

# Attention Allocation in Automated Vehicles

Cailee Markosian

Department of Psychology, University of Utah

Among the advancements in technology over the past several years, autonomous vehicles are now commodities being made available for purchase in the public sphere. Increased automation may have implications on the attentiveness of the driver. Attention allocation in autonomous vehicles is of great interest in discerning where drivers attend their focus when not engaged in the task of manually operating the vehicle. To account for present and future levels of automation, the driving scenarios simulated freeway as well as urban environments. We found no significant differences in directed attention between manual and autonomous drives or between traffic related or unrelated scene types. Other findings show that arousal level (HR) did not affect participants' performance in the scene recognition task. This study motivates future research on ways to examine factors that affect attention while driving and implicates future safety design in automated vehicles to ensure that driver attention is being allocated to traffic relevant information.

## INTRODUCTION

### Attention Allocation

Attention in driving has been observed in regards to distracting influences such as texting, phone conversation, and other secondary tasks that are often performed while driving. Recognition tasks have shown that memory tends to be better when not involved in a secondary task, such as talking on the phone (Strayer, Drews, & Johnston, 2003). In a technologically developing world, driving is meeting higher degrees of automation that can afford the driver to engage in secondary tasks. This raises important questions for the amount of attention to the drive that can be maintained when driving in autonomous vehicles that afford less attentional demand.

When driving any vehicle, a driver is required to remain alert and attentive to the driving environment. When the driver fails to allocate attention to an unanticipated stimulus in a task, inattentive blindness can occur (Simmons, 2000). Mack and Rock (1998) gave participants a distracting task, and then presented an unexpected stimulus. When participants were later asked if they saw the unexpected stimulus, 25% reported they did not. Participants experienced the effects of inattentive blindness. When drivers are engaged in secondary tasks, inattentive blindness may arise as well (Strayer & Drews, 2007). The current state of semi-automation in consumer vehicles requires an operator to maintain attention to the driving task and be prepared to take over control of the vehicle at any moment (e.g., see Tesla, 2016). Where attention is being allocated may determine a driver's ability to respond to dynamic information in a driving environment.

To operate a vehicle safely and efficiently, a driver is required to maintain attention to driving related information; such as traffic lights, road signs, and pedestrians. A driver that shifts attention toward task unrelated stimuli, such as a billboard or a cell phone, is more likely to miss unexpected stimuli or events that may appear in traffic relevant areas. Strayer and Drews (2007) observed how engaging in a hands-free cell phone conversation while driving differs from speaking to a passenger by measuring the number of road

signs remembered after a simulated driving task. The data indicated that those who held a conversation on a hands-free cell phone remembered significantly fewer road signs than those who were speaking to a passenger while driving, conveying that cell phone conversations lower situational awareness. This would indicate that participants' voluntary attentional reserves were absorbed for the task of holding the phone conversation, rather than the driving scenario (Drews et al., 2007).

Inattentive blindness while driving is inherently dangerous when the operator of a vehicle does not have the needed level of engagement to detect important information, such as a construction zone sign or a pedestrian crossing the street. When a driver is not fully focused on traffic related information, inattentive blindness may arise, increasing dangerous driving conditions.

### Distracted Driving

The literature on attention allocation and task performance in vehicles raises the question of whether autonomous technology impacts the effects of distracted driving. The current state of semi-automation in consumer vehicles requires an operator to maintain attention to the driving task and be prepared to take over control of the vehicle at any moment (e.g., see Tesla, 2016). However, because drivers deliberately choose to engage in secondary tasks while engaged in manual driving, it is plausible that the same tendency to engage non-driving related activities could be even more pronounced in the context of automated driving. The implications of reduced attention are of immediate importance in semi-automated and automated vehicles when the system is taking away the operators control in driving, potentially allowing the driver to participate in secondary tasks such as cell phone conversations.

Research on distracted driving has found that even though people feel that it is unsafe, they still choose to engage in secondary tasks while driving (Overton, et. al, 2015). Recent advances in technology have attempted to cope with this undesirable fact by making the secondary tasks more efficient for the driver (Masterson, 2014). With automated driving, if a driver is not being obligated to pay attention to the

road because they are not physically operating the vehicle, their attention may be directed to irrelevant stimuli. Lack of attention to traffic relevant information becomes a risk when the driver needs to quickly reallocate attention back to the driving task after being distracted.

Funkhouser and Drews (in preparation) examined whether drivers opted to attend to secondary tasks or the driving environment while being driven autonomously. They found that those who attended to the driving environment were able to recognize more scenario objects and were faster at reacting to take control of the vehicle.

In another study, Funkhouser and Drews (2016) used a visual distractor task and found that increases in length of time a person is both distracted and not manually driving increases their reaction time to take control of the vehicle. McCarty, Funkhouser, Zadra, and Drews (2016) used an auditory task and asked the driver to maintain visual attention to the roadway. Both studies found that length of time under distraction was a factor in reaction time, regardless of type of secondary task, visual or audible.

In vehicles with higher levels of automation, drivers may be more likely to focus on other non-driving related tasks, such as using their phones, laptop computers, or fixating on other traffic unrelated information. In an environment with traffic and other moving vehicles, shifts of attention from the primary task of driving may have implications for the driver's ability to regain control of their vehicle.

## Physiological Arousal

In the context of driving, researchers have shown that increased heart rate (arousal) negatively correlates with reaction time (Funkhouser & Drews, 2016). For the current study, we are interested in whether arousal affects attention in driving and if arousal implicates the type of information (traffic related or unrelated) attended to.

Williams, Thayer, and Koenig (2016) found that higher vagal mediated heart rate variability (vmHRV) is correlated with better cognitive functioning in cognitively taxing tasks. Using heart rate to observe arousal, we will be able to examine if differences in heart rate between driving manually and autonomously is related to recognition task performance.

It has been shown that heart rate variability (HRV) is the physiological correlate of attentional control (Gillie, & Thayer, 2014). Ramirez, Ortega, and Reyes Del Paso (2015) asked participants to complete an Attention Network Task (ANT) and a Balloon Analog Risk Task (BART) to observe attention, risk aversion and decision making. Findings showed that individuals with greater high frequency-heart rate variability (HF-HRV) had greater attentional control and lower interference. This evidence is important in understanding why physiological arousal may be of importance when observing attention of an operator in a driving environment. Attentional control allows the operator to ignore distractors like traffic unrelated information and maintain focus to driving relevant information.

### Current Study

Previously mentioned studies have demonstrated that uses of cell phones reduce attention to both related and unrelated

environmental information and that both visual and audible secondary tasks reduce the ability to take over control of the vehicle. However, there is not research that explains where visual attention differs between a non-automated vehicle and a fully automated vehicle.

Our current study is built upon the research on attention allocation in manual and autonomous driving, distracted driving, and arousal (Strayer & Drews, 2007; Funkhouser & Drews, 2016; Funkhouser & Drews in preparation). We hypothesized that differences in attention allocation may be an additional factor in a driver's ability to retake control of the vehicle. In order to assess our hypothesis, we created a study to control for driving environments that non-automated and automated vehicles operate in now and the foreseeable future. Using both urban and freeway environments, findings would show that the overall category of items recognized (whether they are related or unrelated to the driving task) will be solely due to manual or autonomous driving. We also controlled for length of time spent in both driving scenarios, as previous studies have shown differences in outcomes depending on length of the drive. We hypothesized that participants would recognize more traffic-related scenes when driving manually and fewer when being driven autonomously.

## METHOD

### Participants

22 participants were recruited on a volunteer basis through a university research pool. Male and female participants between the ages of 18-52 years old were studied. All participants were licensed drivers with normal to corrected vision and were not color blind.

### Materials

The driving simulation took place in an RS 600 high-fidelity driving simulator with a Ford Focus Cab. The driving scenarios were programmed with HyperDrive Authoring Suite™ software. A Zephyr Biometrics heart rate monitor was used to measure heart rate throughout the duration of each drive to observe arousal throughout the scenarios. Before the beginning of the driving scenarios, demographic information and vehicle trust questionnaires were taken by participants to validate their driving experience, factors potentially affecting their driving, and their trust in automation. After both driving scenarios, participants completed the scene recognition task through a Qualtrics.

### Procedure

All 60 participants drove a 5 minute practice driving scenario to make sure they would not get motion sick and to become familiar with the driving simulator. Next, they drove one 20-minute scenario in either manual or autonomous mode before driving the remaining 20-minute scenario. The second driving scenario was counterbalanced against the first scenario to be the opposite of the driving mode (manual or autonomous) and the environment (urban or freeway). With

using different driving environments, we accounted for the types of environments autonomous vehicles operate in now as well as the foreseeable future.

At the end of completing the driving scenarios, the participants were given a surprise scene recognition task, modeled by a similar image recognition task done by Hopman and colleagues (2016). The scene recognition task consisted of 20 traffic-related and 20 non-traffic-related images taken from both the freeway and urban driving scenarios. There were an additional 40 distractor images from the same driving environments in the task that were not present in either of the driving scenarios. Participants were given the task on a Microsoft tablet in a survey platform where they answered yes or no to remembering an image of the different scenes from the driving scenarios. Individual differences in image recognition responses were accounted for by response sensitivity based on Signal Detection Theory (Snodgrass & Corwin, 1988).

## RESULTS

To measure the differences in attention allocation in autonomous and manual driving, we coded items from the driving scenarios as traffic related or traffic unrelated. We used identification scores from the surprise recognition task to calculate hits, misses, false alarms, and correct rejections. By using the sums of each category (H, FA, M, CR), participants' response sensitivity was analyzed with a log ( $\beta$ ) statistic and found that our participants had a negligible bias towards answering "yes" ( $M = -0.21$ ,  $SD = 0.35$ ). Overall performance was analyzed using a  $d'$  statistic given that the scene recognition task was equally weighted with real and distractor images. Participants had a negligible order effect in performance depending on whether they drove automatically or manually first. Overall memory performance was slightly better when driving autonomously first.

A 2-Way ANOVA was used to analyze the variance between autonomous and manual drives in both urban and freeway environments within-participants. As a group, there were no significant differences in overall performance on the scene recognition task between the autonomous and the manual drives. There was also no significant difference in scores between freeway and urban environments or between related and unrelated driving scenes.

To calculate differences in arousal (heart rate) between manual and autonomous mode, we controlled for individual differences in heart rate by recording resting heart rate (HR) along with their change in heart rate during each scenario. Participants showed that arousal does not affect the type of scenes the participants attend to or overall scene recognition task performance. There were no clear differences in arousal between driving manually or autonomously.

## DISCUSSION

This study was conducted to examine whether allocation of attention differs between driving autonomously or manually. Studies examining cognition in relation to cellular use show clear indication of attention deprivation (Hopman,

et.al 2016). Our present study used this previous research and applied it to driving both manually and autonomously. Data from our study showed that automated driving had no main effect on where attention was directed. We found no differences in overall quantity or content of scenes recognized. Arousal level also showed no differences between drives and did not affect overall scene recognition performance. We hypothesized that differences in attention allocation may be an additional factor in a driver's ability to retake control of the vehicle. Although the current study did not have significant findings, the question of differences in attention is still important in studying automation in vehicles. Further research should expand upon our findings to determine possible differences affect reaction time when cued to take control of the vehicle. Strategies for evaluating driver attention and vigilance when being driven autonomously is vital in order to ensure the driver maintains awareness of the state of dynamic driving environments. Furthermore, research on attention while driving should be examined with different levels of automation, as driver involvement reduces with increased automation.

## REFERENCES

- Garrison, T. M., & Williams, C. C. (2013). Impact of relevance and distraction on driving performance and visual attention in a simulated driving environment. *US: John Wiley & Sons*, 27(3), 396-405.
- Gillie, B.L., & Thayer, J.F. (2014). Individual differences in resting heart rate variability and cognitive control in posttraumatic stress disorder. *Front. Psychol.*, 15. Retrieved from <http://journal.frontiersin.org/article/10.3389/fpsyg.2014.00758/full>
- Funkhouser, K., & Drews, F. (2016). Effects of auditory working memory tasks while switching between autonomous and manual driving. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 60(1), 1741-1745.
- Hopman, R. J., Weissinger, K., Carlson, Goodman, C., MacNamee, K. F., Watson, J. M. & Strayer D. L. (2016). Measuring Cognition in Nature: An Exploratory Study using Electroencephalography: PNAS submission.
- Hopstaken, J. F., Van der Linden, D., Bakker, A. B., Kompier, Michiel A. J., Leung, Y.K. (2015). Shift in attention during mental fatigue: evidence from subjective, behavioral, psychological, and eye-tracking data. *US: American Psychological Association*
- Mack, A., & Rock, I. (1998). *Inattention blindness*. Cambridge, MA: MIT Press.
- Masterson, M. (2014) AAA: In-Car voice systems are still dangerous. *Speech Technology Magazine: Winter 2014*, 19(4), 9.
- McCarthy, M., Funkhouser, K., Zadra, J., & Drews, F. (2016). Effects of auditory working memory tasks while switching between autonomous and manual driving. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 60(1), 1854-1858.

- Oveido-Trespalacios, O., Haque, M.M., & King, M. Washington, S. (2016). Understanding the impacts of mobile phone distraction on driving performance: A systematic review. *Transportation Research*, 72, 360-380
- Overton, T.L., Rivers, T.E., Hecht, C., Shafi, S. & Gandhi, R.R. (2015). Distracted driving: prevalence, problems, and prevention. *International Journal of Injury Control & Safety Promotion*, 22(3), 187-192.
- Owner's Manual for Model S, Tesla Motors, Palo Alto, CA, 65-89 (2016). Retrieved from <https://carmanuals2.com/tesla/model-s-2016-owner-s-manual-89478>
- Ramirez, E. & Reyes Del Paso, G.A. (2015). Anxiety, attention, and decision making: The moderating role of heart rate variability. *International Journal of Psychology*, 98(3), 490-496.
- Simons, D. J. (2000). Attentional capture and inattention blindness. *Trends in Cognitive Sciences*, 4(4), 147–155. doi:10.1016/s1364-6613(00)01455-8
- Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *Journal of Experimental Psychology: General*, 117(1), 34.
- Strayer, D. L., & Drews, F. A. (2007). Cell-Phone-Induced driver distraction. *Current Directions in Psychological Science*, 16(3), 128–131. doi:10.1111/j.1467-8721.2007.00489.x
- Strayer, D.L., & Johnston, W.A. (2001). Driven to distraction: dual-task studies of simulated driving conversing on a cellular telephone. *Psychological Science*, 12(6), 462.
- Williams, D.P., Thayer, J.F., & Koenig, J. (2016). Resting cardiac vagal tone predicts intraindividual reaction time variability during an attention task in a sample of young and healthy adults. *Psychophysiology*, 53(12), 1843.