidents occur [13].

Literature Review

Transition Time Required for a Successful Takeover

Several studies investigated adequate takeover response time, which is the time from a TOR until a boundary is reached that a driver needs to safely regain manual vehicle control [20-25, 27]. In studies by Mok et al., drivers had to negotiate a curve in a construction setting where the TOR time budget or time-to-collision (TTC) varied between 2, 5, and 8 seconds between subjects [20-22]. With no secondary task [20], watching a video [21], and a tablet game [22], each study concluded that 2 seconds is not a sufficient time budget for a TOR. Furthermore, 5 seconds was also not sufficient when the secondary task involved a tablet game.

Similar to results by Mok et al. [22], Epple et al. found that all drivers who took over control at least 5 seconds prior to the construction site in the study, where the TOR was presented in two steps at 9 seconds and 3 seconds amidst a questions game on a mounted tablet, were able to do so successfully without crashes, meaning that the time budget should be greater than 5 seconds [27].

Gold et al. [23] and Ito et al. [24] each tested time budgets of 5 and 7 seconds. While the study by Gold et al. [23] involved the SuRT on a handheld device and on the center console, Ito et al. [24] tested NDR tasks of watching a video on the center console, entering 4 digit numbers from a paper onto the center console, and no task. Gold et al. found that the location of the secondary task was not significant and with a shorter takeover time, decision making and reactions are faster compared to a longer time budget, but also generally worse in quality [23].

Results from Ito et al. also showed that reactions were faster when the TTC was 5 seconds compared to 7 seconds. In addition, the results from Ito et al. showed that all participants completed a proper takeover, even when the TTC was 5 seconds [24]. This finding is important because it directly contradicts the claim that 5 seconds is not sufficient that was established by Mok et al. [22] and Epple et al. [27].

Melcher et al. tested a TTC of 10 seconds, and found that all participants were able to takeover control within the allotted time [25]. Radlmayr et al. tested a TTC of 7 seconds, while having subjects engage in no task, the SuRT, or n-back task and changing the lane and traffic density surrounding an accident on a three-lane highway. The results showed that the lowest takeover times were in the baseline group and the TOR accident occurring in the middle-lane had the highest mean takeover time and most collisions [33].

From these studies, it can be said that there is not one fixed minimum transition time that could be applied to all drivers in all scenarios that would result in a safe and successful takeover. Clearly, if there are collisions occurring then the allotted takeover time was not ample. The takeover behavior may be influenced by factors such as takeover cause, transition time, and secondary task. However, with longer transition times, drivers should be better prepared for a takeover.

Takeover Modality

A number of research studies investigated the relationship between the TOR modality (e.g., auditory, visual, haptic), or TOR alert, and takeover performance [25-27, 32, 34]. Melcher et al. presented each TOR with an acoustic gong and an on-screen warning, with an additional integration with the secondary task of a mobile phone and/or a brake jerk in the vehicle. With a

TOR time budget of 10 seconds in a construction zone, all participants were able to takeover vehicle control regardless of how the TOR was presented. Furthermore, Melcher et al. concluded that further enhancements on the modality appeared to have no effect in takeover response time [25].

Van der Heiden et al. tested a repeated burst, increasing pulse, or no audio pre-alert 20 seconds before a TOR, with each variation verbally saying “automation disabled” one second before the TOR. Extending the takeover scenarios to include fog, a dog, a parked vehicle, and construction, pre-alerts were found to increase drivers’ gaze on the road and suspend engagement with the secondary task of a mobile phone earlier compared to no pre-alert, with pre-alerts conveying urgency to be promising [26].

Naujoks et al. tested an auditory-visual alert consisting of a flashing picture and a one second tone and a purely visual alert of only the flashing picture while drivers read from a news magazine. Three takeover scenarios all on a highway setting with heavy traffic were incorporated, including missing lane markings on a straight road segment, following temporary lines, and missing lane markings with high road curvature. The results showed that shorter reaction times and better lane keeping were consistent with the auditory-visual alert, regardless of the driving scenario [34].

Brandenburg et al. tested TORs with either one or two steps (i.e. presenting the alert once 8 seconds before or once 16 seconds before and again 8 seconds before the transition of control), tone or speech, and text or text and a pictogram among online participants. Participants preferred a two-step TOR procedure to a one-step, and speech over tone. Brandenburg et al. concluded that including pictograms with text does not further increase the usefulness of a TOR that already includes speech [32].

Epple et al. tested an auditory TOR with verbal speech and a hybrid visual-auditory TOR with tone and text, where each TOR was presented in two steps occurring 9 seconds and 3 seconds before automation was disabled. The results indicated that the auditory TOR lead to shorter reaction times than the visual-auditory TOR and all participants who took over vehicle control at least 5 seconds before the construction site managed to do so successfully [27].

From these studies, it becomes clear that there are a number of methods in which the TOR can be presented, and a consensus has not been reached on the optimal TOR modality that would elicit the fastest and safest transition of vehicle control. A common strategy across these studies that seems vital involves the use of an auditory alert, either through tone or speech. Agreement has not been reached on the helpfulness of including text, a pictogram, mobile phone integration, haptic integration, or multiple steps to a TOR that already includes an auditory alert. The issue is that a TOR modality has to convey a sense of urgency and quickly make the driver aware of their surroundings, yet also feel intuitive and not increase the mental workload of the driver. Studies on takeover modality need to be replicated and tested for robustness across different takeover scenarios, time budgets, and secondary tasks. Moreover, these studies highlight the care and thoughtfulness that has to go into a TOR in order to result in a successful takeover.

Non-Driving Related Tasks Before Takeover

Some studies explored the effect of automation versus manual driving and implementing a NDR task [28, 35, 36, 37]. Kern et al. had subjects perform various secondary tasks while driving a manual car and found that users compensated by driving slower when engaged in a secondary task [37]. Merat et al. tested responses to events in both a manual and automated

vehicle and noticed that responses to all critical events were much later in the automated condition [35]. In another study, Merat et al. implemented a twenty questions task as well as no task. Merat et al. found that responses to critical events were similar between automated and manual driving when there was no secondary task. The most performance degradation was seen when drivers had to takeover control from automation after being engaged in the secondary task [36]. In contrast to the results from [35], the results from [36] concluded that automated driving did not have a negative effect on performance in the absence of a secondary task. Feldhutter et al. tested the duration before a TOR at 5 minutes and 20 minutes and implemented the SuRT or no task. The results showed that having the SuRT led to longer takeover times and more so after 20 minutes of automated driving [28]. Combined, these studies indicate that engaging in a secondary task, especially when driving automated, leads to poorer takeover performance.

There are some studies that investigated the effects of different types of NDR tasks on takeover performance [29-31]. Nakajima et al. had subjects play a smartphone game, watch a video, converse with a passenger, or not engage in a NDR task. The smartphone task was categorized as an active task, whereas the video was a passive task and conversation was an active and passive task. Nakajima et al. defined the difference between an active and passive task based on whether the task requires a physical and/or mental operation. The results showed that it took longer to takeover vehicle control when participants were previously engaged in a NDR task. Comparing each task, there was little difference between the conversation and video task with no task, but there was an obvious takeover delay with the smartphone task [29].

Wandtner et al. tested NDR tasks labeled as auditory-vocal, visual-manual, and visual-manual: high workload with time budgets of 6 and 8 seconds. The auditory-vocal task involved verbally repeating sentences that were read aloud by a software. The visual-manual task had

participants transcribe sentences that were displayed on a tablet. The visual-manual: high workload task was similar to the visual-manual task with the additional step that each word had to be alphabetized. The results showed that takeover times had a tendency to be longer for the visual-manual task, especially with the high workload factor. The auditory-vocal task was consistent with the fastest takeover reaction times [30].

In another study, Wandtner et al. studied NDR tasks of auditory-vocal, visual-vocal, visual-manual mounted, visual-manual handheld, and no task. The auditory-vocal task was the same as the auditory-vocal task in the previous study by Wandtner et al. [30]. For the visual-vocal task, participants had to read aloud sentences that were presented on a tablet. The visual-manual tasks were the same as the previous visual-manual task, with a variation in if the tablet was mounted on the center console or handheld. Similar to the previous study [30], the results showed that the visual-manual handheld task had the most performance degradation and the auditory-vocal task was comparable to no task. This categorization of secondary tasks is important because the auditory-vocal task could be compared to conversation with a passenger, while the visual-manual handheld task could be representative of sending messages [31].

From these studies that focused on the nature of the secondary task, it appears that an auditory-vocal or conversation task results in the driver being the most prepared to resume vehicle control, which was found to be very similar to not engaging in any non-driving related task. Conversely, playing a smartphone game or transcribing sentences on a tablet appear to result in poorer performance. Undoubtedly, the activity that the driver is engaged in prior to a TOR in an automated vehicle has an effect on their takeover performance. Since it may be unrealistic to expect that drivers will restrict their interaction with specific secondary tasks such as using a smartphone, the critical concern is how to balance driver comfort and satisfaction, yet

also allow the automation to rely on the driver to takeover control in scenarios that the automation is unable to negotiate.

Conclusions

There are numerous research studies surrounding highly automated vehicles that indicate transitioning control between automation and a human driver is a complex issue. The studies show that drivers tend to perform better when provided a longer TTC and when the TOR alarm uses an auditory alert. While an agreement has yet to be reached about the most appropriate time budget and takeover modality, a TOR has to convey a direct sense of urgency and allow the driver to takeover successfully.

The transition of control becomes more complicated when considering the cause of the TOR. Table 1 shows a summary of the TOR causes from other studies. Common scenarios include construction [20, 21, 22, 25, 26, 27, 32], an accident [23, 33], a stopped vehicle [24, 28], a low speed vehicle [29], and a broken down vehicle [30, 31].

Table 1: Summary of takeover request scenarios and causes from other studies.

| <u>TOR Scenario/Cause</u> | <u>Study</u> |
|---|----------------------------|
| Construction | 20, 21, 22, 25, 26, 27, 32 |
| Accident on three-lane highway | 23, 33 |
| Stopped vehicle on highway | 24, 28 |
| Broken down vehicle | 30, 31 |
| Low speed vehicle | 29 |
| Loss of lane line on three-lane highway | 34 |

| | |
|---|--------|
| Parked car | 26, 35 |
| Fog | 26 |
| Dog crossing | 26 |
| Emerger from left | 35 |
| Oncomer turns across | 35 |
| Traffic lights | 35 |
| Obstruction in lane | 36 |
| Non-critical incident on three-lane highway | 36 |

Furthermore, a secondary task can affect a driver's performance when regaining vehicle control. Table 2 provides a summary of the various NDR tasks that were implemented in other studies. The most frequent NDR tasks include no task [20, 24, 28, 29, 35, 36, 37], watching a video [21, 24, 29], playing a question type game [25, 27, 36], playing an electronic game [22, 29], transcription [26, 30, 31], and speaking or conversation [29, 30, 31].

Table 2: Summary of non-driving related tasks from other studies.

| <u>Non-Driving Related Task</u> | <u>Study</u> |
|------------------------------------|----------------------------|
| None | 20, 24, 28, 29, 35, 36, 37 |
| Watch a video | 21, 24, 29 |
| Tablet game of Temple Run 2 | 22 |
| SuRT | 23, 28, 33 |
| Enter digits on a navigator screen | 24 |
| Quiz game on a mobile phone | 25 |

| | |
|---|--------|
| Video transcription | 26 |
| Calendar entry | 26 |
| Questions game on mounted tablet | 27 |
| Read text passages from a news magazine | 34 |
| Sort candy | 37 |
| Take out coins | 37 |
| Answer map questions | 37 |
| n-back task | 33 |
| Twenty questions task | 36 |
| Conversation | 29 |
| Smartphone game | 29 |
| Repeat verbally-spoken sentences aloud | 30, 31 |
| Transcribe sentences | 30, 31 |
| Read sentences aloud | 31 |
| Alphabetize and transcribe sentences | 30 |

As of now, there remain inconsistencies about human behavior and interaction with highly automated vehicles. It is important to understand this complex tradespace as a human driver is required for backup when automation encounters a situation in which the course of action is unclear. For continuing this field of research, there should be studies addressing or confirming the effects of takeover modality, takeover scenario, and takeover time budget. In addition, there need to be studies that speak to the wide array of NDR tasks that drivers are likely to engage in as automation progresses. It is necessary to understand the effect that various

different NDR tasks have on takeover performance, as different NDR tasks can degrade performance differently. There has yet to be a study that investigates the effects of a large number of common NDR tasks on takeover performance. Such a study could provide further insight as to how and which NDR tasks are negligible or detrimental to takeover performance.

The study that is detailed below explores different NDR tasks at the time of a TOR. This pilot study is conducted in a realistic driving simulator where the vehicle is primarily controlled by the automated system, but the driver is needed to control the vehicle as a backup when the automated system is not available. While being driven automated, participants are assigned one of three NDR tasks or no NDR task to engage in. After driving automated for five minutes, the vehicle approaches an accident ahead in its lane and this triggers a TOR which is presented as an auditory alarm. This represents a non-scheduled system initiated handover, where the driver is not previously notified of the TOR and the driver must takeover control immediately because the current situation is beyond the capability of the automated system. Upon hearing the TOR alarm, participants have to cease their secondary task, gain control of the vehicle, and manually drive beyond the incident by using a neighboring lane. Participants experience a driver monitored handover, where they have a time budget of 6 seconds to takeover vehicle control before a collision is inevitable. The NDR tasks tested include no task, closed eyes/relaxed state, a smartphone game, and reading articles. Takeover time, collisions, disengagement from the secondary task, and a video recording during takeover are analyzed for this pilot study. The preliminary results indicate how the different NDR tasks play a role in takeover performance and behavior. This study will continue by verifying findings on more participants and with the inclusion of additional NDR tasks.

Method and Materials

Driver Secondary Task Survey

Prior to allowing participants to take part in the handover 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 voluntary survey is sent out through email and is conducted entirely online. No personally identifiable information is recorded. The survey takes approximately 5 to 10 minutes to complete and is targeted towards those who are 18 years of age or older, are a vehicle driver, and have a driver's license.

There are larger surveys published on the topic of distracted driving such as the National Survey on Distracted Driving Attitudes and Behaviors – 2015 published by U.S. Department of Transportation National Highway Traffic Safety Administration (NHTSA) [43]. However, there are some aspects of this NHTSA survey that the driver secondary task survey administered in this study addresses. To begin, this study is interested in secondary tasks that are very popular today as new trends and habits can be introduced at any time in today's world. Although the NHTSA's survey gathers a large number of responses, this results in the most recent report to be on data from 2015 that was published in 2018. This data is already 5 years old from 2020. In addition, some questions from the NHTSA's survey limits the responses that participants can give. A sample question from the NHTSA's survey is shown in Figure 3. It should be noted that the common activities that are being asked about are already fixed, so participants do not have the option to bring an alternate activity into consideration. It can also be said that asking about an activity such as changing CDs and tapes shows the datedness of some aspects of the survey. The

driver secondary task survey that is being administered for this study remedies these concerns by asking participants about their present engagement and by allowing participants to respond to open-ended questions. As such, participants answers are in no way stifled.

FREQUENCY OF DISTRACTED DRIVING

Q4. I'm going to read a list of common activities people do while driving. For each activity, I'd like you to tell me how often YOU do each while driving. For each, please tell me if you do the activity always, almost always, sometimes, rarely, or never? How often do you...

READ A-O AND CODE FOR EACH:

- A. Talk to passengers in the vehicle
- B. Eat or drink
- C. Make phone calls
- D. Answer phone calls
- E. READ text or e-mail messages
- F. SEND text or e-mail messages
- G. Talk or interact with children in the vehicle
- H. Use a portable music player, including a smartphone, with external speakers or with the car's speakers
- I. Adjust the car radio
- J. Change CDs, DVDs, or tapes
- K. Use a Smartphone for driving directions
- L. Use a navigation system for driving directions
- M. Take pictures with your phone
- N. Use smartphone apps, not including a navigation app
- O. Look up information on the Internet

- 1 Always
- 2 Almost always
- 3 Sometimes
- 4 Rarely
- 5 Never
- 8 (VOL) Don't know
- 9 (VOL) Refuse

Figure 3: Question from National Survey on Distracted Driving Attitudes and Behaviors – 2015 published by U.S. Department of Transportation National Highway Traffic Safety Administration [43].

The driver secondary task survey begins by asking for consent, demographic information, and how often the participant drives, where answer choices range between daily to never for the

frequency of driving. 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, the frequency of engagement, and how the participant thinks engagement in that secondary task would change in a conditionally automated and fully automated vehicle. Another set of questions asks participants to imagine they are in a conditionally automated vehicle and report on the top secondary tasks they think they would engage in. Similarly, participants report on the top tasks they think they would engage in by imaging they are in a fully automated vehicle. 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. Throughout the entire survey, definitions for relevant terms are provided on each page. The driver secondary task survey is available in the Appendix.

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. As shown in Figure 4, 80% of respondents said that they drive daily and the 5% who reported that they never drive are removed from further analysis. In addition, Figure 5 shows that 65% said that their typical drive is 0.5 hours or less, 28% said their typical drive is 1 hour, and no one reported a typical drive longer than 3 hours.

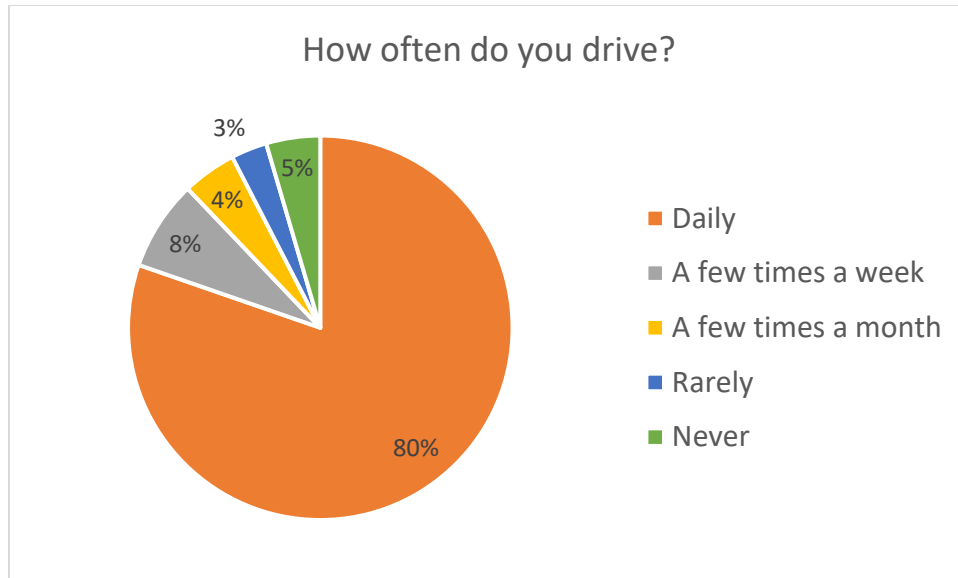


Figure 4: Distribution of how often participants reported driving.

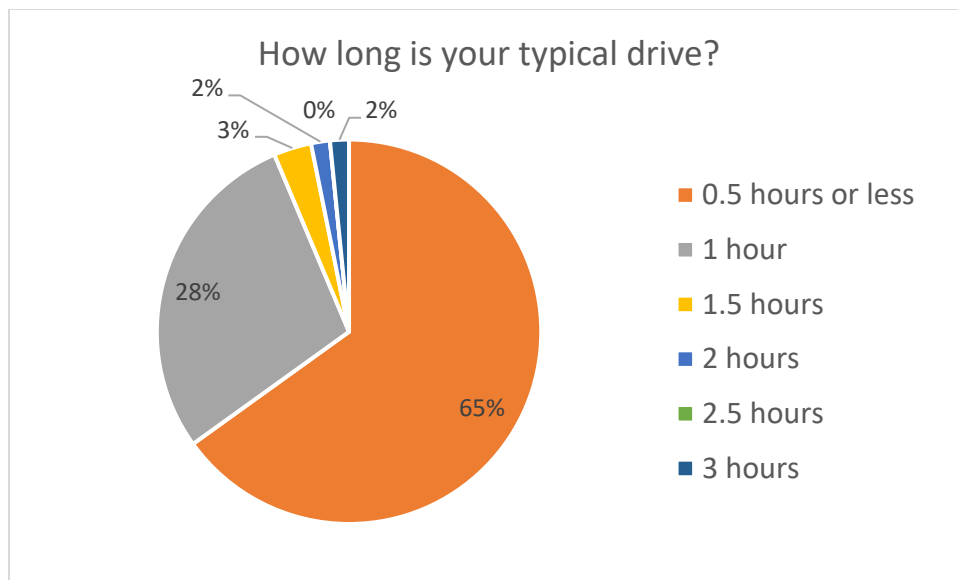


Figure 5: Distribution of how long participants reported a typical drive to be.

When asked about the most commonly engaged in secondary task today, the overwhelming majority of responses related to music/radio as seen in Figure 6, with the majority who self-reported music/radio claiming to always or almost always engage in this NDR task.

When asked about how engagement in this task would change in a conditionally automated vehicle and in a fully automated, both questions resulted in a fairly even split between participants reporting an increase in engagement and engagement staying the same. Of the 33 participants saying that music/radio is their most common secondary task, 12 said they always engage in this task and 13 said they almost always engage in this task. 13 participants think their engagement will increase and 20 think their engagement will stay the same in a conditionally automated vehicle. No participants reported an envisioned decrease in music/radio engagement in a conditionally automated vehicle. 18 participants think their engagement will increase and 15 think their engagement will stay the same in a fully automated vehicle regarding the music/radio task. Again, no participants reported an envisioned decrease in music/radio engagement in a fully autonomous vehicle.

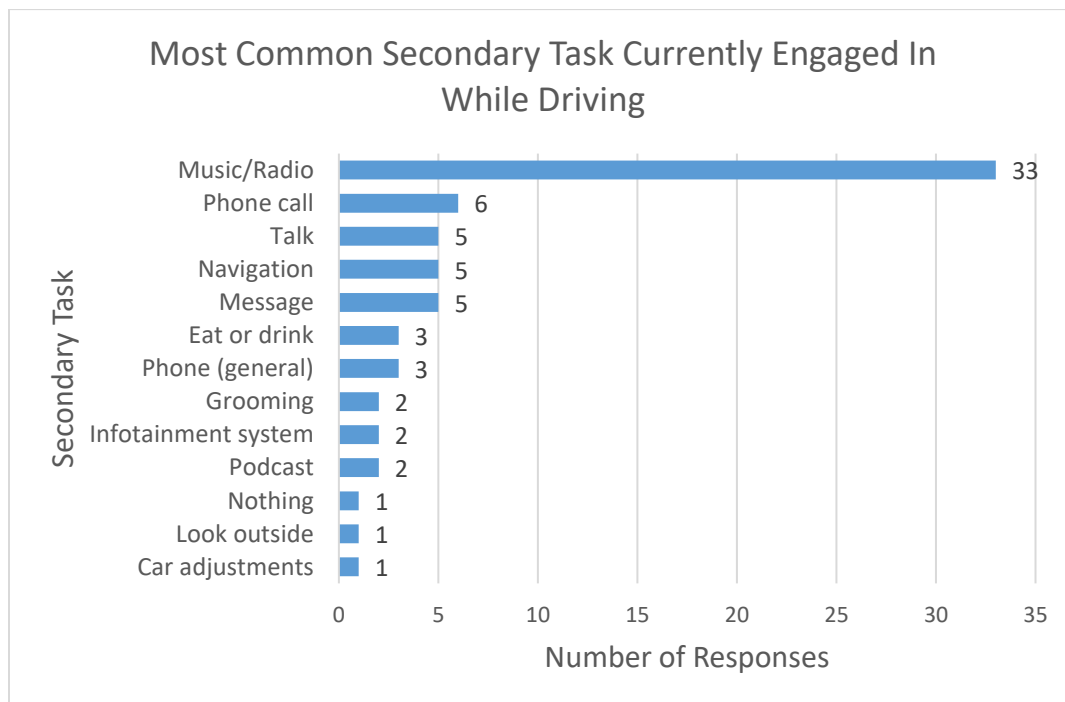


Figure 6: Most common secondary task participants reported currently engaging in while driving.

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. 54 participants reported never reading while driving as shown in Figure 7. 55 participants reported never watching television shows, movies, or clips while driving as shown in Figure 8. 27 participants said they never send messages or emails using the keyboard, with another 20 saying they rarely do as shown in Figure 9. Only one participant reported always sending messages or emails using the keyboard. For the NDR task of using a smartphone to search for a song, play a song, or skip a song, the data is nearly uniformly distributed. 11 reported always, 11 reported almost always, 13 reported sometimes, 13 reported rarely, and 15 reported never engaging in this secondary task as shown in Figure 10. The distribution for daydreaming or getting lost in thought appears to be normally distributed as depicted in Figure 11, 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 12.

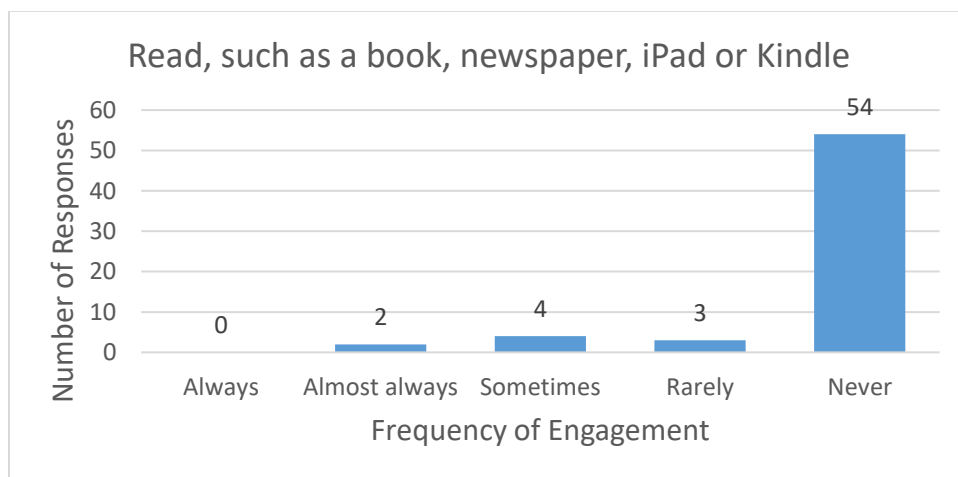


Figure 7: Current engagement reported by participants for the task of read, such as a book, newspaper, iPad or Kindle.

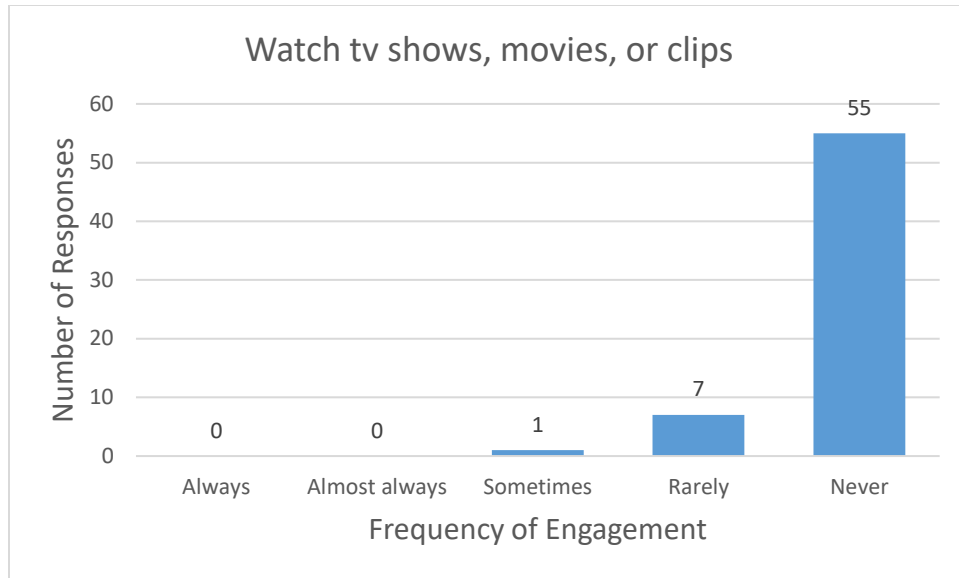


Figure 8: Current engagement reported by participants for the task of watch tv shows, movies, or clips.

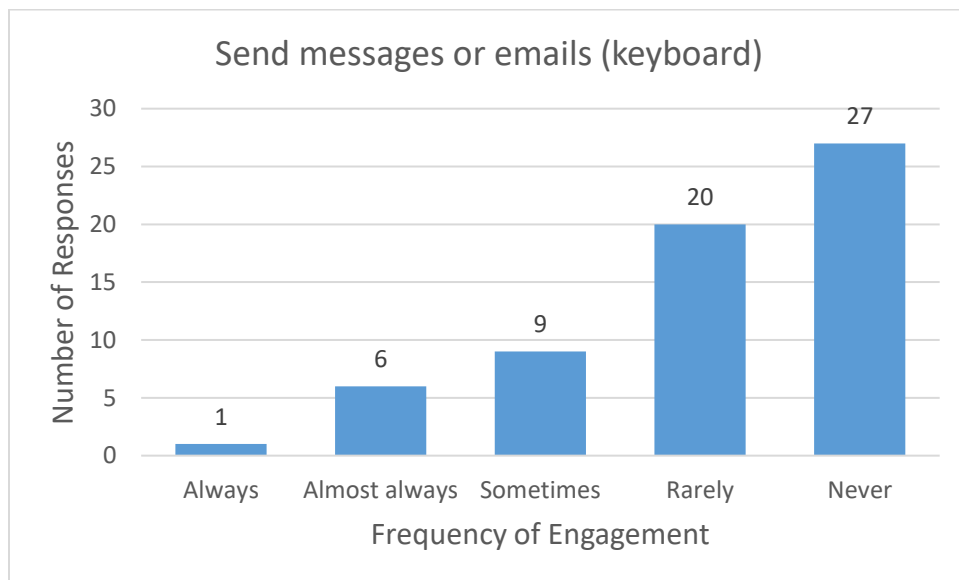


Figure 9: Current engagement reported by participants for the task of send messages or emails (keyboard).

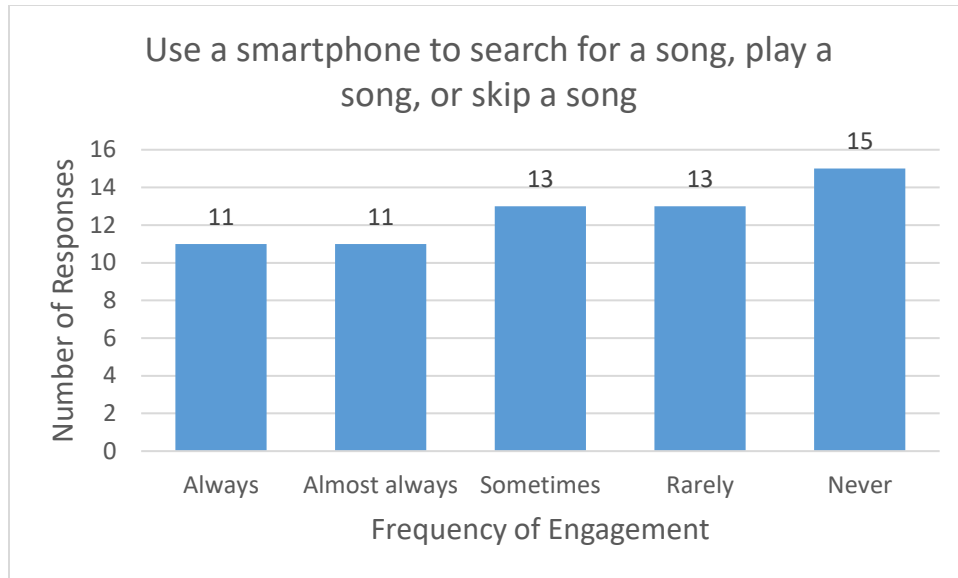


Figure 10: Current engagement reported by participants for the task of use a smartphone to search for a song, play a song, or skip a song.

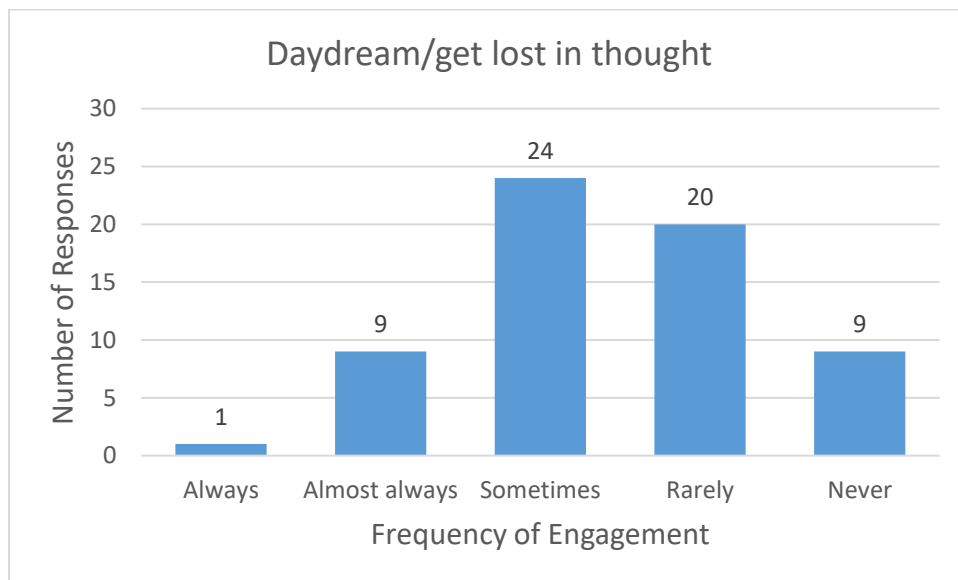


Figure 11: Current engagement reported by participants for the task of daydream/get lost in thought.

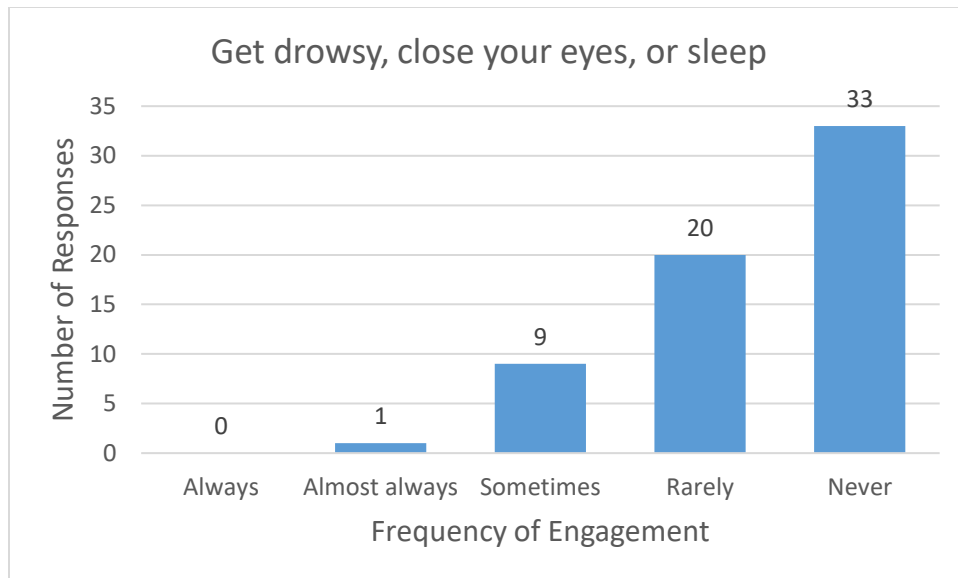


Figure 12: Current engagement reported by participants for the task of get drowsy, close your eyes, or sleep.

Participants are asked about the top three secondary tasks they would imagine engaging in a conditionally automated vehicle. The most frequent responses for the most common engaged in task in a conditionally automated vehicle fall into the categories of music/radio, messaging, and general phone use. The most frequent responses for the second most common task in a conditionally automated vehicle belong to the categories of music/radio, eat or drink, messaging, and phone call. The most frequent responses for the third most common task in a conditionally automated vehicle fall into the categories of eat or drink, music/radio, and general phone use. Bar charts of the categories for these responses are shown in Figures 13-15.

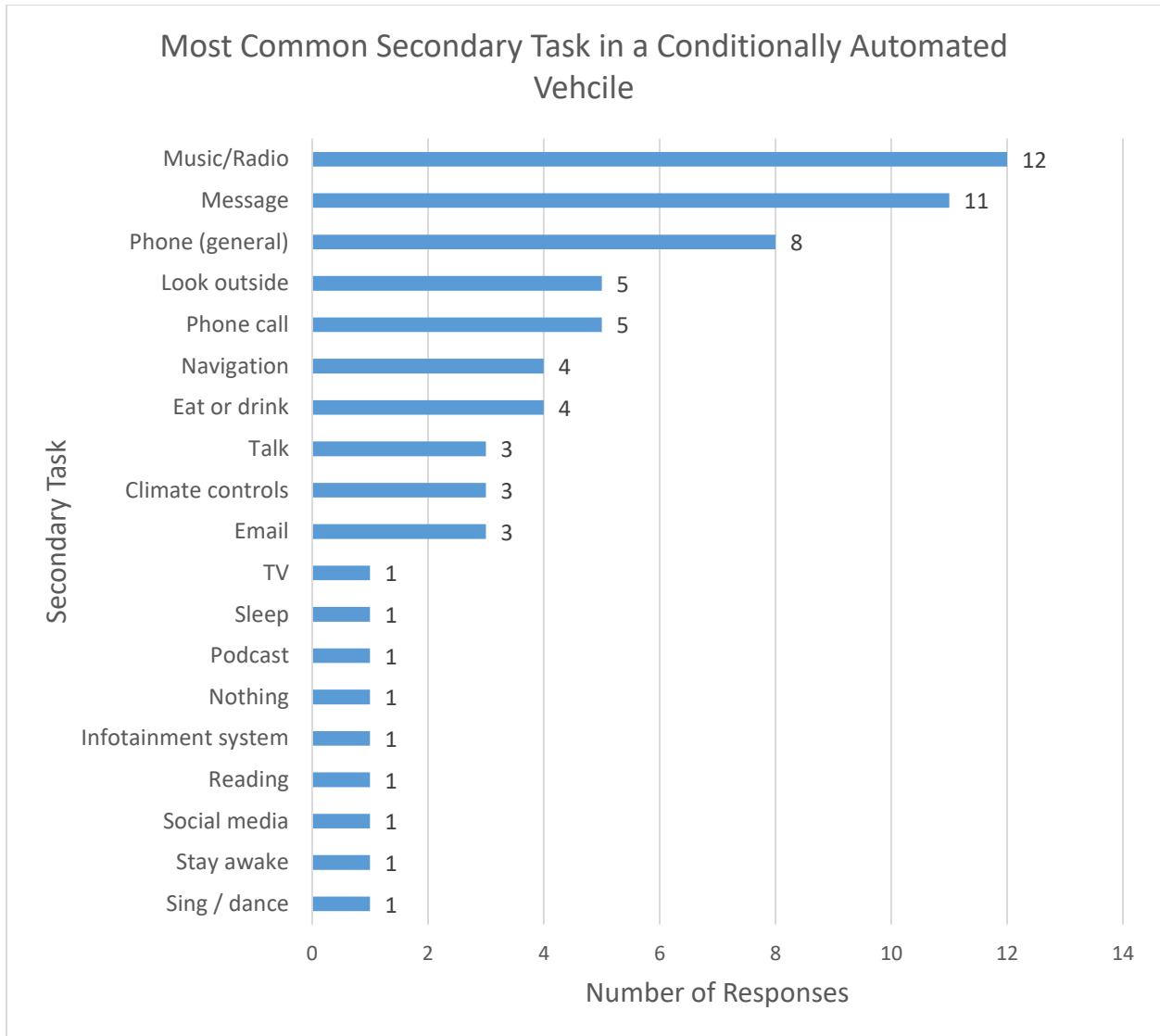


Figure 13: Most common engaged in task participants imagined to occur in a conditionally automated vehicle.

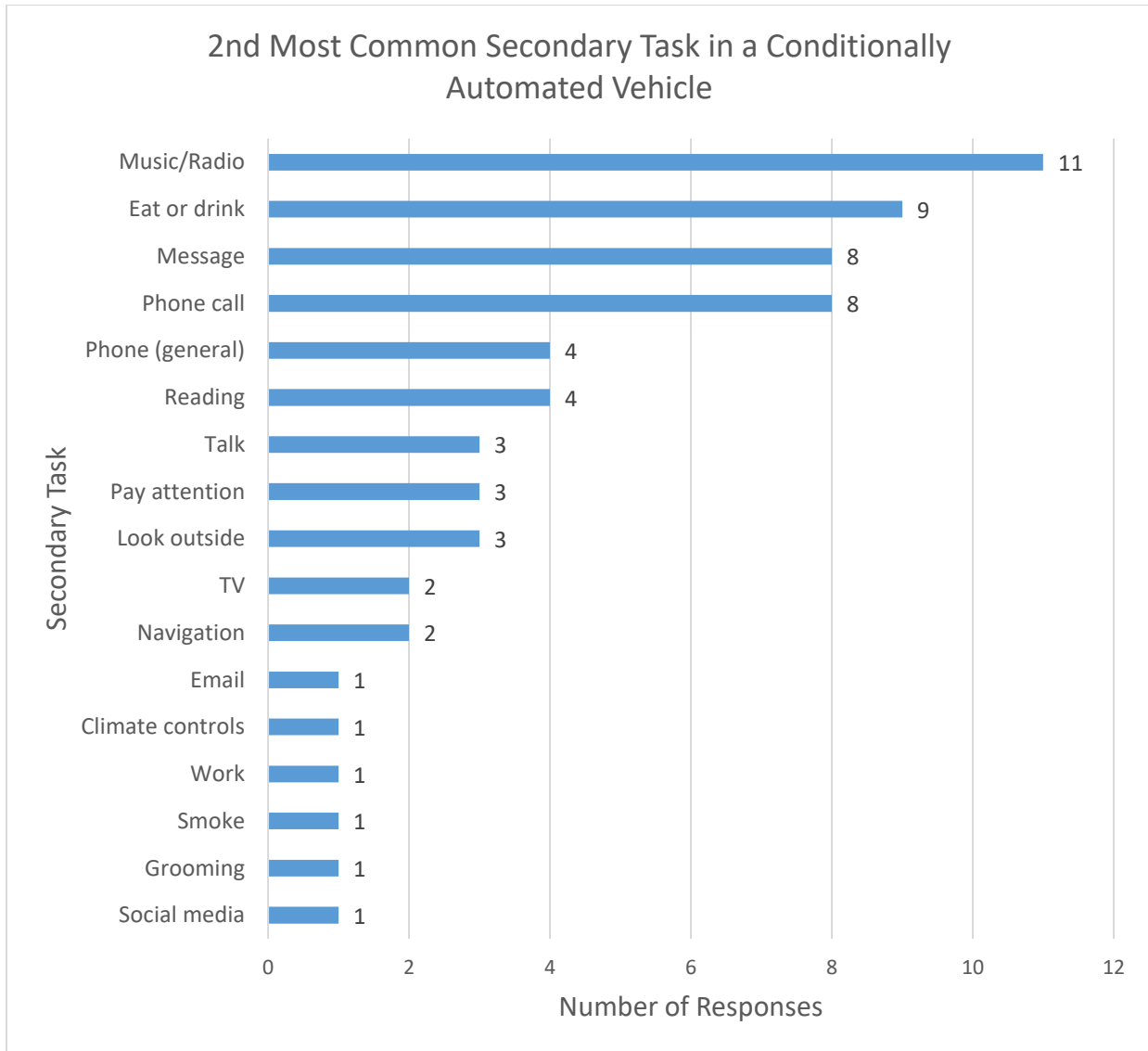


Figure 14: Second most common engaged in task participants imagined to occur in a conditionally automated vehicle.

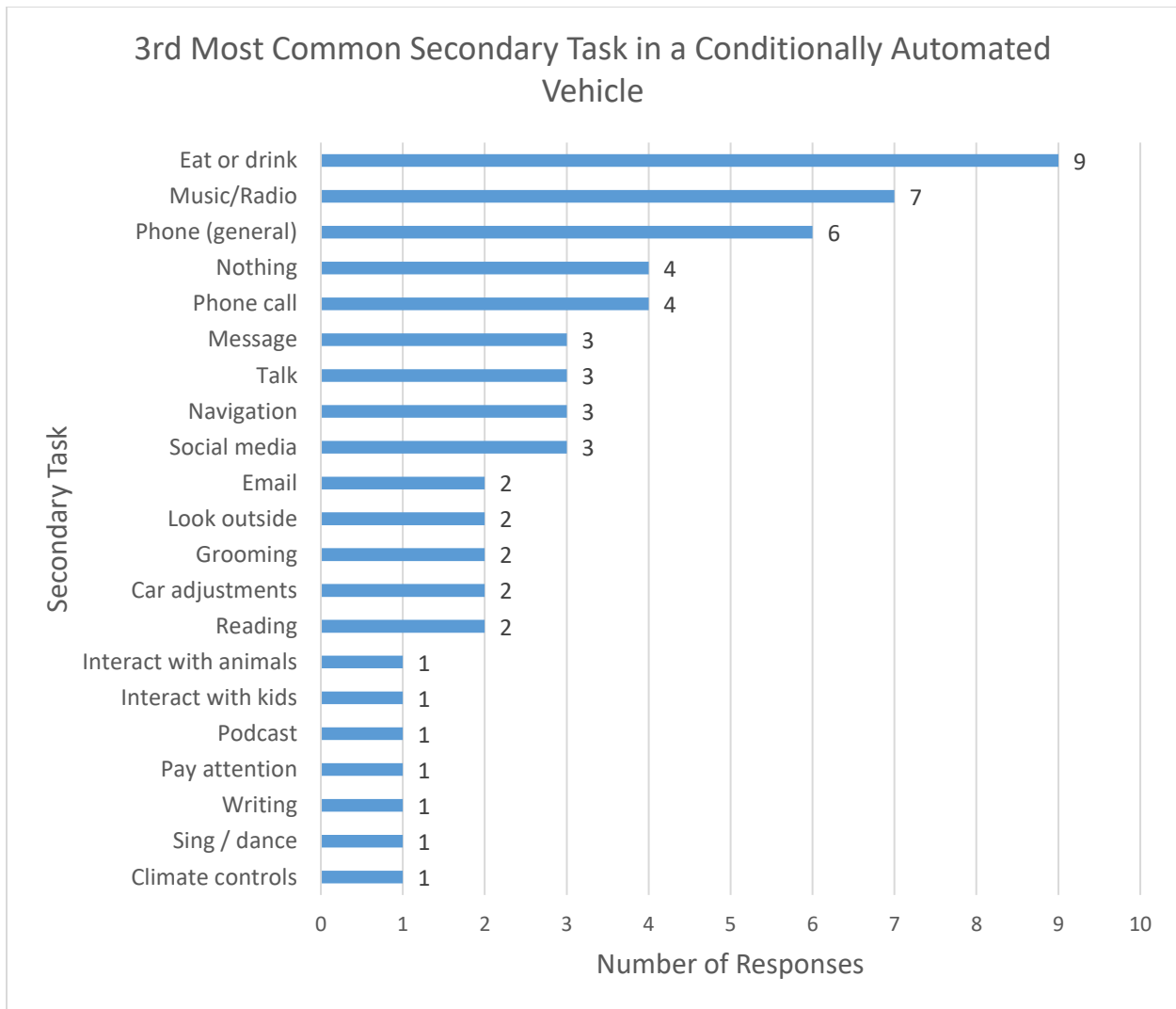


Figure 15: Third most common engaged in task participants imagined to occur in a conditionally automated vehicle.

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 16.

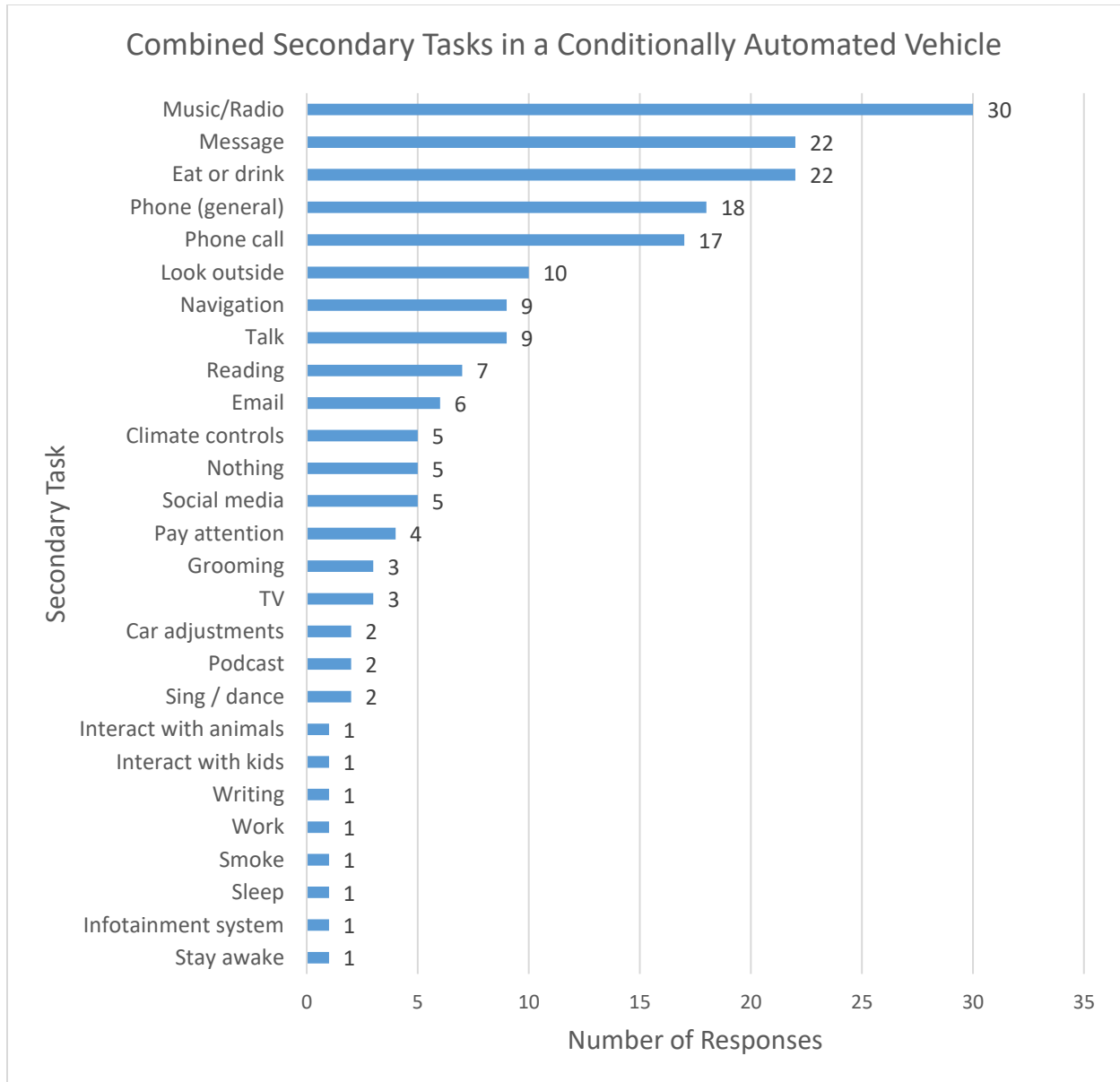


Figure 16: Combined common secondary tasks participants imagined to occur in a conditionally automated vehicle.

Participants are asked about the top three secondary tasks they would imagine engaging in a fully automated vehicle as well. The most frequent responses for the most common engaged in task in a fully automated vehicle fall into the categories of general phone use, messaging, music/radio, and reading. The most frequent responses for the second most common task in a

fully automated vehicle belong to the categories of music/radio, eat or drink, and messaging. The most frequent responses for the third most common task in a fully automated vehicle fall into the categories of eat or drink, sleep, and reading. Bar charts of the categories for these responses are shown in Figures 17-19.

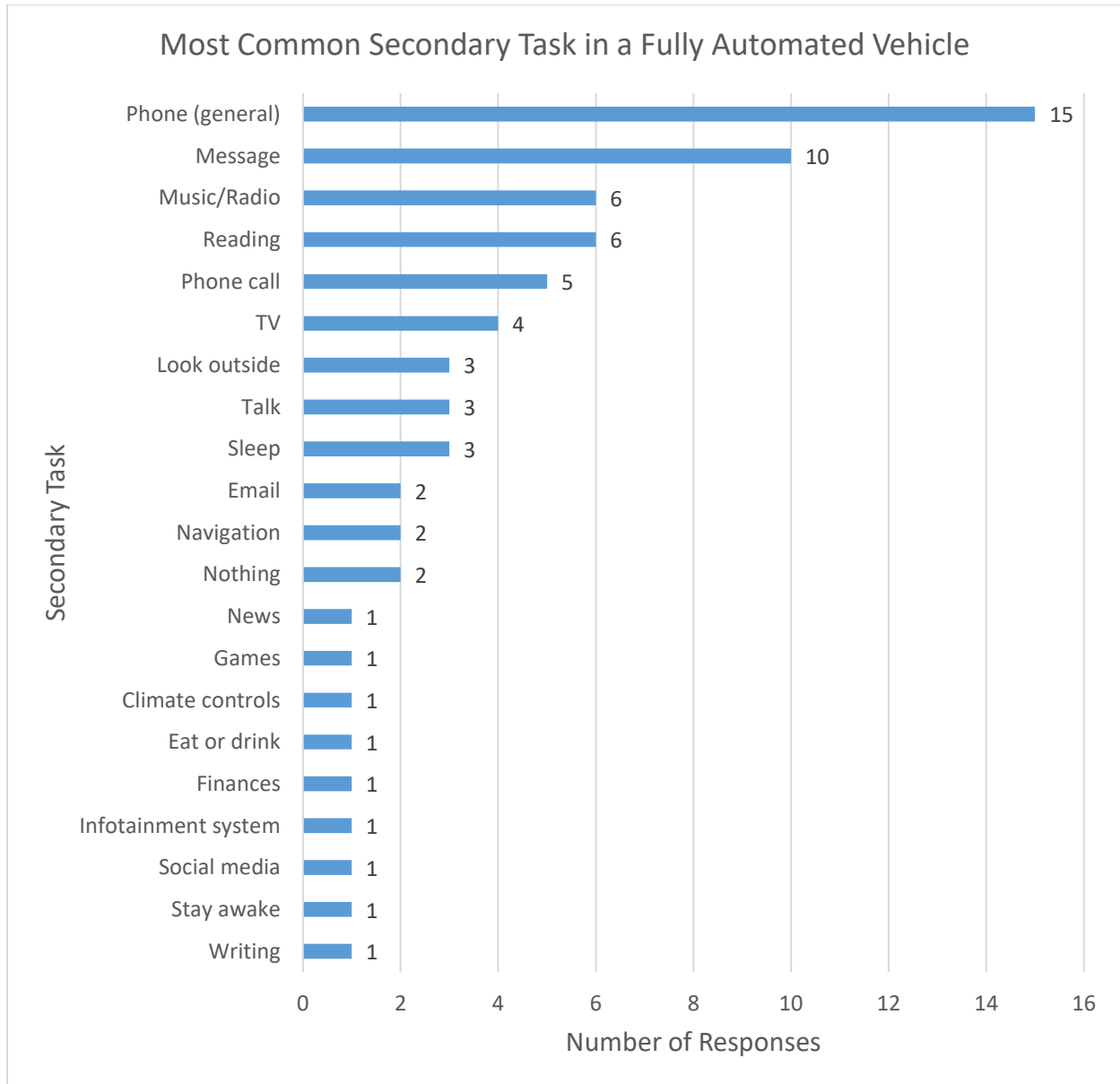


Figure 17: Most common engaged in task participants imagined to occur in a fully automated vehicle.

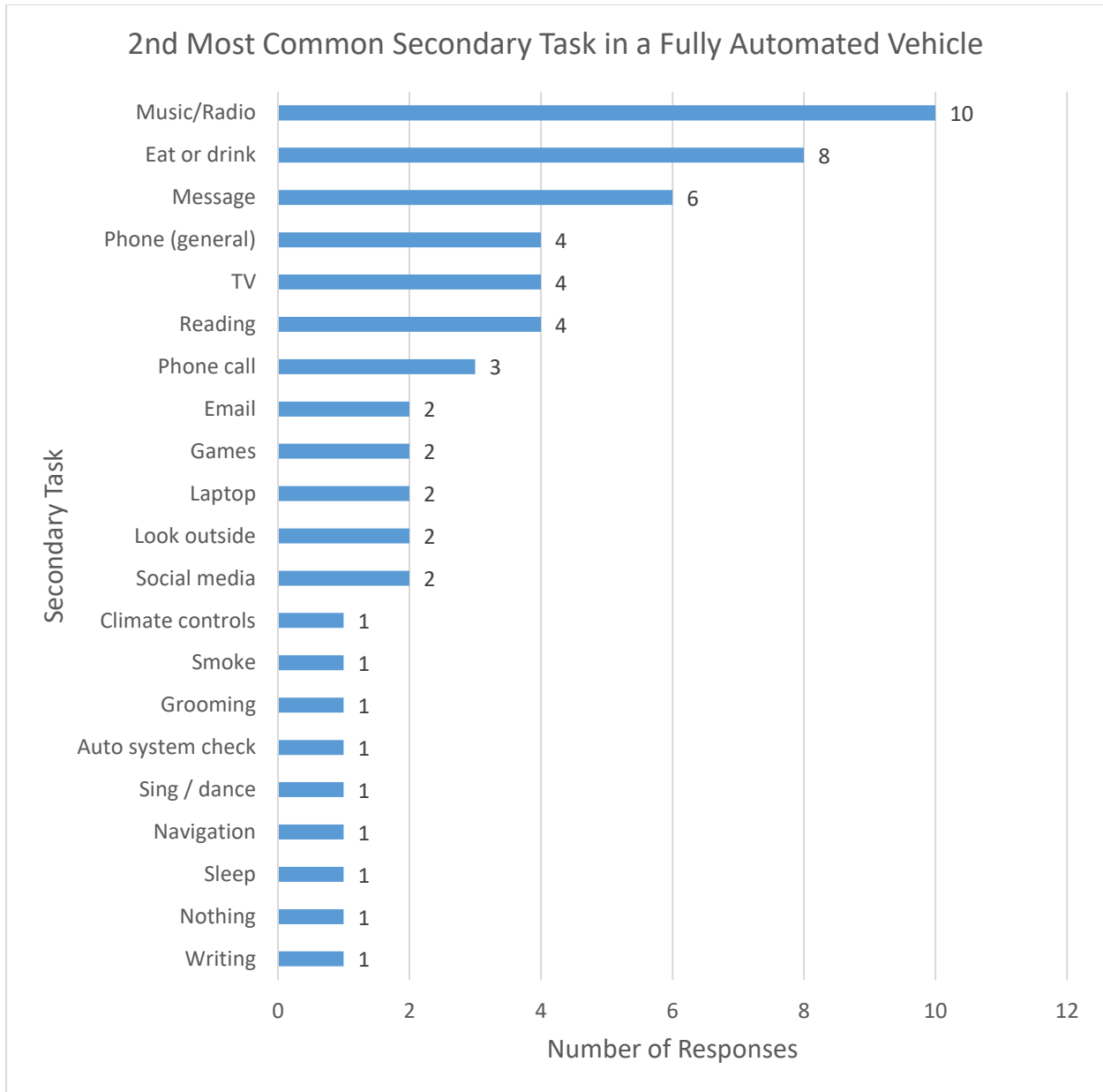


Figure 18: Second most common engaged in task participants imagined to occur in a fully automated vehicle.

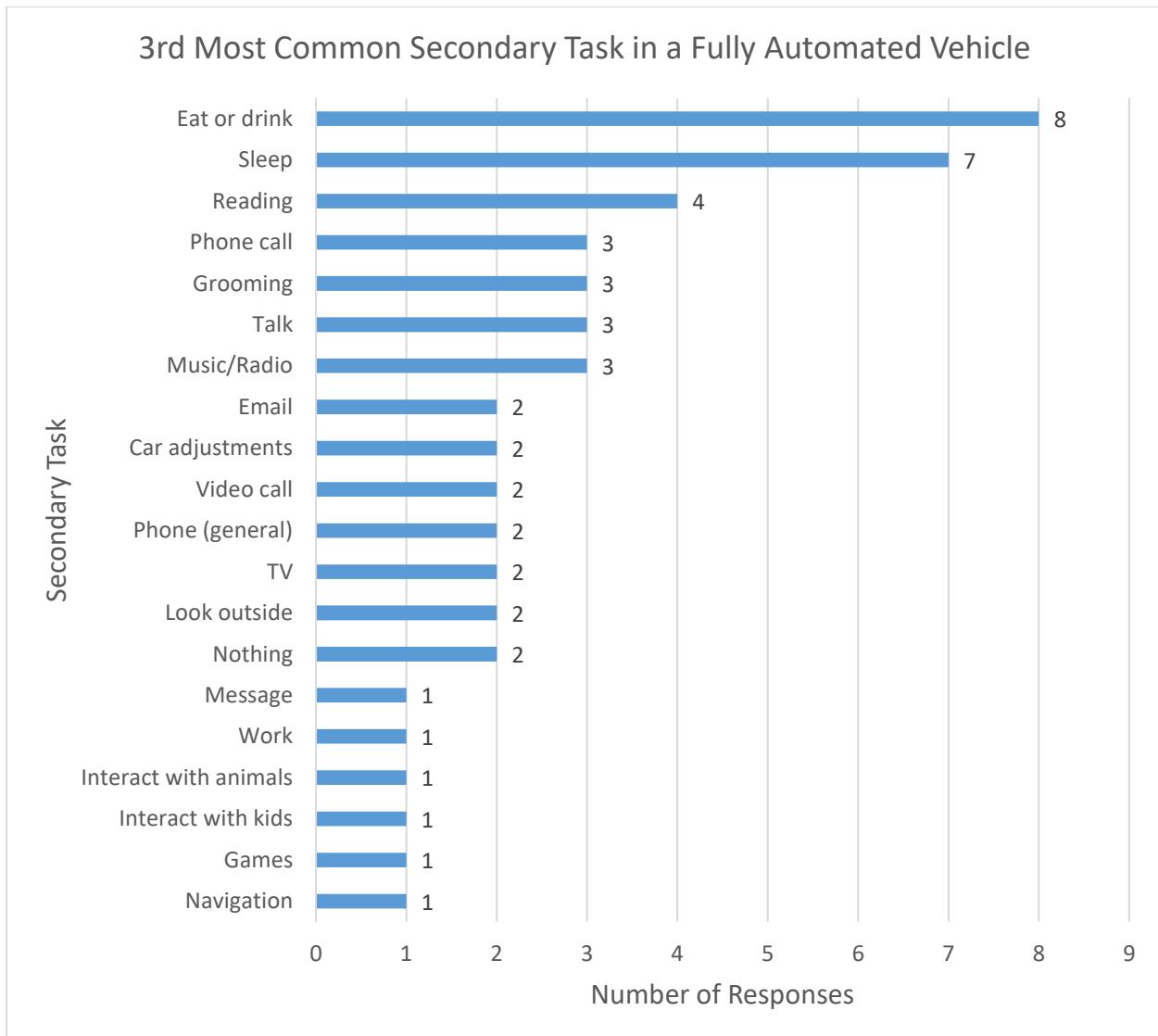


Figure 19: Third most common engaged in task participants imagined to occur in a fully automated vehicle.

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 20.

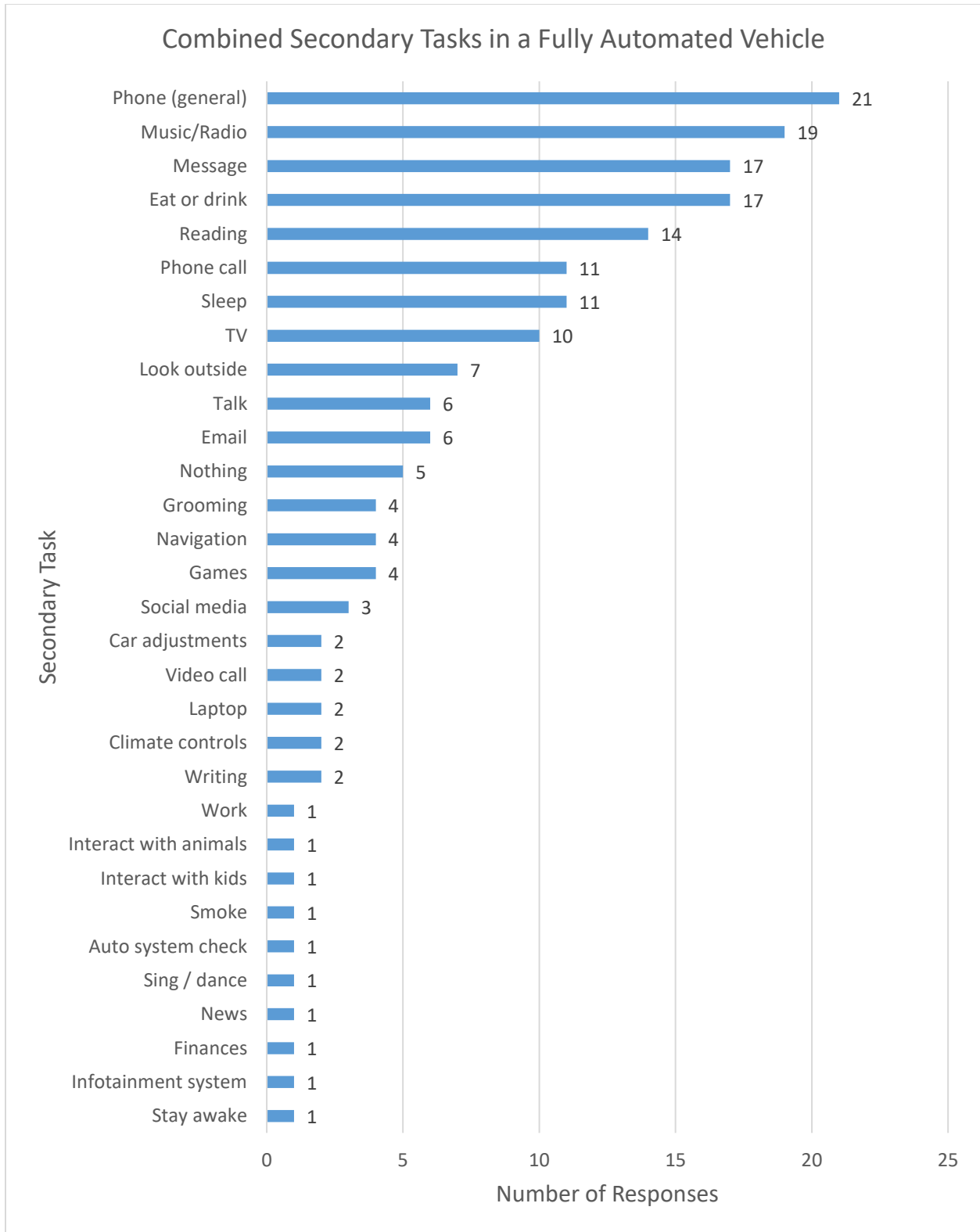


Figure 20: Combined common secondary tasks participants imagined to occur in a fully automated vehicle.

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 total combined responses for the conditionally automated vehicle and fully automated vehicle are similar, at 204 and 206 combined responses respectively. The non-driving related tasks of sleeping, reading, and watching television are more frequently reported for the fully automated vehicle scenario. In total, there are 11 counts for sleeping, 14 counts for reading, and 10 counts for watching television when all responses for the fully automated vehicle are combined. When all responses for the conditionally automated vehicle are combined, there is only one count for sleeping, seven counts for reading, and three counts for watching television. 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 automated progresses. Conversely, where there appeared to be a normal distribution 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. These responses reveal the secondary tasks that drivers find to not be able to multitask while driving, and how a higher automated vehicle would allow such secondary tasks to occur more frequently. In addition, the

task of daydreaming and getting lost in thought was reported to be more common currently than it would be in a higher automated vehicle. Through this survey, the advantage of allowing drivers to redirect themselves to NDR tasks in automated vehicles is evident.

The responses from the driver secondary task survey play a key role in helping to determine the secondary tasks that are implemented in the pilot takeover study.

Driving Simulator

A realistic driving simulator was made from primarily commercial components. The driving simulator consists of three 27-inch Viotek curved gaming monitors, a Thrustmaster TH8A shifter, a Thrustmaster TMX Force Feedback steering wheel, Thrustmaster T3PA-Pro 3 pedals, a Next Level Racing F-GT seat and cushion, a Logitech speaker system, and an iBUYPOWER Pro Gaming computer. The entire simulator rests on caster wheels. The speakers sit below the seat and the computer is placed behind the pedals. Figures 21-24 below show pictures of the setup.



Figure 21: Driving simulator used in study.



Figure 22: Driving simulator used in study.



Figure 23: Pedals used in study.



Figure 24: Steering wheel used in study.

Simulated Course

One course is used for practicing engaging and disengaging from the automated system and one course is used to run the actual experiment. The software used for the simulation is *TASS PreScan*. The testing courses consists of a one-lane looping road, complete with moving pedestrians, buildings, gas stations, bus stops, trees, signs, and other stationary objects that one may encounter on such a road in real life. The experimental course is a three-lane highway with trees, buildings, signs, and other vehicles. The automated system makes use of the right lane of the three-lane highway. The automated system maintains a speed of approximately 67 miles per hour. After five minutes of driving automated, an accident appears in the right lane of the highway that is blocked off with orange traffic cones. At this point, a TOR administers a siren-type alarm and the participant is expected to takeover manual control of the vehicle until the accident is passed. The appropriate response to the TOR would be to manually drive the vehicle to either of the two neighboring lanes and pass the accident. There is traffic in the neighboring lanes at the time of the TOR. There is a time budget of 6 seconds, so if the participant does not takeover within these 6 seconds, a collision is inevitable. Even if there is a collision, the simulation causes the vehicle to go through the virtual object that it collided with so that the study can continue. Figures 25 shows the simulated experimental course and Figure 26 shows the TOR scenario.



Figure 25: Three-lane highway experimental course.



Figure 26: Accident in right lane that causes a takeover request to be administered.

Secondary Tasks

Participants are assigned one of three possible NDR tasks or no NDR task to engage in while the automated system is enabled. In the first case, there is no secondary task and participants can simply monitor the driving environment. In the second case, participants are instructed to close their eyes and pretend that they are in a relaxed state. In the third case, participants are told to play *Fruit Ninja*, a popular smartphone game. This game is chosen because one would risk losing the game if they looked away from the smartphone for more than a few seconds. In the fourth case, participants are to read any articles from a set of articles that are available. The content of the articles includes the subjects of Bob Marley [38], fast food restaurants [39], guacamole [40], dogs [41], and Disney [42]. The reading level of the articles is appropriate for a general audience. In all cases, participants should not stop engaging in the secondary task unless they hear a TOR alarm. Secondary tasks are assigned in an ordered fashion to allow for as much of a balanced distribution between secondary tasks as possible.

Procedure

Participants are asked to fill out and sign a consent form, and briefed on the goals of the study prior to the study starting. Next, participants are allowed to practice engaging and disengaging the automated system on a practice simulation course. Participants are assigned one of the three NDR tasks or no NDR task and allowed to practice to their satisfaction. Participants are told to engage in the NDR task if applicable anytime the automated system is enabled, although they are allowed to glance at the driving environment as they feel natural. Participants are not told that a TOR would or would not occur, but should participants hear a siren-type alarm, they are told to cease secondary task engagement if applicable and drive the vehicle

manually until the automated system is again available. After addressing any questions the participants may have, the actual simulation course starts. In total, the simulation course takes approximately 9 minutes to complete.

Experimental Design

This observational study is to understand driver takeover performance when previously engaged in a NDR task. The same simulation course and conditions are being applied among all the participants, with only a variation in the secondary task between participants. The study is conducted in the Embedded Systems Research Lab in Room 464 of the Engineering Center at Oakland University. The simulated vehicle in the study is considered to be a semi-autonomous level 3 vehicle. The actual experiment starts with the automated system enabled and the participant engaged in the appropriate secondary task. After five minutes, a TOR occurs and the participant has to stop engagement in the secondary task to manually drive the vehicle beyond the accident. After passing the accident, the automated system becomes available again and participants give back control to the automated system and continue engaging in their assigned NDR task if applicable. Participants are recruited through email or by flyer.

Results and Discussions

The pilot study was conducted on four participants, all of whom were 18 years of age or older and had driving experience. The takeover response time was 1.95 seconds for no task, 2 seconds for closed eyes/relaxed state, 2 seconds for the smartphone game, and 2.4 seconds for reading as shown in Figure 27. Collisions were observed only in the closed eyes/relaxed state NDR task. Video recording shows the driver in the smartphone task continued to hold the

smartphone in one hand while performing the steering operation with the other hand. For the driver who was reading, the NDR task was suspended during vehicle takeover by dropping the article in the driver's lap. While the takeover times across the different NDR tasks from the pilot study were similar, there are differences in the quality of driving performance. Collisions only occurring in the closed eyes/relaxed state NDR task and the driver moving the steering wheel left and right very quickly indicate that the driver had a low situational awareness of the driving environment. Although the driver in the closed eyes/relaxed state task reacted in an appropriate time, the quality of driving was worse than the other NDR tasks. By this standard, the closed eyes/relaxed state had the most detrimental effect on takeover performance.

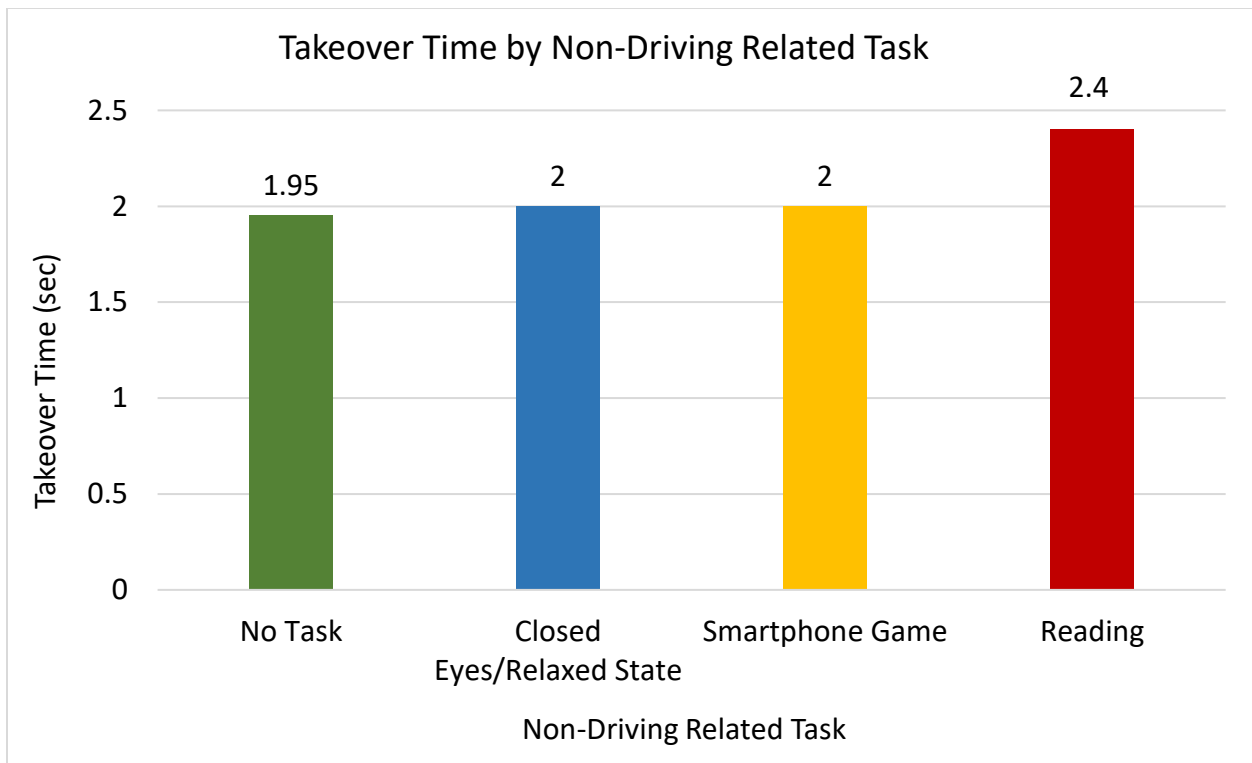


Figure 27: Takeover Time (seconds) by Non-Driving Related Task for Pilot Study.

Outcomes, Future Directions, and Conclusions

This study produced several outcomes, including a review of existing literature, the construction of a driving simulator, the initial results of the driver secondary task survey, and preliminary results on the influence of secondary tasks on taking over vehicle control. These preliminary results clearly indicate that the NDR task that a driver is engaged in prior to a TOR has an effect on takeover performance. To continue, this study will be run on participants to verify the initial findings. This information is of critical relevance to society today because engineers have to design a takeover system in highly automated vehicles that is exceedingly likely to be successful amidst several factors. In the future, it may be practical to consider the state of the driver to predict their readiness to takeover. The state of the driver may include their head orientation, blink rate, eye gaze, and body posture. With such information provided to the automated system, the automated system may be able to determine if issuing a TOR is the best course of action.

References

- [1] “Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems,” *SAE International*, January 16, 2014. [Online]. Available: https://saemobilus.sae.org/content/j3016_201401.
- [2] “Automated Vehicles for Safety,” *NHTSA*. [Online]. Available: <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety>. [Accessed: 19-Jan-2020].
- [3] E. Ackerman, “Transforming Robotic Steering Wheel Is a Reminder That Your Car Needs You,” *IEEE Spectrum: Technology, Engineering, and Science News*, 22-Feb-2018. [Online]. Available: <https://spectrum.ieee.org/cars-that-think/transportation/self-driving/transforming-robotic-steering-wheel-is-a-reminder-that-your-car-needs-you>. [Accessed: 02-May-2019].
- [4] “What is an Autonomous Car?,” *Synopsys*. [Online]. Available: <https://www.synopsys.com/automotive/what-is-autonomous-car.html>. [Accessed: 06-Feb-2020].
- [5] C. Metz, “How Driverless Cars See the World Around Them,” *The New York Times*, 19-Mar-2018. [Online]. Available: <https://www.nytimes.com/2018/03/19/technology/how-driverless-cars-work.html>. [Accessed: 05-Feb-2020].
- [6] “Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey,” *NHTSA*, Feb-2015. [Online]. Available: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115>. [Accessed: 06-Feb-2020].

- [7] “An introduction to autonomous cars”, *Velodyne Lidar*. [Online]. Available: <https://velodynelidar.com/newsroom/an-introduction-to-autonomous-cars-how-they-will-improve-the-cost-convenience-and-safety-of-driving-part-one-of-a-three-part-series/>. [Accessed: 06-Feb-2020].
- [8] “A Different World; Society,” *General OneFile*, 03-Mar-2018. [Online]. Available: https://go-gale-com.portal.oaklandcc.edu/ps/i.do?p=ITOF&u=lom_oakcc&id=GALE|A529405535&v=2.1&it=r&sid=ITOF. [Accessed: 24-May-2018].
- [9] J. M. Anderson, N. Kalra, K. D. Stanley, P. Sorensen, C. Samaras, and T. A. Oluwatola, “Autonomous Vehicle Technology A Guide for Policymakers,” *RAND Corporation*, 22-Mar-2016. [Online]. Available: https://www.rand.org/pubs/research_reports/RR443-2.html. [Accessed: 24-May-2018].
- [10] M. Waldrop, “No drivers required: automation is one of the hottest topics in transportation research and could yield completely driverless cars in less than a decade,” *Gale Academic OneFile*, 05-Feb-2015. [Online]. Available: <https://go.gale.com/ps/anonymous?id=GALE|A400530208&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=00280836&p=AONE&sw=w>. [Accessed: 24-May-2018].
- [11] D. Schaper, “Human Errors Drive Growing Death Toll In Auto Crashes,” *NPR*, 20-Oct-2016. [Online]. Available: <https://www.npr.org/2016/10/20/498406570/tech-human-errors-drive-growing-death-toll-in-auto-crashes>. [Accessed: 24-Dec-2019].
- [12] “Road Safety Facts,” *Association for Safe International Road Travel*. [Online]. Available: <https://www.asirt.org/safe-travel/road-safety-facts/>. [Accessed: 15-Feb-2020].

- [13] R. Bailey, "Will Politicians Block Our Driverless Future? Autopia Is Within Our Grasp - If Government Doesn't Screw It Up," *General Reference Center GOLD*, p. 18, July 2016. [Online]. Available: http://link.galegroup.com/apps/doc/A454488534/GRGM?u=lom_oakcc&sid=GRGM&xid=aebf156e. [Accessed: 24-May-2018].
- [14] N. Kalra and S. M. Paddock, "Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?," *JSTOR*, pp. 1–16, 2016. [Online]. Available: www.jstor.org/stable/10.7249/j.ctt1btc0xw.1. [Accessed: 24-May-2018].
- [15] "From Here to Autonomy; Technology" "From Here to Autonomy; Technology," *General OneFile*, p. 7, 03-Mar-2018. [Online]. Available: https://go-gale-com.portal.oaklandcc.edu/ps/i.do?p=ITOF&u=lom_oakcc&id=GALE|A529405532&v=2.1&it=r&sid=ITOF&asid=f6. [Accessed: 28-May-2018].
- [16] B. Collie, J. Rose, R. Choraria, and A. Wegscheider, "The Reimagined Car: Shared, Autonomous, and Electric Vehicle," <https://www.bcg.com>, 18-Dec-2017. [Online]. Available: <https://www.bcg.com/publications/2017/reimagined-car-shared-autonomous-electric.aspx>. [Accessed: 28-May-2018].
- [17] B. Hayes, "Computing Science: Leave the Driving to It," *JSTOR*, pp. 362–366, 2011. [Online]. Available: www.jstor.org/stable/23019343. [Accessed: 28-May-2018].
- [18] W. H. Lucy, "Mortality risk associated with leaving home: recognizing the relevance of the built environment," *American journal of public health*, Sep-2003. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1448011/>. [Accessed: 28-May-2018].

- [19] A. Stutzer and B. S. Frey, "Stress That Doesn't Pay: The Commuting Paradox," *JSTOR*, pp. 339-366, 2008. [Online]. Available: www.jstor.org/stable/25195346. [Accessed: 24-May-2018].
- [20] B. K.-J. Mok, M. Johns, K. J. Lee, H. P. Ive, D. Miller, and W. Ju, "Timing of unstructured transitions of control in automated driving," *2015 IEEE Intelligent Vehicles Symposium (IV)*, 2015.
- [21] B. Mok, M. Johns, K. J. Lee, D. Miller, D. Sirkin, P. Ive, and W. Ju, "Emergency, Automation Off: Unstructured Transition Timing for Distracted Drivers of Automated Vehicles," *2015 IEEE 18th International Conference on Intelligent Transportation Systems*, 2015.
- [22] B. Mok, M. Johns, D. Miller, and W. Ju, "Tunneled In: Drivers with Active Secondary Tasks Need More Time to Transition From Automation," *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI 17*, 2017.
- [23] C. Gold, D. Damböck, L. Lorenz, and K. Bengler, "'Take over!' How long does it take to get the driver back into the loop?," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 57, no. 1, pp. 1938–1942, 2013.
- [24] T. Ito, A. Takata, and K. Oosawa, "Time Required for Take-over from Automated to Manual Driving," *SAE Technical Paper Series*, May 2016.
- [25] V. Melcher, S. Rauh, F. Diederichs, H. Widlroither, and W. Bauer, "Take-Over Requests for Automated Driving," *Procedia Manufacturing*, vol. 3, pp. 2867–2873, 2015.
- [26] R. M. V. D. Heiden, S. T. Iqbal, and C. P. Janssen, "Priming Drivers before Handover in Semi-Autonomous Cars," *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI 17*, 2017.

- [27] S. Epple, F. Roche, and S. Brandenburg, “The Sooner the Better: Drivers’ Reactions to Two-Step Take-Over Requests in Highly Automated Driving,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 62, no. 1, pp. 1883–1887, 2018.
- [28] A. Feldhütter, C. Gold, S. Schneider, and K. Bengler, “How the Duration of Automated Driving Influences Take-Over Performance and Gaze Behavior,” *Advances in Ergonomic Design of Systems, Products and Processes*, pp. 309–318, 2016.
- [29] Y. Nakajima and K. Tanaka, “Effects of active and passive secondary tasks in a take-over situation during automated driving,” *2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, October 5-8, 2017.
- [30] B. Wandtner, G. Schmidt, N. Schömig, and W. Kunde, “Non-driving related tasks in highly automated driving – Effects of task modalities and cognitive workload on take-over performance,” *AmE 2018 - Automotive meets Electronics*, March 2018.
- [31] B. Wandtner, N. Schömig, and G. Schmidt, “Effects of Non-Driving Related Task Modalities on Takeover Performance in Highly Automated Driving,” *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 60, no. 6, pp. 870–881, April 2018.
- [32] S. Brandenburg and S. Epple, “Designing the Transition from Highly Automated Driving to Manual Driving: A Study of Drivers’ Preferences,” *Proceedings of the 6th Humanist Conference*, Jun. 2018.
- [33] J. Radlmayr, C. Gold, L. Lorenz, M. Farid, and K. Bengler, “How Traffic Situations and Non-Driving Related Tasks Affect the Take-Over Quality in Highly Automated Driving,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 58, no. 1, pp. 2063–2067, 2014.

- [34] F. Naujoks, A. Neukum, and C. Mai, "The Effect of Urgency of Take-Over Requests During Highly Automated Driving Under Distraction Condition," *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014*, Jul. 2014.
- [35] N. Merat and A. H. Jamson, "How Do Drivers Behave in a Highly Automated Car?," *Proceedings of the 5th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design: Driving Assessment 2009*, 2009.
- [36] N. Merat, A. H. Jamson, F. Lai, and O. Carsten, "Highly Automated Driving, Secondary Task Performance, and Driver State," *Human Factors and Ergonomics Society*, vol. 54, no. 5, pp. 762–771, Oct. 2012.
- [37] D. Kern, M. Konersmann, S. Schneegab, and A. Schmidt, "CARS – Configurable Automotive Research Simulator," Sep. 2008.
- [38] S. Maganga, "Under the influence of ... Bob Marley, the timeless music man," *The Conversation*, 01-Oct-2019. [Online]. Available: <http://theconversation.com/under-the-influence-of-bob-marley-the-timeless-music-man-63347>. [Accessed: 19-Jan-2020].
- [39] M. Jones, "How McDonald's Played a Major Role in the Success of Chipotle," *Reader's Digest*. [Online]. Available: <https://www.rd.com/food/fun/mcdonalds-chipotle-success/>. [Accessed: 19-Jan-2020].
- [40] D. Walpole, "The Real Reason Guacamole Costs Extra in Restaurants," *Reader's Digest*, 22-Aug-2019. [Online]. Available: <https://www.rd.com/food/why-guacamole-costs-extra/>. [Accessed: 19-Jan-2020].

- [41] T. Pultarova, “Why Do Dogs Chew Everything?,” *LiveScience*, 05-Dec-2017. [Online]. Available: <https://www.livescience.com/61096-why-dogs-chew-everything.html>. [Accessed: 19-Jan-2020].
- [42] T. Zoellner, “Dreaming Up Disneyland,” *The New York Times*, 25-Nov-2019. [Online]. Available: <https://www.nytimes.com/2019/11/25/books/review/disneys-land-richard-snow-disneyland.html>. [Accessed: 19-Jan-2020].
- [43] “National Survey on Distracted Driving Attitudes and Behaviors – 2015,” *NHTSA*. [Online]. Available: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13123-2015_natl_survey_distracted_driving_031418_v5_tag.pdf. [Accessed: 19-Jan-2020].

Appendix

Driver Secondary Task Survey

Driver Secondary Task Survey

Section 1

Consent form

Introduction

You are being asked to be in a research study that is being done by Arsha Ali, Alaaldin Hijaz, Matthew Bellafaire, and Qinghua Chen under the direction of Dr. Wing-Yue Geoffrey Louie, Assistant Professor in Electrical and Computer Engineering Department, and Dr. Osamah Rawashdeh, Professor and academic programs coordinator, the faculty advisors for this project.

Your decision to participate in this study is voluntary. You can choose to stop your participation at any time or skip any part of the study if you are not comfortable. Your decision will not affect your present or future relationship with Oakland University, the researcher, the Electrical and Computer Engineering Department.

If you are a student or employee at Oakland University, your decision about participation will not affect your grades or employment status.

What is the purpose of this study?

The purpose of this research study is to determine the most common secondary tasks that drivers currently engage in while driving and what secondary tasks drivers think they may engage in as vehicle automation progresses. The information from this survey will help support future research regarding non-driving related tasks and semi-autonomous vehicles.

Who can participate in this study?

You are being asked to participate in the study because you are an adult (age 18 years or older), vehicle driver and have a driver's license. The survey will conclude immediately for those who indicate that they never drive. For those that indicate that they are under 18 years of age, the survey response will be removed from further consideration.

What do I have to do?

You will be asked to fill out a survey regarding driver secondary tasks.

How long will I be in the study?

The online survey will take approximately 5-10 minutes to complete.

Where will this study take place?

The survey is online using Google forms.

Are there any risks to me?

For this study, there are no known research-related risks or discomforts that we know about.

With many research studies, there is a risk that someone who is not part of this research may accidentally see your personal information. However, the survey does not collect any identifiable information. Safeguards will be in place to minimize this risk by keeping your research records as confidential as possible. When the results of this research are published or presented at conferences, no information will be included that personally identifies you.

Some questions may ask for information about your involvement in illegal activity related to driving. There may be possible social and legal consequences for you if someone who is not part of this study sees this information. We will try to make sure that this does not happen. However, this risk is low because no identifiable information is being collected.

Are there any benefits to me?

Although there may be no direct benefits to you, the results of this study may benefit others in the future. We hope that the data obtained from this study will help with future research regarding semi-autonomous vehicles.

Will I receive anything for participating?

You will not receive anything for participating in this study.

Who is the financial sponsor for this study?

The financial sponsor of this study is Dura Automotive Inc.

Who could see my information?

Your research records may be shared and reviewed by the following groups:

- Representatives of the Oakland University Institutional Review Board and/or other regulatory compliance staff, whose job is to protect people who are in research studies.
- Regulatory authorities who oversee research (Office for Human Research Protections, or other federal, state, or international regulatory agencies)
- The financial sponsor supporting the study and their agents or monitors
- All other survey information will only be accessible by the investigators, supervisors, and study personnel who work for the supervisors of the project

De-identified data may be used or distributed to another investigator for future research use without additional informed consent from you.

What if I want to stop participating in this study?

If you want to stop participating, close your browser before clicking 'submit.' If you click 'submit,' it will not be possible to stop participating.

Who do I contact if I have questions about this study?

Contact the primary researcher (PI) Alaaldin Hijaz, DH 106, phone number (248) 840 – 4517, email: ahijaz@oakland.edu.

Or the Co-PI Arsha Ali, EC-464, phone number: (248) 525-2932, email: arshaali@oakland.edu

Or the faculty adviser Osamah Rawashdeh, EC-446, phone number: (248) 370-2866, email: rawashd2@oakland.edu

For questions regarding your rights as a participant in human subject research, you may contact the Oakland University Institutional Review Board, 248-370-2762.

Signing the consent form

By clicking the box below, you agree to participate in this research. Please print a copy of this consent form for your information.

- I agree to be in this study.

Today's Date**FOR IRB USE ONLY**

This form was approved by the Oakland University Institutional Review Board on 3/10/2020 under IRBNet# 1484085.

Section 2

Please use the "Back" and "Next" buttons (shown in picture below) located at the bottom of this form to navigate through the survey. Using the forward and backward arrows on your browser may require re-entering your responses.



Gender

- Female
 Male

- Prefer not to say
- Other

Age: _____

Highest Educational Background

- Some high school, no diploma
- High School graduate, diploma or the equivalent (for example: GED)
- Some college credit, no degree
- Trade/technical/vocational training
- Associate degree
- Bachelor's degree
- Master's degree
- Professional degree
- Doctorate degree
- Other: _____

Are you currently a college or university student?

- Yes
- No

How often do you drive?

- Daily
- A few times a week
- A few times a month
- Rarely
- Never

If answer to previous question is Never, the survey is completed.

Section 3

Definitions:

Secondary Task - Any activity that could divert or distract a person's attention away from the primary task of driving.

Accident/Crash - A collision that occurs when a vehicle touches another vehicle, a stationary object, a pedestrian, or an animal.

Conditionally Automated Vehicle – An automated driving system monitors the environment and performs all aspects of driving when activated. With a request from the automated system, the human driver is expected to takeover and drive. The automated driving system is available under conditions for which it was designed.

Fully Automated Vehicle – An automated driving system monitors the environment and performs all aspects of driving when activated. With a request from the human driver, the automated system can deactivate. The automated driving system is available under all conditions.

On average, currently how long is your typical drive? Round up to the nearest choice.

- 0.5 hours or less
- 1 hour
- 1.5 hours
- 2 hours
- 2.5 hours
- 3 hours
- 3.5 hours
- 4 hours
- 4.5 hours
- 5 or more hours

What is the most common secondary task that you currently engage in while driving? Be specific.

How often do you currently engage in the above mentioned secondary task on a typical drive?

- Always
- Almost Always
- Sometimes
- Rarely
- Never

Imagine you are the driver in a conditionally automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

Imagine you are the driver in a fully automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

What is the 2nd most common secondary task that you currently engage in while driving? Be specific.

How often do you currently engage in the above mentioned secondary task on a typical drive?

- Always
- Almost Always
- Sometimes
- Rarely
- Never

Imagine you are the driver in a conditionally automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

Imagine you are the driver in a fully automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

What is the 3rd most common secondary task that you currently engage in while driving? Be specific.

How often do you currently engage in the above mentioned secondary task on a typical drive?

- Always
- Almost Always
- Sometimes
- Rarely
- Never

Imagine you are the driver in a conditionally automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

Imagine you are the driver in a fully automated vehicle. How do you think your engagement in the above mentioned secondary task would change in comparison to your current engagement on a typical drive?

- Increase
- Decrease
- Stay the same

As the driver behind the steering wheel, have you ever been in an accident, crash, or lost vehicle control in the past?

- Yes
- No

As the driver behind the steering wheel, has a secondary task ever caused you to get into an accident, crash, or to lose vehicle control in the past?

- Yes
- No

Section 4 (complete only if answer to previous question is Yes)

Definitions:

Secondary Task - Any activity that could divert or distract a person's attention away from the primary task of driving.

Accident/Crash - A collision that occurs when a vehicle touches another vehicle, a stationary object, a pedestrian, or an animal.

If a secondary task has caused you to get into an accident, crash, or to lose vehicle control in the past, what was the secondary task?

Section 5

Definitions:

Secondary Task - Any activity that could divert or distract a person's attention away from the primary task of driving.

Conditionally Automated Vehicle – An automated driving system monitors the environment and performs all aspects of driving when activated. With a request from the automated system, the human driver is expected to takeover and drive.

The automated driving system is available under conditions for which it was designed.

Fully Automated Vehicle – An automated driving system monitors the environment and performs all aspects of driving when activated. With a request from the human driver, the automated system can deactivate. The automated driving system is available under all conditions.

Imagine you are the driver in a conditionally automated vehicle. What do you think is the most common secondary task that you would engage in on a typical drive? Be specific.

Imagine you are the driver in a conditionally automated vehicle. What do you think is the 2nd most common secondary task that you would engage in on a typical drive? Be specific.

Imagine you are the driver in a conditionally automated vehicle. What do you think is the 3rd most common secondary task that you would engage in on a typical drive? Be specific.

Imagine you are the driver in a fully automated vehicle. What do you think is the most common secondary task that you would engage in on a typical drive? Be specific.

Imagine you are the driver in a fully automated vehicle. What do you think is the 2nd most common secondary task that you would engage in on a typical drive? Be specific.

Imagine you are the driver in a fully automated vehicle. What do you think is the 3rd most common secondary task that you would engage in on a typical drive? Be specific.

Section 6

Definition:

Secondary Task - Any activity that could divert or distract a person's attention away from the primary task of driving.

How often do you currently engage in each of these secondary tasks while driving on a typical drive?

| <u>Secondary Task</u> | <u>Always</u> | <u>Almost always</u> | <u>Sometimes</u> | <u>Rarely</u> | <u>Never</u> |
|--|----------------------|-----------------------------|-------------------------|----------------------|---------------------|
| Talk to other passengers in the vehicle | | | | | |
| Talk or interact with children in the back seat | | | | | |
| Interact with a pet or animal | | | | | |
| Eat or drink | | | | | |
| Make phone calls | | | | | |
| Answer phone calls | | | | | |
| Read, such as a book, newspaper, iPad or Kindle | | | | | |
| Read emails or messages | | | | | |
| Send messages or emails (keyboard) | | | | | |
| Send messages or emails (voice dictation) | | | | | |
| Do personal grooming, such as put on make-up, shave, or look at yourself in the mirror | | | | | |
| Adjust the car radio, tape, or CD player | | | | | |
| Adjust climate controls | | | | | |

| | | | | | |
|--|--|--|--|--|--|
| Adjust dashboard camera | | | | | |
| Change CDs, DVDs, or tapes | | | | | |
| Use a portable music player, including a smartphone, with headphones on | | | | | |
| Use a portable music player, including a smartphone, with external speakers or with the car's speakers | | | | | |
| Use a smartphone to search for a song, play a song, or skip a song | | | | | |
| Sing along to a song | | | | | |
| Use a smartphone for driving directions | | | | | |
| Use a GPS car navigation system for driving directions | | | | | |
| Record audio/video on a smartphone or camera | | | | | |
| Take pictures with a camera or phone | | | | | |
| Use an electronic device (e.g., smartphone, laptop, tablet, etc.) for social media | | | | | |
| Look up information on the Internet | | | | | |
| Use a laptop computer | | | | | |
| Watch television shows, movies, or clips | | | | | |
| Play an electronic game | | | | | |

| | | | | | |
|---|--|--|--|--|--|
| Play a non-electronic game | | | | | |
| Smoke/vape | | | | | |
| Daydream/get lost in thought | | | | | |
| Look at an outside person, object, or event | | | | | |
| Explore unfamiliar vehicle features (e.g., new display, adjust time, adjust seat) | | | | | |
| Get drowsy, close your eyes, or sleep | | | | | |
| Experience strong emotions | | | | | |

Section 7

Thank you for completing this survey. Please click the "Submit" button.