When Jesus Takes the Wheel: An Investigation of Distraction in Autonomous Vehicles

Ashleigh Wise
M.A., University of Kansas, 2017
B.A., Baylor University, 2015

Submitted to the graduate degree program in Psychology and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Chair: Michael Vitevitch, Ph.D.

Paul Atchley, Ph.D.

Derek Reed, Ph.D.

Andrea Greenhoot, Ph.D.

Omri Gillath, Ph.D.

Date Defended: 10 December 2019

The dissertation committee for Ashleigh Wise certifies that this is the
approved version of the following dissertation:

When Jesus Takes the Wheel: An Investigation of Distraction in Autonomous Vehicles

Chair: Michael Vitevitch, Ph.D.

Date Approved: 10 December 2019

Abstract

Autonomous vehicles have been suggested to be a solution to the problem of distracted driving. However, because autonomous vehicles are still developing, little is known about how drivers interact with them. Today's autonomous vehicles still require drivers to be available to take control quickly. If drivers are engaged in secondary tasks, they are less able to safely take control or detect system notifications to take control. Using the delay discounting method, the cognitive underpinnings of the human decision-making process can be understood to inform us of the extent to which drivers are willing to engage with a distraction. The current work found a distinct group of high impulsivity group who were more willing to engage with distraction sooner, opposed to the low impulsive group. Regardless of impulsivity group, willingness to engage with distraction decreased after driving a partially autonomous vehicle. This timing effect was present in subsequent analyses for the high impulsive group but not the low impulsive group. However, there was an interaction for timing and vehicle driven among both the high and low groups in which the high impulsive group generally became less willing to engage with distraction after driving the most vehicles, and the low impulsive group became more willing to engage with distraction. Also, the overall group was less willing to engage with distraction when hypothetically driving a standard vehicle than a fully autonomous vehicle. This effect was also found among the high impulsivity group but not the low impulsivity group. Finally, only the low impulsivity group reported less willingness to respond when the message was on the phone's screen rather than the vehicle voice system. However, there was an interaction with the message modality and timing. After driving, both the overall sample and low impulsivity group were less willing to respond to a message via the phone but more willing to respond via voice system. Examining driver behavior and cognitive demand in autonomous vehicles has critical implications for understanding how drivers interact with these vehicles. As autonomous vehicles become more mainstream, it becomes increasingly necessary for our safety to understand driver behavior in varying circumstances.

Table of Contents

List of Figures

Chapter 1 : The Problem of Distracted Driving

The World Health Organization (WHO) reported in 2012 that road traffic crashes are the leading cause of death for those 15-29 years old, followed by suicide, HIV/AIDS, and homicide. When traffic crashes do not result in death, the outcome is often still tragic; annually, an estimated 50 million people are injured worldwide as the result of road traffic crashes (World Health Organization, 2015). This growing epidemic is not limited to a single region nor is itexplainable by an “East vs. West” discussion, as traffic safety is a worldwide problem. However, road crashes are distinguished from these other causes of death because they are completely preventable. As a result, the traffic safety field, which is generally comprised of law enforcement, researchers, and advocates, prefer to refrain from referring to a crash or collision as an “accident” because there is always a cause for the collision—a cause that could have been prevented.

Among all driving behaviors, driving under the influence of a substance and distracted driving are among the most dangerous. When impaired by a substance, drivers have diminished perception, an increased reaction time, and a reduced information processing capability. They are also less able to concentrate and maintain control over speed, and are therefore more likely to crash than when sober (Howat, Sleet, & Smith, 1991; Moskowitz & Fiorentino, 2000; Zador, Krawchuk, & Voas, 2000; Compton, Blomberg, Moscowitz, Burns, Peck, & Fiorentino, 2002; Strayer, Drews, & Crouch, 2006). Though many efforts have helped to reduce the prevalence of driving under the influence of a substance, it remains a societal concern, as about 10,500 people were killed in crashes involving an impaired driver in 2016 (National Highway and Traffic Safety Administration, 2016). In 2014, the National Highway and Traffic Safety Administration (NHTSA) found in a roadside survey that nearly twenty percent of randomly selected road users tested positive for at least one substance that could affect safety (Berning, Compton, & Wochinger, 2015).

In comparison, distracted drivers are, broadly, less able to respond to stimuli and hazards on the roadway, which decreases their ability to control their lane position, maintain a consistent distance behind the leading vehicle, and appropriately brake. They are more likely to get into collisions than drivers only focused on the task of driving (Atchley, Tran, & Salehinejad, 2017). Comparatively, impaired drivers are four times more likely to get into a collision than non-distracted drivers (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). When driving while distracted by talking on their phone, drivers have a similar risk of getting into a collision as impaired drivers, but when distracted by a text message, drivers are five to six times more likely to get into a collision than when driving while impaired and twenty times more likely to get into a collision than the non-distracted driver (Klauer et al., 2006; Strayer et al., 2006; Virginia Tech Transportation Institute, 2009). However, distracted driving was reported to be more preventable than impaired driving in a survey of college students (Atchley, Atwood, & Boulton, 2011). Of the sample, only two percent reported that they never drove distracted. Similar estimates have found 69 percent of adults reported using their phones while driving (Centers for Disease Prevention and Control, 2013). Any estimate of distracted driving is likely to be underestimated due to social desirability bias. Distracted driving has been understood to be more dangerous than impaired driving and more preventable than impaired driving, and yet it remains a highly prevalent behavior.

Chapter 2 : Methods for Studying Distracted Driving

Distracted driving has been thoroughly investigated for over 50 years. These findings are overwhelmingly consistent that driving performance is degraded as the product of distraction

(Atchley, Tran, & Salehinejad, 2017). The field has used various methodologies to approach the problem. This section will provide a short summary of the methods widely-used to study distracted driving.

In-vehicle experimentation

An effective and ecologically valid way to evaluate driving behavior is to test drivers in vehicles. In-vehicle experiments can take place on a driving track or on roads. Two significant barriers to consider with in-vehicle experiments are the increased safety risk of driving while distracted and the cost of vehicles. Another limitation of in-vehicle experimentation is the potential lack of internal validity, as participant experiences can be impacted by the weather, road conditions, and unexpected construction. Regardless, driving behavior and participant secondary driving-related behavior has been studied in vehicles to understand a variety of constructs, including the measurement of cognitive demand associated with in-vehicle infotainment systems (IVIS; Strayer, Cooper, Goethe, McCarty, Getty, & Biondi, 2017), the effect of talking on a handheld phone while driving (Brookhuis, de Vries, & de Waard, 1991; Patten, Kircher, Östlund, & Nilsson, 2004; Lamble, Kauranen, Laakso, & Summala, 1999; Hancock, Lesch, & Simmons, 2003), and the effects of using voice-technology on driving performance (Ranney, Harbluk, & Noy, 2005). Each study found driving performance degradation as the product of distraction.

Driving simulator experimentation

One safe and cost-efficient alternative method of studying distracted driving is with a driving simulator. Driving simulators range in configurations but are typically high-fidelity fixed-base simulators with a virtual driving scene projected in front of the participant. Because of the high risk and high cost associated with a collision when driving a vehicle, many dangerous behaviors can be safely effectively studied in a simulator. Driving simulators have been used to study a range of driving behaviors such as the impact of hands-free phone conversations on driving performance (Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001; Strayer et al., 2006), driving behavior when engaged in a text message conversation (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009; Hosking, Young, & Regan, 2009; Rumschlag, Palumbo, Martin, Head, George, & Commissaris, 2014), and compensatory driving behaviors when distracted (Haigney, Taylor, & Westerman, 2000). Driving simulators provide a clean data output with relatively few cleaning procedures required by the researcher. They generally provide output of steering wheel position changes, lane position, speed, distance traveled, distance between vehicles, brake onset time and pressure, and frequency of crashes recorded. Overall, driving performance in a driving simulator was found to be degraded when distracted, and the use of driving simulators has been meaningful to help researchers pinpoint specific driving performance changes as the product of distraction. However, because the risk of driving is removed, participants have been observed to behave differently than they would in a real vehicle. Participants asking the researcher if they can crash the virtual car is a common occurrence. This observation among participants suggests that driving simulators, while they do offer benefits of efficiency and safety, are not the most ecologically valid way to measure distracted driving.

A notable finding from the previously discussed methods is the prevalence and high risk of text messaging while driving. Text messaging while driving is particularly risky because it includes a cognitive, visual, and manual component. Across all methods, text messaging had no associated measurements that found driving performance to be improved (Atchley et al., 2017). When attempting to text and drive, braking reaction time increases (Drews et al., 2005; Hosking et al., 2009; He et al., 2014), lane position is less stable (Drews et al., 2005; Hosking et al., 2009; He et al., 2014; Alvarez, Alnizami, Dunbar, Jackson, & Gilbert, 2015; Rumschlag et al., 2015; Thapa, Codjoe, Ishak, & McCarter, 2015), speed maintenance and following distance inappropriately fluctuates (Drews et al., 2005; Hosking et al., 2009; He et al., 2014; Thapa et al., 2015), crash risk increases (Drews et al., 2005; Hickman, Hanowski, & Bocanegra, 2010), and cognitive workload increases (Alvarez et al., 2015).

Observational studies

Another method for studying distracted driving in which drivers are not influenced by the presence of a researcher in the vehicle or nearby is to observe them anonymously. This method is particularly useful in measuring prevalence of distractions in a geographical area without having to control for a social desirability bias. This method has been used to examine prevalence of phone use at traffic signals and subsequent driver behavior (Huth, Sanchez, & Brusque, 2015), the impact of hands-free cell phone use while driving (Rosenbloom 2006), and glance behavior for road signs (Beijer, Smiley, & Eizenman, 2007). However, observation does not provide detailed information to the researcher regarding the specific secondary task drivers are engaged in or insight into the decision of why drivers choose to engage in secondary tasks. Further, observational data generally must be coded manually and can be very time intensive.

Archival studies

Like the observational method, archival studies are a way to obtain data regarding distracted driving without the influence of social desirability induced by the researcher's presence. The archival method has been used to understand prevalence of a variety of driving behaviors, including predictors of drinking and driving (Treno, Grube, & Martin, 2003) and trends in fatalities from distracted driving (Wilson & Stimpson, 2010). Generally, this data is maintained by independent agencies in each state and reported to a larger government organization, such as the National Highway and Traffic Safety Administration (NHTSA). However, because of the variation of collection between parties and organizations, this data can be inconsistent, and it does not capture the entire picture. For example, DUIs/DWIs involving drivers under the influence of a drug and drivers under the influence of alcohol are generally coded by policing agencies uniformly, and one cannot differentiate between them. Further, the number of citations issued by policing agencies is generally the primary data reported and the number of violation advisories (i.e., “warnings”) is not considered.

Survey studies

Surveys offer an alternative way to study prevalence and motivation in participants in a relatively quick manner. However, when reporting past behaviors or likelihood of a behavior, such as texting and driving frequency, participants are concerned about the stigma associated with reporting such conduct. Surveys have been successfully used to study the extent that anger, sensation seeking, impulsiveness, and boredom proneness can predict unsafe driving (Dahlen, Martin, Ragan, & Kuhlman, 2005), attitudes and prevalence of distracted driving (Tison, Chaudhary, & Cosgrove, 2011), and attitudes and prevalence of drowsy driving (Vanlaar, Simpson, Mayhew, & Robertson, 2008). However, surveys cannot capture driver behaviors when no actual driving is involved.

The delay discounting method

An alternative way to study the decision to drive distracted is the delay discounting method, which is rooted in behavioral economics. Behavioral economics refers to the application of economic concepts and approaches to the study of individuals’ choices and decisions controlled by reinforcement contingencies operating over extended periods of time (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014). The delay discounting method is one approach based on the decision-making paradigm that helps us understand how people value their decisions (Green, Fry, & Myerson, 1994; Myerson & Green, 1995). Delay discounting is a behavioral method that measures the value of behaviors based on the consequences of decisions. This method assesses the rate at which the value of a behavior decreases relative to other choices by presenting participants with choices between smaller/sooner rewards and larger/later rewards (Myerson & Green, 1995). The delay discounting method has been shown to be useful for studying humans' decision-making process (Doya, 2008), making it a robust way to understand the underlying behavioral-cognitive dynamics of decision-making (Matta, Gonçalves, & Bizarro, 2012).

Delay discounting implies that when a choice is made there is an automatic attribution of values for both the immediate choice and the delayed choice (Matta et al., 2012). These values are subjective and are associated with self-control. The value of delayed rewards decreases as a function of the delay interval, and depending on the rate at which a reward is discounted, preferences may shift in favor of a smaller but more immediate reward (Petry, 2001). To "discount" means to sacrifice reward value for time, or the ability to gain a reward sooner, even if it is smaller. Applying this concept to the current work, a "greater degree of discounting" in response to a message implies there is an inability to wait to respond to a message later and receive a larger reward. If participants prefer to respond to a message now and get a smaller reward, it would demonstrate that the message has value.

Prior research has used the delay discounting method to examine preferences as they relate to driving. The delay discounting method was applied and fitted with a hyperbolic delay discounting curve to conclude that college students who reported frequently texting and driving discounted a text message at a greater rate than a control group of students who did not report frequently texting and driving (Hayashi, Russo, & Wirth, 2015). Further, these findings support that texting and driving is an impulsive choice. The use of a hyperbolic curve and the application of the delay discounting method to distracted driving was validated by Hayashi, Miller, Foreman, and Wirth (2016). This work also found that students who reported texting and driving more frequently discounted at higher rates than those who did not report a high frequency of texting and driving. Additionally, this work found more of an emphasis on the message rather than money given when discounting. Finally, Hayashi et al. (2016) also found texting and driving to be an impulsive choice, suggesting the decision to be related to a more stable trait than a state.

An alternative application of the delay discounting method is to use a hypothetical situational approach. This approach validated a discounting procedure related to text messages and found greater phone dependence among individuals with a high rate of discounting compared to those with a low rate of discounting (Reed, Becirevic, Atchley, Kaplan, & Liese, 2016). Also using the hypothetical situational approach, Atchley and Warden (2012) found that using the delay discounting method was a useful and meaningful way to examine the choice to text and found that information is associated with a high value that subjectively decreases in value within minutes. Specifically, a text message lost 25 percent of its value, or was “discounted,” in ten minutes, compared to $100, which lost 25 percent of its value in 12 days. Further, this study found social distance influenced the decision to text while driving and the strongest urgency to respond was associated with a text message from a significant other (Atchley & Warden, 2012).

Another study used the delay discounting method to investigate the role of message immediacy on information processing and found participants had the strongest urgency to respond to messages received through a smartphone, regardless of the medium of the message (Wise, Atchley, & Salehinejad, in preparation a). Participants were asked to indicate their delay discounting preferences for responding to a message from their significant other that was presented either via text message, post-it note, or postcard. Participants indicated a preference to respond the most quickly in the text message condition but did not differ in preferences in responding to the post-it note and postcard modality. In the next experiment, participants were to indicate their delay discounting preferences between different types of instantaneous messages (i.e., text message, email, and voicemail) delivered via smartphone. Participants did not differ in their preference to respond to these different forms of instantaneous messages. These results suggest that the immediacy of the message influences the value associated with the message, and the instantaneous nature of digital communication is preferred.

The preference to respond to text messages delivered either via a handheld device or via an IVIS was also investigated (Wise, Salehinejad, & Atchley, in preparation b). This study found that participants preferred responding via the IVIS rather than the smartphone. Additionally, participants were presented the scenario in different hypothetical weather conditions and found that the value of the message superseded the risk of the weather. These findings suggest the perception that technology built into the vehicle is perceived as safe. Further, these findings suggested the decision to drive distracted was the most impacted by the value of the message rather than the risks associated with responding.

Chapter 3 : The Decision to Drive Distracted

The consequences of distracted driving have been well understood, leaving an important research question of why drivers choose to drive distracted. The delay discounting method is useful for examining the underlying mechanisms involved in the decision. However, investigation into why people choose to drive distracted has found that the decision is the product of a variety of factors.

Individual need for belonging

The need for belonging and connection with others is not society-specific but has rather been understood to be a fundamental human need (Baumeister & Leary, 1995; Lee & Robbins, 1995; Maslow, Frager, & Cox, 1970). Social capital is conceptualized as the total of resources that an individual will accrue due to a durable network of relationships of mutual acquaintance and recognition. These resources can either be actual or virtual (Bourdieu & Wacquant, 1992). Social capital has been associated with positive social outcomes at both group and personal levels. At the group level, a higher level of social capital is generally accompanied by an increased commitment to a community, better public health, lower crime rates, and more efficient financial markets (Helliwell & Putnam, 2004; Adler & Kwon, 2002). At a personal level, individuals with higher social capital have the option of drawing on the resources from those in their network (Paxton, 1999). Further, social capital has been related to self-esteem and life satisfaction, which are associated with psychological well-being (Bargh & McKenna, 2004; Helliwell & Putnam, 2004).

Since social capital is the product of connections, there are two further implications: one, that people spend a significant amount of time maintaining these relationships, (Ellison et al., 2007); and two, the absence of these connections should have negative consequences. When excluded in the classic virtual ball-tossing game paradigm, participants reported feeling ignored and excluded. This study was conducted using an fMRI and found increased anterior cingulate cortex (ACC) activity during social exclusion; however, right ventral prefrontal cortex (RVPFC) was more active during social inclusion and was negatively correlated with ACC activation during social exclusion. ACC activation has been associated with the experience of pain distress. On the other hand, the RVPFC has been associated with the regulation of pain distress and was associated with diminished distress after social exclusion in this study (Eisenberger, Lieberman, & Williams, 2003).

A product of social connections is the formation of larger groups of people unified by a similar set of ideals. In maintaining connections with others, one must conform to the ideals and patterns of a culture. Consequently, the ideals of a culture influence the individual and the individual also plays a role in influencing the culture.

Cultural factors influencing the decision to drive distracted

Other important motives in the decision to drive distracted are external factors. One powerful external factor is the influence of culture; specifically, the mutually constituted idea that one should be connected to others influences the mindset of individuals. The connected mindset is a set of attitudes an individual possesses to enable and encourage them to constantly engage with others through verbal and nonverbal communication. The concept of mutual constitution emerged as the idea that culture and the psyche reciprocally inform and influence each other, or rather, the idea that society constructs and maintains the materiality worlds that reflect intention, and in turn these worlds then impact the individuals within that society (Shweder, 1990). Consequently, through the lens of mutual constitution, to fully understand something, we must look at how mind and culture influence each other. What we build into our worlds reflects and expresses what we desire on a deeper level. The current section intends to examine the role of the connected mindset as it influences the decision to drive distracted, through the lens of mutual constitution.

In many instances, both researchers and media are quick to suggest an addiction to smartphones as some sort of pathology (Takao, Takahashi, & Kitamura, 2013; Chóliz, 2010, 2012; Roberts, Pullig, & Manolis, 2015) which causes a reliance on technology; however, the behavioral criteria used to determine disorders does not support this approach. The criteria for determining if a behavior is abnormal is based on the violation of social norms (i.e., deviance), statistical rarity, personal distress, and dysfunction (American Psychiatric Association, 2013). In previous generations and time periods, spending time on a device rather than with actual people would be a rude and unacceptable violation of other's time and would therefore be a violation of the social norm of what behavior is acceptable when with others. However, because social norms are determined by the culture and time in which they exist, the definition of a social norm is not fixed and can therefore reflect the connected preferences of individuals in that culture, which may then result in a cultural shift. Based on these criteria regarding deviance from social norms, the connected mindset would not be considered abnormal or a disorder. The next criterion is statistical rarity, which is important in understanding abnormal behavior because it is intended to be only a small percentage of the population which expresses the behavior. While there may be some individuals who do indeed show abnormal behaviors regarding connectedness to their phones, a large portion of the population displays the pattern of connectedness, and it therefore is not a statistical rarity. Next, personal distress as a criterion for abnormal behavior explains that an individual feels an aversive, self-focused emotional reaction to a behavior. Summarily, people find some sort of comfort or reward from social connection, so this criterion of an abnormal behavior does not apply to an over-connected behavior. The final criterion is dysfunction, where the behavior causes some sort of harm, either physically or socially, to the individual or others. This criterion may not be as immediately evident but may apply to the connected mindset because individuals may not be aware of the social harm they are doing to themselves or others as the result of being hyper-connected via technology. Generally, though some may exhibit abnormal behaviors regarding their technological connectedness, the overall population has the same orientation, and it should not be attributed to a single instance of an abnormal behavior or addiction, but rather as a culture-wide issue that has been embodied.

The development of the connected mindset

How children learn of an ideal is a primary mechanism of investigation when understanding the same ideal in a societal context. When exploring the connected mindset, we can begin by examining technology acquisition, or the age at which children first attain technology. In a survey of 2290 American parents, 53 percent of children had a cell phone by the age of seven (Gaston, 2015). When parents were asked about the reasoning for why they bought cell phones for their children, they reported that safety was a concern, and that cell phones enabled their children to keep in touch with family and friends. Of this sample, 20 percent also reported that they wanted their children to have cell phones to keep up with their classmates. Further, 83 percent of parents reported they had bought their child a television, 75 percent a tablet, 71 percent a handheld gaming system, 65 percent an eBook reader, and 51 percent had purchased their child a gaming system (Gaston, 2015). The implications of these data suggest that it is more common for children under the age of seven to have a cell phone than to not. These findings converge well with similar studies that take income into consideration. In a 2014 survey of an urban, low-income, minority community, 97 percent of children used mobile devices, with most having used the devices before the age of one (Kabali, 2015). Additionally, by the age of four, half of the children in the sample had their own television and three-fourths of children had their own mobile devices. By the age of two, most of the children in the sample used a device daily, and by the age of three and four, most children were able to use these devices without help. Further, one-third of the children in the sample engaged in media multitasking, in which they interact with multiple media sources over a short span (Kabali, 2015). These findings suggest that access to technology for children is no longer bound to income level, and there is an early adoption of technology that is accompanied by frequent and independent use and media multitasking.

In addition to the early age of technological acquisition, children also are occupied with mobile devices by their parents during times of limited social interaction. In a 2012 survey, only 20 percent of parents reported that they had never used a device to keep their child (age 18 and below) entertained (Richter, 2013). Of these, 61 percent had used a smartphone or tablet. These and similar devices have been regarded as the “21st century nanny” as they are an easy way for parents to distract their children that requires minimal effort (Richter, 2013). Parents reported giving their children devices while doing household chores, to keep them calm, and at bedtime (Kabali, 2015). Additionally, children’s usage of technology is reinforced by their parents’ affirmative attitudes after successfully distracting their children using technology.

In addition to the reward when technology is used, children also regularly observe their parents using technology and then engage in that behavior later as a product of observational learning. Rather than a purse, diaper bag, or snacks, the smartphone is now considered the one item that mothers feel they cannot leave the house without (Insight Central, 2016). Further, 81 percent of mothers reported they kept their smartphone near their bed at night, and 53 percent use the phone as an alarm clock. Additionally, approximately 40 percent of mothers reported using the phone to search the internet, 33 percent use it as a GPS device, 51 percent use the phone to connect to social media, and 57 percent use the phone to send text messages. Further, 57 percent admit to talking on the phone while driving, and 44 percent admit to text messaging while driving, even if children are in the vehicle (Insight Central, 2016). Consequently, the phone is present with the parent from their waking moment each day for a variety of uses, and therefore becomes modeled as such to children despite the risk of doing so. It comes as no surprise that children are frequently on their devices.

Global prevalence

Though one's access to technology, and therefore one's connectedness, was initially the product of their nation's economy (i.e., those in advanced economies used the internet more and tended to own more advanced technologies), worldwide access to technology is increasing. As of 2016, two-thirds (67 percent) of the world regularly used the internet (Pew Research Center, 2015). Though there is less usage of the internet in Africa and South Asia, global use is continually increasing. Further, almost half (43 percent) of adults worldwide own a smartphone (Pew Research Center, 2015). Consequently, it is becoming easier to be connected to people across the world. Our relationships are no longer bound to a single geographic area as the affordances to stay connected to others becomes widespread, and access to connections with others is no longer the product of privilege it once was. As the popularity of virtual connections increases and spreads globally, social norms must be developed to maintain these connections.

Though the connected mindset may be most visible in younger populations (i.e., adolescents) the use of technology to connect to others, especially through social media, is not limited to these populations. A reported 68 percent of all Americans used Facebook in 2016, which is the most popular social media platform (Pew Research Center, 2016). Though 88 percent of online adults age 18-29 have a Facebook profile, which is the largest representation among all age groups, 72 percent of online adults age 50-64 and 62 percent of online adults age

65 and older have a Facebook profile. Seventy-six percent of Facebook users report that they visit the site at least daily. Further, 56 percent of online adults use more than one of the five major social media platforms (i.e., Facebook, Twitter, Instagram, Pinterest, LinkedIn). These findings suggest that the need for connectedness is not limited to a single age group but is widespread within American culture. Social media offers a new way for individuals to connect and be affirmed by their social networks, thus creating a connected mindset wherein individuals seek out and add to their culture.

Consequences of constant connection

Since the explosion of technology in society, there have been notable behavioral changes in adolescents. Once archetypal teen activities have been replaced or modified because of technology's increasing role in social interaction. Adolescents now report spending time physically with their friends while simultaneously communicating with each other digitally on their phones (Twenge, 2017). However, teens are spending less time physically with their friends than previous generations. Twelfth graders in 2015 are going out less often than eighth-graders did in 2009. Of a sample of high school seniors in 2015, 56 percent reported going out on dates, whereas in the 2009 sample, 85 percent reported going out on dates. Further, the average age of receiving a driver's license has increased, the amount of underage drinking in high school has decreased, and the number of employed teenagers has decreased. These behavioral changes have coincided with the development and popularity of smartphones, which have been suggested to be the cause of these changes.

The more time teens spend looking at screens, the more likely they are to report symptoms of depression. Eighth graders who spend 10 or more hours a week on social media are 56 percent more likely to say they are unhappy than those who devote less time to social media

(Twenge, 2017). Further, in 2015, the Centers for Disease Control and Prevention (2016) reported the rate of females aged 15-19 who have self-harmed has increased by 20 percent since 2009. So, while in-person social behaviors and happiness have decreased, time invested with technology, for both entertainment and socialization, has rapidly increased. These findings suggest that social approval and acceptance has changed modalities from in-person verbal and non-verbal communication to a virtual form which may be one factor underlying the increased reliance on smartphones. Further, as an individual receives this social currency it becomes reinforced as a mindset, and they in turn seek out more of this reward and reciprocate this reward, informing the culture while also allowing the culture to inform their mindset.

As the widespread popularity of Facebook and other similar social media sites continues to grow, the previously proposed six degrees of separation between any two individuals in the world is now shrinking (Backstrom, Boldi, Rosa, Ugander, & Vigna, 2012). With more than 1.86 billion Facebook users, the average observed distance between individuals is suggested to be 4.74 and decreasing. Fifty-seven percent of teens reported that they had made a new friend online in the past year (Pew Research Center, 2015). However, of these, only 20 percent had met an online friend in person. These findings suggest that social networks are increasing because of social media and technology, but these same networks are primarily maintained virtually. So, while the world is shrinking in how we relate to others, the mechanisms that we utilize to relate to each other are also changing to become more technocentric.

Technological developments to enable connections

The overwhelming need for connection between individuals has not necessarily changed in nature but has changed mediums with the constant development of new technologies. The United States Postal Service reported that the average home only received a personal letter once every seven weeks in 2010, which is significantly less than in 1987 when a personal letter was received once every two weeks on average (Mazzone & Pickett, 2011). Furthermore, the amount of time spent talking on the phone decreased 25 percent between 2012 and 2015 (Gaskill, 2016). While these older communication modes have declined, others, newer modes, have increased. The first text message was sent in 1992. Since that time, text messaging has exponentially increased in popularity. Worldwide, roughly 561 billion text messages were sent in June of 2014 alone, or about 18.7 billion of text messages were sent per day (Burke, 2016). Texting has become “the preferred channel of basic communication between teens and their friends and cell calling is a close second” (Lenhart, Purcell, Smith, & Zickuhr, 2010; Subrahmanyam & Greenfield, 2008). It is “exploding” among teenagers, and the frequency of texting usage has now overtaken the frequency of every other common form of interaction with their friends such as cell phone conversations, social media networks, or face-to-face meetings (Lenhart, Ling, Campbell, & Purcell, 2010).

Unlike other communication mediums, text messaging provides more immediate gratification and reward. However, this gratification and reward tend to operate on a variable reinforcement schedule. As a result, the anticipation of receiving a text message has been associated with a more intense release of dopamine. This release of chemicals supplements preexisting dopamine reward pathways and have been understood to rival those associated with other highly addictive behaviors, such as sex (Weinschenk, 2012).

Although neither technology or phone addictions have been specified, habitual orientation, or automaticity, occurs when people instinctively and immediately attend to their phone when they are alerted of a notification. Responding to a phone may not only give the recipient an informational reward but may also be done habitually and without conscious thought. Furthermore, automaticity has been understood to predict text messaging while driving even when controlling for past texting frequency (Bayer & Campbell, 2012). However, this orientation to respond to messages may also be accompanied by a social pressure or expectation to respond to the message.

The connected mindset has been created as the product of increased technological development and access which itself has created an expectation that instantaneous messages require an equally instantaneous response. When examining expected response time, there are a variety of factors to consider, including the modality of the message, the sender, and the time of day. Regarding social media, 42 percent of users in a survey reported that they expect a response to a message sent via social media within 60 minutes, and 32 percent expect a response within 30 minutes (Baer, 2012). Further, the sender of a text message sent during work hours expects a reply from a client within one hour, between 15 to 60 minutes from a boss, within 15 minutes from a colleague, within 60 minutes from a family member, within 60 minutes from a friend, and within five minutes from a significant other (High-Touch Communications, 2013). When not during work hours, a reply to a text message is expected within 24 hours from a client, boss, and colleague, but within five minutes for a family member or romantic partner, and between five to 15 minutes from a friend.

During work hours, a response to an email is expected within four hours from a client, within one hour for a boss or colleague, between one and four hours for a family member, within 24 hours for a friend, and within four hours for a romantic partner. When not during work hours, a response to an email is expected within 24 hours for a client, boss, colleague, family member, and friend, but within one hour for a romantic partner. Finally, a response to a voicemail sent during work hours is expected within four hours for a client or friend, but within one hour for a boss, colleague, family member, and romantic partner. A response to a voicemail not sent during work hours is expected within 24 hours for a client, boss, colleague, and family member, within four hours for a friend, and within one hour for a romantic partner (High-touch Communications, 2013). These expectations and the discomfort associated with a violation of these expectations suggest the immersion of social norms for these connections and the embodiment of these cultural expectations in the individual mindset.

In addition to response expectations, there are implications of what not responding indicates. Not responding to a text message or taking too long to respond is proposed to be the first step in social rejection (Smith & Williams, 2004). This has been suggested because the lack of a response is an indication of a lack of care. Further, it has been suggested that not responding to a message also is a “no” response because silence is interpreted negatively (Tugend, 2013). Consequently, young adults are more threatened by the threat of social exclusion than the threat of injury or death associated with traffic collisions, and therefore are likely to make the decision to use their phone and text message while driving (Roberts, 2017). Rather than the presence of a pathological issue in a single individual, there exists a culture-wide preference to stay connected to others, which in turn influences individuals to remain connected constantly, this informs the culture, which again influences the individual mindset and so on, creating the cycle of the mutual constitution of the connected mindset.

To reduce the urgency associated with potentially missing out on a message, technology has been shaped to enable communication with others regardless of context. IVISs have been developed to deliver entertainment and information to drivers and passengers. The specific configurations of IVIS differ between vehicles and can be manipulated either by physical controls, by touchscreen input, or by input from Bluetooth devices. Further, different levels of capabilities between IVISs vary, but IVISs can be used to manage and play audio content, utilize navigation, deliver rear-seat entertainment, listen to incoming and send outgoing text messages, make phone calls, and access internet-enabled or smartphone-enabled content (Newport, 2004). When using an IVIS, drivers were observed to have impaired braking, shorter time-to-collision, and less stable lane position (Jamson & Merat, 2005; Santos, Merat, Mouta, Brookhuis, & de Waard, 2005). Further, the use of these systems has been associated with increased cognitive workload (Strayer, Cooper, Turrill, Coleman, & Hopman, 2015; Strayer, Turrill, Coleman, Ortiz, & Cooper, 2014; Strayer, Cooper, Goethe, McCarty, Getty, & Biondi, 2017). So, though the IVIS does offer more connectivity, it is associated with a degraded driver performance. Nevertheless, previous research has found that drivers were willing to engage with these systems and prefer using them over handheld smartphones to communicate with others, regardless of the risk (Wise et al., in preparation b).

An alternative to communicating through an IVIS is using smartphone digital assistants (SDA). SDA systems are configured differently based on the type of device. With these systems, users can complete a variety of tasks by verbally asking the system to complete a command. These tasks can include searching the internet for answers to questions, activating navigation to a destination, reading and dictating a text message, playing audio content, and placing calls. The widespread use of SDA systems in the vehicle have brought about deeper phone and vehicle integration, in which the SDA is routed through the IVIS to provide the user with an experience centered around their SDA rather than native IVIS. CarPlay and AndroidAuto are SDAs that have been associated with lower overall cognitive distraction than native IVIS systems but are still more cognitively demanding than a single task (Strayer et al., 2018). Consequently, although these systems can be completed without the use of one’s hands, they are still a cognitive distraction that typically becomes a visual distraction as well. Further, the cognitive demand of completing these tasks is greatly increased. Residual cognitive demand does not return to baseline until nearly 20 seconds after the completion of a task (Turrill, Coleman, Hopman, Cooper, & Strayer, 2016). These findings suggest that while SDA systems are convenient to use, both on the phone and through the IVIS, they are not a safe way to use a smartphone while driving.

Generally, there are few or no negative consequences of being overly connected with technology. However, when attempting to use that technology when driving, the costs of error are far more serious. Though technological advances offer alternative ways to stay connected to others while driving, these advances do not remove the risk associated with these tasks. As a result, the natural progression of this trend is to develop a way to allow individuals to remain in communication with others while traveling. This has been suggested to be one potential benefit of autonomous vehicles.

Chapter 4 : Autonomous Vehicles

Autonomous vehicles can drive themselves on existing roads and can navigate many types of roadways and environmental contexts with almost no direct human input (Fagnant & Kockelman, 2015). Autonomous vehicles are presented as an alternative to vehicles that must be driven manually and require drivers to be fully engaged to maintain safety. In 2004, the Defense Advanced Research Projects Agency (DARPA) launched the Grand Challenge, with the goal of demonstrating autonomous vehicle feasibility. To successfully complete this challenge, vehicles had to navigate a 150-mile route while obeying traffic rules, overcome blocked routes, and maneuver around obstacles in a realistic scenario. By 2007, six teams successfully completed this challenge (Defense Advanced Research Projects Agency, 2012). Since then, the popularity of autonomous vehicles has been increased by Google’s self-driving cars, which have reportedly driven over 700,000 miles on California public roads, and the release of the Tesla Model S, which came equipped with Autopilot features with autonomous capabilities in 2015 that could be purchased (Anthony, 2014; Ziegler, 2015).

How autonomous vehicles function

Autonomous vehicles have been a lofty goal for decades, requiring cooperation from a variety of disciplines to successfully enable a vehicle to function as a human would without traditional human input. To accomplish this, autonomous vehicles must be equipped with a variety of systems that interoperate with an assortment of functions, including environment perception, localization, planning, and control (Levinson et al., 2011; Aeberhard, 2015). To make these functions possible, autonomous vehicles come equipped with advanced hardware. Sensors capable of exceeding the abilities of human drivers enable the vehicle to sense their environment (Rychel, 2017). These sensors include ultrasonic sensors, image sensors, radar sensors, and LIDAR sensors. Ultrasonic sensors send out sound waves, and when the wave contacts an object, an echo is reflected to the sensor to reveal the precise location of obstacles. Ultrasonic sensors are used in autonomous vehicles to detect objects in the immediate vicinity of the vehicle and are critically important for navigating congested roadways and executing autonomous parking functions. However, ultrasonic sensors can only be used at very low speeds. Image sensors generate images of the vehicle’s surroundings, which imitate human eyesight and are capable of three-dimensional vision. These sensors can detect colors and fonts, which enables the system to detect and interpret traffic signs, signals, and lane markings. Currently, image sensors have a limited range that is further impeded by weather limitations. Separately, radar sensors transmit electromagnetic waves. When these waves contact an obstacle, they are reflected to the sensor and reveal the distance and speed of the object. The electromagnetic waves are transmitted by short and long-range radars transmitters around the vehicle to track the speed of other vehicles, but the technology cannot currently determine an object's height. Light detection and ranging (LIDAR) sensors are the final type of sensor. LIDAR sensors emit a low intensity, non-harmful, and non-visible laser beam to visualize objects and their ranges, then create a three-dimensional image of the vehicle's environment. The information from these sensors is mapped onto real-time map data maintained in the cloud. The cloud compiles and updates the information from all the sensors to allow the vehicle to more accurately anticipate what is upcoming on the roadway (Rychel, 2017).

Levels of automation

Currently, vehicles are not rigidly autonomous, as there are various levels of partial automation available. To differentiate between amounts of automation, definitions for each variation have been established (National Highway and Traffic Safety Administration, 2013). A Level 0 vehicle has no automation, and the driver is in complete and sole control of the primary vehicle controls. Included in this level are autonomous warnings (i.e., forward collision warning, lane departure warning, blind spot monitoring) and autonomous secondary functions (i.e., headlights, wipers, etc.). A Level 1 vehicle has function-specific automation, which involves one or more specific control functions. In this level, the driver has overall control and is solely responsible for safe operation, but the vehicle may have capabilities combining individual driver support and crash avoidance technology that does not replace driver vigilance and does not assume driving responsibility. Examples of function-specific automation systems are adaptive cruise control, automatic braking, and assisted lane keeping. Next, a Level 2 vehicle has combined function automation in which there is automation of at least two primary control functions, which are designed to work in unison to relieve the driver of control of those specific functions. In this level, the driver is still responsible for monitoring the roadway and is expected to always be available for manual control on short notice. A combined function autonomous vehicle could allow the driver to engage in adaptive cruise control combined with lane centering. This is differentiated from the previous level in that there are two functions engaged simultaneously. In comparison, a Level 3 vehicle has limited self-driving automation which enables the driver to cede full control of all safety-critical functions under specific traffic or conditions. Though the driver has ceded control, the driver is still required to monitor for changes in conditions should it become necessary to transition back to driver control, which is expected to occur occasionally. This level is differentiated from the previous level in that the driver is not expected to be constantly monitoring the roadway while driving. An example of this level is an autonomous vehicle that can determine when the system can no longer support automation, such as a construction area, at which time the vehicle would signal to the driver to take control. Finally, a Level 4 vehicle has full self-driving automation and is designed to perform safety-critical driving functions and monitor roadway conditions for an entire trip. Though the driver is expected to input the destination, the driver is not expected to be available for control during the trip (National Highway and Traffic Safety Administration, 2013). These defined levels are important for understanding the capabilities of a vehicle, as well as the expectations of the driver and are useful when purchasing, designing, licensing, and creating policies for autonomous vehicles.

Benefits of autonomous vehicles

Autonomous vehicles, when equipped with a variety of sensors that can function more effectively than a human, promise the potential of safer roads. Over 90 percent of crashes are believed to be the product of driver error, to include errors related to alcohol, distraction, drugs, and fatigue (National Highway Traffic Safety Administration, 2008). Because autonomous vehicles are programmed to follow the law, they are more likely to complete the trip in a safe manner without falling prey to human error. Thus, in a perfect world autonomous vehicles could hypothetically prevent almost all crashes, which translates roughly to saving over 30 thousand lives and preventing injuries from over 2.2 million crashes in the United States (Fagnant & Kockelman, 2015; National Highway Traffic Safety Administration, 2013; Traffic Safety Facts, 2013).

In addition to removing human error from collisions, autonomous vehicles could potentially reduce traffic congestion. Autonomous vehicles are programmed to sense and anticipate the braking and acceleration decisions of the vehicles around it, which can lead to smoother braking and finer speed adjustments when following vehicles (Fagnant & Kockelman, 2015). These adjustments would reduce gaps between vehicles, which would lead to a reduction in congestion on crowded roadways and further reduce the risk of human-error collisions due to failures of attention or misjudgments. Further, the reduction of congestion would result in the more efficient use of roadway capacity, which reduces travel time and fuel usage (Fagnant & Kockelman, 2015; Bose & Ioannou, 2003).

With changes in the vigilance required to safely operate a vehicle, the potential of fully autonomous vehicles suggests increased mobility for those previously unable to drive, such as children, the elderly, and drivers with disabilities. For these non-traditional drivers, appropriate autonomous vehicle licensing policies must be implemented to ensure the driver could safely take over control of the vehicle in the event of an unforeseen emergency. With this option, however, drivers who were either previously engaged in self-regulated driving behaviors, such as avoiding heavy traffic, night driving, and poor weather could potentially be safer travelling to destinations with autonomous vehicles (Wood, 2002; Fagnant & Kockelman, 2015).

In addition to increased safety for the drivers of autonomous vehicles, pedestrian and cyclist injuries and deaths could also be reduced as the result of autonomous vehicles. Though these road users are still at risk of not being detected, the advanced sensors in autonomous vehicles are theoretically likely to detect pedestrians and cyclists earlier and more consistently than human drivers (Fagnant & Kockelman, 2015; Rychel, 2017).

Barriers in implementation of autonomous vehicles

Though autonomous vehicles offer compelling benefits, as with any developing technology, they also come with barriers to implementation. One significant barrier is the purchase price. On average, autonomous vehicles cost $15,000 to $50,000 more than their non-autonomous counterparts with additional hardware costs (Shchetko, 2014; Boesler, 2012; Fagnant & Kockelman, 2015). Dellenback (2013) estimates current civilian autonomous vehicles in total will cost over $100,000 each. The current novelty of autonomous vehicles is one contributing factor of their high cost. Additionally, LIDAR technology is very expensive, so reducing the cost of autonomous vehicles and associated demand would either require using non-LIDAR sensors or a reduction in their price (Shchetko, 2014).

Although autonomous vehicles can be purchased by consumers for a high cost, these vehicles are associated with a variety of concerns. A recent international survey suggests that consumers were highly concerned about software hacking/misuse and legal issues, which would prevent them from purchasing an autonomous vehicle (Kyriakidis, Happee, & de Winter, 2015; Schoettle & Sivak, 2014). As with any connected technology, there is potential for unethical hacking to occur, which consumers will have to be assured is unlikely. Further, legal issues concerning autonomous vehicles in the immediate future will be maintained under pre-existing policies regarding non-autonomous vehicles, but they will likely evolve in the coming years. Fortunately, the classification of autonomous vehicles has provided some preliminary criteria for future decisions.

Among the most significant barriers involved with autonomous vehicles is the concern for safety. These consumer worries are not without warrant as reports of autonomous vehicle collisions are widely disseminated, with particularly salient examples including an autonomous vehicle in autopilot mode that collided with a parked firetruck on a highway (Stewart, 2018). According to the Tesla Model S owner's manual, Autopilot is "a hands-on feature… [and drivers should] hold the steering wheel and be mindful of road conditions and surrounding traffic" (Tesla Motors, 2016, p. 82). However, this is counter to the expectations of consumers, as indicated in a survey finding that only 15 percent of a sample of 5000 drivers reported that they would not engage in secondary tasks while driving an autonomous vehicle (Kyriakidis et al., 2015). As drivers begin to conduct other tasks while behind the wheel of autonomous vehicles, their risk of not responding safety alerts to take manual control increases, which may lead to collisions. Previous research has found that driving while completing secondary tasks of varying levels of cognitive engagement are all associated with an increased reaction time to stimuli (Strayer & Johnston, 2001). Further, when attempting to multitask, drivers required an average of 18 seconds to dis-engage from the secondary task and reengage in the primary task of driving, which suggests a residual cognitive demand in multitasking while driving (Turrill, 2016). These results suggest that a warning communicating the need to take over must be appropriately timed so a driver can be fully engaged in the driving scene in order to operate the vehicle safely.

Previous research in autonomous driving

Given the ambitious nature of autonomous vehicles, extensive design and technology research has been conducted regarding their feasibility and the advances of autonomous vehicles (Levinson et al., 2011; Aeberhard, 2015; Frazzoli, Dahleh, & Feron, 2002; Saffarian, de Winter, & Happee, 2012). Further, the human factors components of hypothetical autonomous vehicles have been thoroughly investigated but have not been verified on actual vehicles (Hoogendoorn, van Arem, & Hoogendoorn, 2015; Merat, & Lee, 2012; Saffarian, de Winter, & Happee, 2012). Limited research has been conducted regarding driver behavior while operating autonomous vehicles.

Much of the previous research on autonomous vehicles has regarded drivers' trust in the vehicles. Trust can be defined as "the attitude that an agent will help achieve an individual's goal in a situation characterized by uncertainty and vulnerability" (Lee & See, 2004, p. 54). Trust has been an important research area regarding automation, as without an appropriate level of trust, people may refuse to use the technology, or they may misuse the technology if they have too much trust in its abilities (Parasuranman & Riley, 1997). Further, the benefits of automation are not possible if drivers are not willing to trust and use these systems. In a survey regarding factors that influence trust in autonomous vehicles, participants reported statistics of the vehicle's past performance, extent of external research on the vehicle's reliability, personal research on the vehicle, and the existence of error as the factors that most influenced their trust in automation (Carloson, Desai, Drury, Kwak, & Yanco, 2014). In a study utilizing a driving simulator, driver behavior and intervention was influenced by trust in the vehicle. Specifically, the more trust the participant reported in the autonomous system, the more disconnected the driver was from the driving activity, which can lead to difficulty when manual control is necessary (Payre, Cestac, &

Delhomme, 2016). However, the authors caution against generalizing from these findings because of the study’s use of a driving simulator, which had little implications of any real danger. Regardless, these findings suggest that trust in autonomous vehicles influences the likelihood of consumers purchasing and utilizing such a vehicle, as well as the driver’s behavior when faced with taking over control from the vehicle.

Just as trust influences a driver’s behavior and urgency to take over control from the vehicle, a driver’s experience with the vehicle after a required takeover of control influences their trust. In an investigation using a driving simulator, drivers reported their trust of autonomous vehicles before completing a simulated autonomous drive in which the drivers encountered a situation that required them to take over control. After completion of these brief drives, drivers again reported their trust of autonomous vehicles. Drivers reported a higher level of trust in automation than their original level of trust (Gold, Körber, Hohenberger, Lechner, & Bengler, 2015). However, when drivers do take control of the vehicle, their level of engagement and performance may be impacted by the type and level of automation. Specifically, when a lane keeping system is assisting the driver, they have decreased visual attention to the roadway (Carsten, Lai, Barnard, Jamson, & Merat, 2012). In a similar simulator study evaluating driver behavior when manual control was required after a takeover, drivers had less stable lateral control (i.e., lane keeping) and visual attention. Drivers generally took about 15 seconds to resume control over the vehicle but did not have complete control of driving performance until after about 40 seconds, which has implications for warning timing recommendations (Merat, Jamson, Lai, Daly, & Carsten, 2014). Further, a variety of factors influence the success of a driver’s take-over of control in an autonomous vehicle. One critical factor is the volume of traffic. Interestingly, the volume of traffic does not influence the time required for takeover, but it did influence the performance of the takeover. The presence of traffic had a negative influence on takeover performance (Gold, Körber, Lechner, & Bengler, 2016). Another critical factor that influences the success of the driver's takeover of the vehicle is their engagement in other activities. In higher levels of autonomous vehicles, drivers were observed to engage in secondary activities more frequently, likely because of reduced cognitive workload. When the driver needed to resume control of the vehicle, attention to the roadway was impacted and driver performance was deteriorated as the product of these distractions (Jamson, Merat, Carsten, & Lai, 2013; Merat, Jamson, Lai, & Carsten, 2012). These poor performance episodes are suggested to be the product of a dangerous and sudden change in workload, which can be detrimental to driving safely (Rudin-Brown & Parker, 2004). When the vehicle is in autonomous mode, the vehicle is not impacted by the driver's decision to be distracted. However, when the vehicle requires the driver to take over control with little or no warning and the driver is engaged in secondary tasks, the driver is less capable of quickly, safely, and effectively taking over control. Consequently, the nature of distracted driving has now shifted. There is now a need for research into understanding the extent to which a driver is willing to engage with distractions while operating an autonomous vehicle and how this willingness to engage with distraction manifests itself in driving performance.

Behavioral investigations of autonomous driving are currently limited by scope and methodology. Attitudes toward autonomous vehicles, as previously discussed, have been investigated using survey methodology. However, these important findings are limited in nature and cannot inform us of individual differences in driver behavior while operating autonomous vehicles. Previous work with autonomous vehicles has been conducted using driving simulators (Gold et al., 2015; Gold et al., 2016; Merat et al., 2012; Jamson et al., 2013; Rudin-Brown, &

Parker, 2004). As with any work utilizing simulations, this method is useful for investigating dangerous conditions in a safe and cost-effective manner. However, this work should be accompanied by on-road investigations, which are currently absent from the literature. On-road behavioral investigations in autonomous vehicles are now vital to understand this new arena of driver behavior. Further, on-road investigations with autonomous vehicles are necessary to understand how findings in this setting converge with previous investigations using simulators and evaluating attitudes.

In sum, there are several ways to evaluate distracted driving. Distracted driving is known to be a dangerous activity, and yet, distracted driving persists as a common behavior. The delay discounting method is a useful way to understand the underlying decision-making process of the choice to drive distracted. The motivation to drive distracted is internally driven by the fundamental need to belong, which manifests itself in constant communication using instantaneous messages via smartphone. Further, culture has influenced the motivation to drive distracted through the cycle of mutual constitution in which culture and mindset create each other.

A new prospect in technological advances is autonomous vehicles, which offer the potential to remain in contact with others and engage in secondary tasks while traveling without risk. However, autonomous vehicles are still in their beginning stages of development and the current consumer products require human engagement and attention. To date, few studies have investigated the behavioral changes associated with autonomous driving. Driver behaviors have not been extensively studied in autonomous vehicles. By using the delay discounting method, I examined the decision to engage in distraction while driving an autonomous vehicle, how this decision influences driving performance, and how this decision is influenced by one's experience with an autonomous vehicle.

Chapter 5 : The Current Work

The current work investigated willingness to engage with distraction through the implementation of the delay discounting method, how this willingness impacts driver behavior in a manual and autonomous drive, and how this willingness changes after experience with an autonomous vehicle. This work is unlike previous research in the investigation of the new problem of autonomous driving as it is using a unique method of delay discounting with unique materials-autonomous vehicles.

The most ecologically valid way to evaluate driver behavior is to evaluate drivers on an actual drive. Using three autonomous vehicles, drivers completed two long drives. To ensure safety of the driver and researcher, only drivers with a clean driving record who have completed a defensive driving course were eligible to participate. The use of in-vehicle experimentation is preferable to driving simulator experimentation in order to maintain realistic and generalizable findings. When driving in a simulator, drivers are not threatened by the risks of the road and are willing to drive more aggressively with riskier maneuvers. When operating an actual vehicle, drivers recognize the risk of the situation and must be cognizant of real factors while navigating. The current work further informs us of how information is meaningfully prioritized when an individual in faced with social information from their devices, safety information from the vehicle, and travel information from the roadway.

Chapter 6 : Method

Participants

Sixty-three participants ranging from 25 to 36 years old (M_{Age}= 29, *NMale*= 42) were recruited using the University of Utah Center for Distracted Driving Research participant database and online advertising sites. Participants were compensated $20 per hour for their participation, which took approximately four hours. To be eligible for participation, participants were required to be 21 to 36 years old, have a valid driver's license, have no at-fault collisions within the past two years, and have proof of vehicle liability insurance.

Materials

Autonomous vehicles. Three vehicles were used for testing participants that allow for both manual and partially autonomous driving: a 2018 Cadillac CT6, a 2018 Volvo XC90, and a 2017 Tesla Model S.

Cadillac CT6. The Cadillac CT6 is equipped with the "Super Cruise package," which is an advanced adaptive cruise control option. Once the driver is centered in the lane, the vehicle utilizes cameras, sensors, and an advanced global positioning system (GPS) to maintain the vehicle's position in the center of the lane while maintaining a safe distance behind the vehicle in front of it (General Motors, 2018). Because the system utilizes GPS, the partially autonomous features are not available for use on all roadways. The CT6 is classified as a level two autonomous vehicle. The CT6 also utilizes infrared cameras to detect driver eye position to ensure the driver is continually paying attention to the forward roadway. Should the cameras detect the driver's eyes divert from the roadway, the vehicle warns the driver to focus on the roadway via a vibrating motor below the seat.

Volvo XC90. The Volvo XC90 is equipped with cameras, radar, sensors, LIDAR, and a three-dimensional map that can detect close range objects and obstacles ahead, and can monitor lane markings, even at low speeds. The vehicle's radar transmitters provide a detailed, 360-degree view of its surroundings and help the driver change lanes by detecting vehicles approaching from behind. A multiple-beam LIDAR scanner with a 150-meter sensitivity range located at the front of the vehicle provides early warnings to drivers of hazards. Finally, a three-dimensional digital map operates with a GPS interface to inform the driver where they are located and what objects are surrounding the vehicle, as well as the most efficient route to their destination (Volvo Car Corporation, 2018). The XC90 is classified as a level two autonomous vehicle. The ensure the driver is maintaining a safe driving position, the XC90 requires the driver's hands to be on the wheel continually. Should both of the driver's hands not be detected on the wheel, drivers are visually warned to place their hands back on the wheel.

Tesla Model S. The Tesla Model S is equipped with cameras to provide a 360-degree view around the car with a 250-meter range. The Model S is also equipped with ultrasonic sensors to detect both hard and soft objects. A forward-facing radar provides additional information about the vehicle's surroundings with the ability to "see" through rain, fog, dust, and surrounding vehicles (Tesla, 2018). The Model S is classified as a level two autonomous vehicle. The Model S requires drivers to keep both hands on the wheel to ensure they are fully able to take control quickly if needed. If both hands are not detected on the wheel, drivers are visually warned by a red light in the instrument cluster. Should drivers not respond to the warning, the vehicle will "ding" at the driver as a reminder to replace their hands on the wheel. Should the driver continue to fail to place their hands on the wheel, the adaptive cruise control and lane keeping functions will be deactivated and will not be reactivated until the car has been powered off.

Delay Discounting Questionnaire. Delay discounting is a method that has been used to study impulsivity-related behaviors by assessing the rate at which the value of a behavior decreases relative to other choices. Participants are given choices between smaller/sooner rewards and larger/later rewards. In the current work, participants viewed a scenario in which they received a text message from their significant other which read, "Contact me when you can." This scenario was selected to induce the most urgency in the participant (Atchley & Warden, 2012). Participants indicated their preference between replying immediately for a smaller hypothetical monetary reward (11 values between $5 and $95) or after a delay (one minute, five minutes, 30 minutes, one hour, and eight hours). The values for the smaller rewards and length of delays were adopted from previous work (Atchley & Warden, 2012). Additionally, the scenario was presented in the context of four circumstances, in a two-by-two design: 1) the message was presented on the participant's smartphone screen while driving a vehicle with no autonomous capabilities, 2) the message was presented on the participant's smartphone screen while driving a vehicle with full autonomous capabilities, 3) the message was presented over the vehicle's voice response messaging system while driving a vehicle with no autonomous capabilities, and 4) the message was presented over the vehicle's voice response messaging system while driving a vehicle with full autonomous capabilities. All four scenarios were randomly presented, and participants indicated their preference for all 11 smaller/sooner rewards across all five delays for each scenario.

Barratt Impulsiveness Questionnaire (BIS-11). The BIS-11 is a widely used impulsivity scale intended to measure the personality/behavioral construct of impulsiveness

(Patton, Stanford, & Barratt, 1995; Stanford et al., 2009). It has 30 items, and scores of these items can measure impulsiveness in six first-order factors (e.g., attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability impulsiveness). Patton et al. (1995) reported the internal consistency range for BIS-11 from 0.79 to 0.83 for undergraduates, substance-abuse patients, general psychiatric patients, and prison inmates. Items are presented on a 4-point Likert scale from one to four. This questionnaire was included in this experiment to determine the relationship between individual differences in impulsiveness scales and participants' discounting rate for each messaging scenario.

Procedure

Prior to arrival, participants completed an online defensive driver course. These online modules are to be completed at least 24 hours before the experimental session. Upon arrival, participants reported demographic information, any at-fault collisions that may have occurred since the pre-screening questionnaire, and the number of hours slept the night before to ensure that participants would not be driving drowsy. Next, participants completed the delay discounting questionnaire and the BIS-11. Upon completion, participants were given the opportunity to adjust the ergonomic settings of the vehicle and were given an introduction to the vehicle and its controls.

Once participants were familiarized with the vehicle, they completed a manual drive (with no assistance from autonomous capabilities) from downtown Salt Lake City, Utah to a portion of highway with few curves and few other road users. On the way to the stretch of highway, participants were advised by the experimenter on how the autonomous functions operated in the vehicle and were given the opportunity to ask the experimenter any questions regarding the vehicle, its functions, or the procedure. This drive was approximately 20 minutes in duration along Interstate 80 (I-80). Participants then completed two drives along I-80 in either partial autonomous mode or manual mode with no assistance from the vehicle. For the safety of the participants and researcher, participants were required to get out of the vehicle and take a break at a rest stop between each drive. The order of these drives was counterbalanced, and participants were randomly assigned to a vehicle. After completion, participants drove back to downtown Salt Lake City. Upon returning, participants completed the delay discounting questionnaire once more.

Analysis

Data analyzed from each participant included their delay discounting preferences, measured prior to driving a partially autonomous vehicle and after driving a partially autonomous vehicle. From the delay discounting measure, the indifference point was indicated, which is the point at which participants switched from selecting the larger, later option to the smaller, immediate option. The indifference point informs us of when the value of the message is subjectively equal to the risk. This value was reported as monetary amounts and was reported across all five delays for each of the four scenarios. A participant's discounting curve was calculated according to the following function: $V = A/(1+kD)$. V represents the present value of the delayed reward A at delay D, and k is the rate of discounting. k typically falls between 0.0 and 0.5, with smaller values indicating a lack of discounting and a preference for delayed rewards, and higher values indicating strong discounting and a preference for immediate rewards. Thus, higher values of k are indicative of high levels of impulsivity (Kirby, 2000). The k values across the different delays were plotted to inform us of the area under the curve (AUC) for each individual.

The plotted indifference points and corresponding AUCs provide insight of the value of a stimulus after a variety of factors have been considered. A lower AUC indicates the stimulus does not hold its value over time because it is preferred to be attended to sooner. On the other hand, a larger AUC indicates that the larger reward has more value, and the stimuli holds its value over time. When this method is applied to risky behaviors, we can understand the value of the behavior as a function of both the value of the behavior and the risk associated with that behavior. If an individual were given the options of receiving $15 and responding to a text message immediately or the option of receiving $100 and responding to the text message after 30 minutes, all while driving, the individual would consider factors associated with the reward, but also the behavior. The individual would consider the social connection associated with the text message and the potential implications of not responding to the message or not responding immediately, as well as the risks associated with responding to the text message while driving. In this scenario, an individual who has a lower AUC would indicate that the implications of not responding to the message immediately outweigh the risk of texting while driving. On the other hand, an individual with a high AUC would be more sensitive to the risks of texting and driving and would therefore be willing to put off responding to the message because of those risks.

Chapter 7 : Results

Overall Sample

Participants were split into groups of low and high impulsivity level based on a mean split of the BIS-11 ($M = 67$). Given the non-normal distribution of the data, a log transformation was applied to achieve normal distributions. A 2 (Group) X 2 (Time) X 3 (Vehicle) between-within ANOVA on AUC found a main effect for impulsivity group, in which the high impulsivity group had higher AUCs than the low impulsivity group $F(1, 493) = 5.95$, $p < 0.01$,

(M_{Low} = 0.62, M_{High} = 0.50). There was also a main effect for the experience of driving a partially autonomous vehicle (time), in which AUC increased after driving ($F(1, 493) = 2.84$, $p < 0.05$, (M_{Pre} = 0.54, M_{Post} = 0.61). However, there was no difference among the vehicles driven $F(2, 493) = 0.04$, $p = .963$. Further, there was not an interaction between impulsivity group and time $F(1, 493) = 1.59$, $p = .208$, between impulsivity group and vehicle $F(2, 493) = 1.98$, $p = .139$, or between time and the vehicle driven $F(2, 493) = 0.80$, $p = .451$. Finally, there was not a three-way interaction between impulsivity group, time, and the vehicle driven F(2, 493) = 1.585, p = .206. The results of this model are presented in Figure 1.

A 2 (Message modality) X 2 (Autonomous capabilities) X 2 (Group) X 2 (Time) between-within ANOVA on AUC found the same main effect for group and time, but also found a main effect for autonomous capabilities of the hypothetical scenario given in the delay discounting questionnaire in which there was a lower AUC for the hypothetical vehicle with full autonomous capabilities $F(1, 489) = 4.23$, $p<0.05$, ($M_{FullAutonomous}$ = 0.55, $M_{NoAutonomou}s$ = 0.62). Also in this model was a significant interaction for message modality and time, in which there was a decrease in AUC for messages presented on the phone after driving ($M_{PrePhone}$ = 0.60, $M_{PostPhone}$ = 0.57) but an increase in AUC for messages presented over the in-vehicle voice system after driving ($M_{PreVoice}$ = 0.53, $M_{PostVoice}$ = 0.59). There was not a significant interaction between message modality and time $F(1, 489) = 0.41$, $p = .518$, between autonomous capabilities and time $F(1, 489) = 0.14$, $p = .708$, between message modality and group $F(1, 489) = 1.18$, $p = .277$, between autonomous capabilities and group $F(1, 489) = 2.58$, $p = .109$, or between time and group $F(1, 489) = 1.13$, $p = .287$. There was also no significant three-way interactions between message modality, autonomous capabilities, and time $F(1, 489) = 1.91$, $p = .168$, between message modality, autonomous capabilities, and group $F(1, 489) = 0.50$, $p = .48$, between message modality, time, and group $F(1, 489) = 0.05$, $p = .829$, or between autonomous capabilities, time, and group $F(1, 489) = 0.21$, $p = 0.650$. Finally, there was no four-way interaction between message modality, autonomous capabilities, time, and group $F(1, 489) = 0.22$, $p = 0.637$. These results are presented in Figure 2.

Low impulsivity group

A 2 (time) X 3 (vehicle) between-within ANOVA on AUC found similar AUC values after driving (time) $F(1, 331) = 0.02$, $p = .897$ and similar AUC values for the vehicle driven $F(2, 331) = 0.13$, $p = .876$. For the low impulsivity group, there was an interaction between time and vehicle $F(2, 331) = 4.21$, $p < .01$, in which there was an decrease in AUC after driving the Cadillac ($M_{PreCadillac} = 0.66$, $M_{PostCadillac} = 0.60$) and a decrease in AUC after driving the Volvo ($M_{PreVolvo} = 0.61$, $M_{PostVolvo} = 0.58$) but an increase in AUC after driving the Tesla ($M_{PreTesla} = 0.59$, $M_{PostTesla} = 0.64$). Of these differences, the time effect was significant for the Cadillac and Tesla, but not the Volvo at a Bonferroni adjusted $p < .05$ value. These results are presented in Figure 3.

For the hypothetical scenario given, a 2 (Autonomous capabilities) X 2 (Message modality) X 2 (Time) between-within ANOVA on AUC found a lower AUC for a message presented over the in-vehicle voice system than on the phone screen $F(1, 329) = 3.01$, $p < .05$ ($M_{VoiceSystem} = 0.59$, $M_{PhoneScreen} = 0.64$). There were similar AUC values for the hypothetical vehicle's autonomous capabilities $F(1, 329) = 0.20$, $p = .658$ and similar AUC values for time $F(1, 329) = 0.13$, $p = .714$. Further, there was a significant interaction between message modality and time $F(1, 329) = 5.89$, $p < .01$ in which the low impulsivity group had lower AUC values for messages presented on the phone screen after driving ($M_{PrePhoneScreen} = 0.65$, $M_{PostPhoneScreen} = 0.61$) and a higher AUC for messages presented over the vehicle's voice response system after driving ($M_{PreVoiceSystem}$ = 0.59, $M_{PostVoiceSystem}$ = 0.61). There were no significant interactions between autonomous capabilities and message modality $F(1, 329) = 0.03$, $p = .954$ or between autonomous capabilities and time $F(1, 329) = 0.67$, $p = .415$. There was not an interaction between autonomous capabilities, message modality, and time $F(1, 329) = 0.80$, $p = .372$. These results are presented in Figure 4.

High impulsivity group

A 2 (Time) X 3 (Vehicle) between-within ANOVA on AUC found higher AUC values after driving (time) $F(1, 163) = 2.82$, $p < .05$ (M_{Pre} = 0.46, M_{Post} = 0.54), and similar AUC values for the vehicle driven $F(2, 163) = 1.16$, $p = .328$. For the high impulsivity group, the model did find an interaction between time and vehicle $F(2, 163) = 2.73$, $p < .05$ in which there was an increase in AUC after driving the Cadillac ($M_{PreCadillac}$ = 0.43, $M_{PostCadillac}$ = 0.62) and a slight increase in AUC after driving the Volvo ($M_{PreVolvo}$ = 0.51, $M_{PostVolvo}$ = 0.54) but a decrease in AUC after driving the Tesla ($M_{PreTesla}$ = 0.43, $M_{PostTesla}$ = 0.37). Of these differences, the time effect was significant for the Cadillac and Tesla, but not the Volvo at a Bonferroni adjusted $p < .05$ value. These findings are depicted in Figure 5.

For the hypothetical scenario given, a 2 (autonomous capabilities) X 2 (message modality) X 2 (time) between-within ANOVA on AUC found a similar main effect for time as the previous model and a lower AUC for hypothetical vehicles with full autonomous capabilities $F(1, 161) = 4.06$, $p < .05$ ($M_{FullAutonomous}$ = 0.47, $M_{NoAutonomous}$ = 0.52). There were similar AUC values for the message modality $F(1, 161) = 0.06$, $p = .808$. Additionally, there were no significant interactions between autonomous capabilities and message modality $F(1, 161) = 0.55$, $p = .458$, between autonomous capabilities and time $F(1, 161) = 0.02$, $p = .965$, between message modality and time $F(1, 161) = 1.25$, $p = .265$. There was not an interaction between autonomous capabilities, message modality, and time *F*(1, 161) = 1.04, $p = .310$. The findings from this model are presented in Figure 6.

Chapter 8 : Discussion

The current work sought to understand perceptions regarding distraction in vehicles with different autonomous capabilities and how those perceptions may be influenced by experiences with a partially autonomous vehicle. For the overall sample, there was a difference between the low and high impulsivity groups in which the low impulsivity group had a higher AUC. The high impulsivity group were more willing to engage with distraction sooner and were therefore less willing to wait to respond to the message in general. This finding is not particularly surprising as it confirms that people with differing levels of general impulsivity do indeed differ in their willingness to engage with distraction. Identifying and validating the differences between these groups of people supports different approaches of meaningfully disseminating information regarding risks, particularly as it relates to rewards. One limitation of this finding is that the limited size of the sample may not capture the breadth of impulsivity that may exist in the entire population.

For the total sample, experience driving a partially autonomous vehicle did impact willingness to engage with distraction. Participants were less willing to engage with distraction after driving. When analyses were conducted among the high and low impulsivity groups, this effect was found among the high impulsivity group, who became more conservative after driving, but was not found among the low impulsivity group who had similar willingness to engage with distraction before and after driving. The low impulsivity group started at a higher AUC, suggesting a greater propensity to put off the distraction. They maintained this high level, even after the opportunity to experience a partially autonomous vehicle. However, the high impulsivity group encountered the partially autonomous vehicle and may have become more aware of the dangers of driving and therefore became less willing to engage with distraction. In other words, those less risk-aversive would continue to maintain their level of skepticism, while those more risk-aversive would be more aware of the potential risk. This finding highlights the importance of the first encounter with a new technology on individual risk-taking and reinforces the importance of proper regulation standards and honest representation of features before they can be responsibly consumed by the public, as these initial impressions may be the most impactful for longer-term trust in autonomous vehicles.

The similarity of opinion among the overall sample amid the three vehicles suggests a consistency of experience. This suggests that the classification scheme of Level 2 autonomous vehicle is consistent and accurate among available features. Should one of the vehicles have been classified as a Level 1 or Level 3 autonomous vehicle, there likely would have been more of an effect for the three vehicle types. Because this classification information was shared with participants to ensure they were fully aware of the features of the vehicle, this may have influenced participant’s opinions of the vehicle. However, this does exemplify the importance of consistency and dissemination on behalf of regulatory bodies and safety advisory boards as the public places a high level of trust in these institutions. Another limitation is that the particular set of vehicles used are all higher-end vehicles in the United States market which people may associate with more advanced technology and safety features. Should other-more common and economical brands of vehicles become available with the same caliber of capabilities, there may be more pronounced perception of differences between vehicles because of the associated emotionality toward the vehicle brands as a symbol of internal beliefs or status (Rezvani, Jansson, & Bodin, 2015).

Interestingly, there was an interaction for the experience of driving and the vehicle among both the low and high impulsivity group, but not for the overall sample. For the low impulsivity group, there was a trend to become slightly more willing to engage with distraction after driving the Cadillac and the Volvo and a trend to become less willing to engage with distraction after driving the Tesla. In comparison, the high impulsivity group exhibited the opposite pattern and became less willing to engage with distraction after driving the Cadillac and Volvo, but more willing to engage with distraction after driving the Tesla. One explanation for this finding is that the low impulsivity group may recognize that the assistive measures do offer a degree of safety when properly used but maintain their risk-aversive tendencies. At the same time, the high impulsivity group may initially report a stronger need to attend to the distraction but are faced with the potential shortcomings along the roadway which remain a salient deterrent in the decision to be distracted. However, the emotionality and reputation surrounding the Tesla, which is regarded as being the first widely available autonomous vehicle and therefore must carry the most advanced technology, may have different effect on groups with different risk aversions. Specifically, the high impulsivity group may see the failures of all three vehicles as more salient for the Tesla because of the reputation it carries. However, the low impulsivity group recognize the novel interior and technological advances and align their skepticism with the public perception of acceptance towards the Tesla. Regardless, the high impulsivity group AUCs after driving the vehicles become more closely aligned with the end responses from the low impulsivity group.

For the hypothetically given scenario, there was a trend among the overall sample to be more willing to engage with distraction when in a vehicle with full autonomous capabilities rather than a vehicle with no autonomous capabilities. Should fully autonomous vehicles be capable of fulfilling their proposed potential, this should not be a concern and should, theoretically, be safe. However, given the current availability of only Level 2 (or below) autonomous vehicle, the willingness to engage in other tasks despite the need for attention along the driving scene should be met with concern. Importantly, this effect was not influenced by the experience of actually interacting with a partially autonomous vehicle. One limitation of this finding is that the vehicle driven only offered partial autonomous capabilities, leaving the hypothetical vehicle with full autonomous capabilities to the participant's imagination, as it differed from their actual driving experience.

Also among the overall sample was no main effect for the modality of the message, suggesting that the message will be responded to in equal amounts of time, regardless of if whether it appears on the phone screen or is read aloud over the vehicle's voice system. However, there was an interaction between the modality of the message and driving. Specifically, there was a decrease in willingness to respond to the message when the message was on the phone after driving but an increase in willingness to respond to a message read aloud over the vehicle's voice system after driving. This finding may suggest that time spent driving may remind people of the risks associated with technology not native to the vehicle. However, experience with these specific vehicles may have induced trust in the advanced technology they come outfitted with. Logically, should a vehicle have some capabilities to control itself, it makes sense for it to also handle reading and responding to a message well, despite contradictory research (Cooper et al., 2014, Strayer et al., 2017, Strayer et al., 2018).

For the high impulsivity group, there was a trend to engage with distraction more when the vehicle was equipped with full autonomous capabilities in the hypothetically given scenario. However, this finding was not replicated among the low impulsivity group. Neither the high or low impulsivity group preferences for autonomous capabilities was impacted by the experience of driving a partially autonomous vehicle.

Conversely, in the given hypothetical scenario, the low impulsivity group were even less willing to respond to a message on their phone screen but more willing to respond to a message over their in-vehicle voice system after driving. However, the high impulsivity group showed no differentiation for these modalities or interaction with time. These findings may suggest that the low impulsivity group are more impacted by risks that are concrete and imaginable, opposed to purely hypothetical situations. In other words, the low impulsivity group do not have difficulty imagining receiving a text message while driving and they understand the threat of such a scenario. However, they may be less able to imagine the experience of driving a fully autonomous vehicle, and they therefore do not differentiate in the hypothetical experience. On the other hand, the high impulsivity group are more influenced by the hypothetical stimuli and show no effect for the risks that are currently present while driving.

Contrary to previous research that found differences in attitudes and behaviors based on components of the hypothetically given situation (Wise et al., in preparation a, Wise et al., in preparation b), the current work also found differences after an in-person encounter. This finding is intuitive and supports the preference for on-road experimentation and studies with high ecological validity. Further, this finding emphasizes the importance of stringent regulation on autonomous technology introduction. For many of the participants, this was their first true encounter with a partially autonomous vehicle. Among the low impulsivity group, this experience potentially instilled a renewed appreciation for the dangers of distracted driving. However, the experience could also have instilled a level of distrust for autonomous vehicles. While there is an appropriate level of reasonable skepticism, the distrust will have to be intentionally reduced in future encounters before full acceptance occurs and potential safety benefits of autonomous vehicle can be enacted. Furthermore, these findings suggest that the low impulsivity group had a continued high level of trust in the partially autonomous vehicles after experiencing them. Given this inclination, there is a strong obligation to regulatory bodies to stringently evaluate products prior to their release to the public to ensure public safety. Likewise, vehicle manufacturers have an obligation to be realistic and transparent in the claims of the vehicle's capabilities to encourage an appropriate use and trust in features.

Importantly, the stability of attitudes after the experience of driving a partially autonomous vehicle is only present in the low impulsivity group, suggesting that a portion of the population will remain steadfast in their attitudes and behavior regarding distraction, likely until a stimulus with a perceived higher value is presented or a true aversive event occurs. One stimulus that may be perceived as having a higher value may be the vehicle itself. The perception of an autonomous vehicle as "high tech," "cool," as a symbol of one's monetary status, or as an endorsement for environmental care will increase the likelihood of widespread adoption (Rezvani et al., 2015). However, if these same vehicles maintain stringent driver distraction requirements in which the driver is prohibited from using the autonomous features of the vehicle if distraction is detected may reduce distraction in an effort to maintain status.

Another implication of the consistency of attitudes and behaviors is the shift in perception of what is potentially dangerous while driving. Previous generations were alarmed at the notion of talking on or using the phone while driving, a now a commonly accepted behavior despite its continued risk (Schroeder, Wilbur, & Peña, 2018). Likewise, texting and driving was considered to be socially unacceptable but has become a more prevalent behavior across various age groups (Schroeder et al., 2018). However, the lack of an effect for the risk associated with the potential distraction could suggest that the issue of texting and driving is publicly viewed as resolved and no longer an important issue. Should this be the case, the dangers of texting and driving would be amplified as autonomous vehicles are continually added to roadways. As human drivers attempt to text and drive, their driving behavior becomes unpredictable to the autonomous vehicle's algorithms which lack the ability to alter physics in such a way to always avoid a collision, perpetuating the problem of distracted driving until there is full acceptance of autonomous and connected vehicles.

The relative stability of reported attitudes from the low impulsivity group despite differences in the hypothetical situation and experiences of the vehicles was particularly interesting. Because the low impulsivity group initially have a high discounting rate, it does suggest that there was some consideration given to the components of the hypothetical scenarios given, but they were unaffected despite the factors that would make the message more or less accessible. Further, after having exposure to technology that could foreseeably remove the risk of driving, the low impulsivity group did not report a higher willingness to engage with distraction integrated with the vehicle and less willingness to engage with distraction on the phone directly.

On the other hand, the high impulsivity group showed an effect for autonomous capabilities and not for message modality. One interpretation of this is that the high impulsivity group will engage with distractions, such as text messages at a similar rate regardless of the components of a situation, as they have already determined the message to have a high value. This finding implies that to effectively change attitudes and therefore behavior among the high impulsivity group, typical approaches, such as presenting statistics or personal narratives or exposure to the danger, are ineffective. More effective strategies should be focused on introducing a stimulus with a higher reward than a message.

Warnings of the over-reliance on technology have been given by authors throughout history, yet the general course of society has continued to make more technological advancements. In Huxley's *A Brave New World*, we are warned of the consequences of being constantly bombarded by information around us, such as a diminished capability to meaningfully prioritize information. This warning is more applicable than ever. Our ways of connecting to the world has extended beyond the television and now includes devices that we carry with us in our pockets and that goes everywhere with us, including when we drive. With the average smartphone, users can access the internet and its endless volumes of information, as well as video streaming applications, games, a variety of messaging platforms, and instantaneous notifications of important news events happening around the world. With the unprecedented and overwhelming level of access to information at our fingertips, access which has become increasingly interwoven in our lives, we are less and less able to determine what information is important. Much like Huxley cautioned, we risk becoming so inundated with handheld technological barrages of information that soon we may find ourselves failing to appropriately prioritize driving information over simultaneous notifications, to the detriment of our own safety.

One limitation of the current work is ecological validity. Though the participant was in a vehicle rather than a simulator, a researcher was still present, which likely influenced driving behavior. Further, participants were instructed to silence their personal phones and put them out of reach. This was necessary to maintain safety, but as a result we were unable to observe how participants would deal with an authentic distraction. In addition, a majority of the data collection occurred during the winter, a time when drivers report enhanced vigilance due to increased risk has been well documented (National Center for Statistics and Analysis, 2019).

The current work sought to use the delay discounting method to understand willingness to engage with distraction when driving a vehicle during manual and autonomous conditions. Additionally, this work sought to understand how these differences in willingness to engage was influenced by driving both in partially autonomous mode and with no assistance. To date, autonomous vehicles are still a relatively new technology, and research is necessary to understand not only the extent to which individuals drive autonomous vehicles distracted, but also how those differences in preference translate to driving performance. Currently, only Level Two autonomous vehicles are available for consumers, despite inaccurate claims by some industry executives. These vehicles still require driver awareness and frequent interjection. Yet, when engaged in secondary tasks, drivers have a diminished ability to respond to hazards and need additional time to cognitively disengage from the secondary task and re-engage with the primary task of driving. Consequently, the current work provides critical information on drivers' willingness to engage in secondary tasks when operating an autonomous vehicle. These findings can be used to educate public officials in their pursuit of appropriate policies regarding autonomous vehicles, as well as provide data to vehicle engineers for the development of appropriately timed warnings. And perhaps most imperatively, these findings inform us on the continued importance of the need to create impactful and meaningful intervention techniques to reduce traffic crashes and increase road safety. The current work also informs us of how individuals with different propensities to engage with distractions drive differently. Further, this work informs us of the perceived risk of autonomous vehicles, as understood by drivers' willingness to engage in secondary tasks while driving these types of vehicles.

References

AAA Foundation (2008, December). *Cell Phones and Driving: Research Update.* Washington, DC. Retrieved from: https://www.aaafoundation.org/sites/default/files/CellPhonesandDrivingReport.pdf

Alvarez, I., Alnizami, H., Dunbar, J., Jackson, F., & Gilbert, J. E. (2015). Help on the road: Effects of vehicle manual consultation in driving performance across modalities. *International Journal of Human-Computer Studies, 73*, 19-29. doi:10.1016/j.ijhcs.2014.07.001

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Anthony, S. (2014). Google's self-driving car passes 700,000 accident-free miles, can now avoid cyclist, stop at railroad crossings. *Extreme Tech, 29*(5). 6.

Atchley, P., Atwood, S., & Boulton, A. (2011). The choice to text and drive in younger drivers: Behavior may shape attitude. *Accident Analysis and Prevention, 43*, 134-142. doi: 10.1016/j.aap.2010.08.003

Atchley, P., Tran, A. V., & Salehinejad, M. A. (2017). Constructing a publically available distracted driving database and research too. Accident Analysis & Prevention, 99, 306-311. doi: 10.1016/j.aap.2016.12.005

Atchley, P. & Warden, A. C. (2012). The need of young adults to text *now*: Using delay discounting to assess informational choice. *Journal of Applied Research in Memory and Cognition, 1*(4), 229-234. doi: 10.1016.j.jarmac.2012.09.001

Baer, J. (2012). 42 percent of consumers complaining in social media expect 60-minute response time. *Convince & Convert, 2012*.

Bayer, J. B. & Campbell, S. W. (2012). Texting while driving on automatic: Considering the frequency-independent side of habit. *Computers in Human Behavior, 28,* 2083-2090. doi: 10.1016/j.chb.2012.06.012

Beijer, D., Smiley, A., & Eizenman, M. (2004). Observed driver glance behavior at roadside advertising signs. *Transportation Research Record: Journal of the Transportation Research Board, 1899*(1), 96-103. doi:10.3141/1899-13

Berning, A., Compton, R., & Wochinger, K. (2015, February). Results of the 2013–2014 National Roadside Survey of alcohol and drug use by drivers. (Traffic Safety Facts Research Note. Report No. DOT HS 812 118). Washington, DC: National Highway Traffic Safety Administration.

Bickel, W. K., Johnson, M. W., Koffarnus, M. N., MacKillop, J., & Murphy, J. G. (2014). The behavioral economics of substance use disorders: Reinforcement pathologies and their repair. *Annual Review of Clinical Psychology, 10*, 641-677. doi: 10.1146/annurev-clinpsy-032813-153724

Boesler, M. (2012). The 27 Best Selling Vehicles in America. *Business Insider.*

Bose, A. & Ioannou, P. A. (2003). Analysis of traffic flow with mixed manual and semiautomated vehicles. *IEEE Transactions on Intelligent Transportation Systems, 4*(4), 173-188. doi: 10.1109/TITS.2003/821340

Brookhuis, K. A., de Vries, G., & de Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis & Prevention, 23*(4), 309-316. doi:10.1016/0001-4575(91)90008-S

Bruyas, M. P., Dumont, L., & Bron, F. (2013, June). Sensitivity of Detection Response Task (DRT) to the driving demand and task difficulty. In *Proceedings of the Seventh*

International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design (pp.64-70). Retrieved from: http://drivingassessment.uiowa.edu.www2.lib.ku.edu/sites/default/files/DA2013/Papers/011_Bruyas_0.pdf

Carlson, M. S., Desai, M., Drury, J. L., Kwak, H., & Yanco, H. A. (2014). Identifying factors that influence trust. *2014 AAAI Spring Symposium Series*, 20-27. Retrieved from: http://www.aaai.org/ocs/index.php/SSS/SSS14/paper/download/7729/7725

Carsten, O., Lai, F. C., Barnard, Y., Jamson, A. H., & Merat, N. (2012). Control task substitution in semiautomated driving: Does it matter what aspects are automated? *Human Factors: Journal of the Human Factors and Ergonomic Society*, *54*(5), 747-761. doi: 10.1177/0018720812460246

Centers for Disease Prevention and Control (2017). Rates of self-harm—United States, 2015. *JAMA*. Retrieved from: http://www.dailymail.co.uk/health/article-5104445/Self-harm-surged-teen-girls-CDC-data-shows.html

Centers for Disease Prevention and Control (2013). Mobile device use while driving — United States and seven European countries, 2011. Morbidity and Mortality Weekly Report (MMWR). 2013; 62(10);177–182 Retrieved from: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6210a1.htm?s_cid=mm6210a1_w

Chóliz, M. (2010). Mobile phone addiction: A point of issue. *Addiction*, *105*(2), 373-374. doi: 10.1111/j/1360-0443.2009.02854.x

Chóliz, M. (2012). Mobile-phone addiction in adolescence: The test of mobile phone dependence (TMD). *Prog Health Sci*, *2*(1), 33-44. Retrieved from: https://pdfs.semanticscholar.org/91b9/d3cfbac601754e8a3ba8f8c8c6aa0d082b15.pdf

Compton, R. P., Blomberg, R. D., Moscowitz, H., Burns, M., Peck, R. C., & Fiorentino, D. D. (2002). Crash risk of alcohol impaired driving. In *Proceedings International Council on Alcohol, Drugs, and Traffic Safety Conference* (Vol. 2002, pp. 39-44). International Council on Alcohol, Drugs and Traffic Safety. Retrieved from: https://www.safetylit.org/citations/index.php?fuseaction=citations.viewdetails&citationIds[]=citjournalarticle_246699_38

Cooper, J. M., Ingebretsen, H., & Strayer, D. L. (2014). Mental workload of common voicebased vehicle interactions across six different systems. Retrieved from: https://www.aaafoundation.org/sites/default/files/Cog%20Distraction%20Phase%20IIA%20FINAL%20FTS%20FORMAT.pdf

da Matta, A., Gonçalves, F. L., & Bizarro, L. (2012). Delay discounting: Concepts and measures. *Psychology & Neuroscience, 5*(2), 135-146. doi: 10.3922/j/psns.2012.2.03

Dahlen, E. R., Martin, R. C., Ragan, K., & Kuhlman, M. M. (2005). Driving anger, sensation seeking, impulsiveness, and boredom proneness in the prediction of unsafe driving. *Accident Analysis and Prevention, 37*(2), 341-348. doi: 10.1016/j.aap.2004.10.006

Defense Advanced Research Projects Agency (2012). Grand Challenge ’05. Washington, D. C.

Dellenback, S. (2013). Director, Intelligent Systems Department, Automation and Drat Systems Division, Southwest Research Institute.

Doya, K. (2008). Modulators of decision making. *Nature Neuroscience, 11*(4), 410-416. doi: 10.1038.nn2077

Drews, F. A., Yazdani, H., Godfrey, C. N., Cooper, J. M., & Strayer, D. L. (2009). Text messaging during simulated driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 51*(5), 762-770. doi:10.1177/0018720809353319

Fagnant, D. J. & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers, and policy recommendations. *Transportation Research Part A: Policy and Practice, 77,* 167-181. doi: 10.1016/j.tra.2015.04.003

Frazzoli, E., Dahleh, M. A., & Feron, E. (2002). Real-time motion planning for agile autonomous vehicles. *Journal of Guidance, Control, and Dynamics, 25*(1), 116-129. doi: 10.2514/2.4856

General Motors (2018). Cadillac CT6 Owner's Manual. Retrieved February 9, 2018.

Gold, C., Körber, M., Hohenberger, C., Lechner, D., & Bengler, K. (2015). Trust in automation - Before and after the experience of take-over scenarios in a highly automated vehicle. *Procedia Manufacturing, 3*(2015), 3025-3032. doi: 10.1016/j.promfg/2015.07.847

Gold, C., Körber, M., Lechner, D., & Bengler, K. (2016). Taking over control from highly automated vehicles in complex traffic situations: The role of traffic density. *Human Factors: Journal of the Human Factors and Ergonomic Society, 58*(4), 642-652. doi: 10.1177/0018720816634226

Green, L., Fry, A. F., & Myerson, J. (1994). Discounting of delayed rewards: A life-span comparison. *Psychological Science, 5*(1), 33-36. doi: 10.1111/j.1467-9280.1994.tb00610.x

Haigney, D., Taylor, R., & Westerman, S. (2000). Concurrent mobile (cellular) phone use and driving performance: Task demand characteristics and compensatory processes. *Transportation Research Part F: Traffic Psychology and Behaviour, 3*(3), 113-121. doi:10.1016/S1369-8478(00)00020-6

Hancock, P., Lesch, M., & Simmons, L. (2003). The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis & Prevention, 35*(4), 501-514. doi:10.1016/S0001-4575(02)00028-3

Hart, S. G. (2006). Nasa-task load index (NASA-TLX); 20 years later. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 50*(9), 904-908. doi: 10.1177/154193120605000909

He, J., Chaparro, A., Nguyen, B., Burge, R. J., Crandall, J., Chaparro, B., . . . Cao, S. (2014). Texting while driving: Is speech-based text entry less risky than handheld text entry? *Accident Analysis & Prevention, 72*, 287-295. doi:10.1016/j.aap.2014.07.014

Hickman, J. S., Hanowski, R. J., & Bocanegra, J. (2010*). Distraction in commercial trucks and buses: Assessing prevalence and risk in conjunction with crashes and near-crashes* (FMCSA-RRR-10-049). Washington, DC. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.173.3995&rep=rep1&type=pdf

High-Touch Communications (2013). *Response-Time Protocols in the Internet Age: Survey Results*. Montreal, Canada. Retrieved from: https://blog.htc.ca/wp-content/uploads/2013/05/HTC_Response_Time_Protocols_Survey_Results.pdf

Hoogendoorn, R., van Arem, B., & Hoogendoorn, S. (2015). Automated driving, traffic flow efficiency, and human factors: Literature Review. *Transportation Research Record: Journal of the Transportation Research Board, 2422*, 113-120. doi: 10.3141/2422-13

Hosking, S. G., Young, K. L., & Regan, M. A. (2009). The effects of text messaging on young drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 51*(4), 582-592. doi:10.1177/0018720809341575

Howat, P., Sleet, D. A., & Smith, I. (1991). Alcohol and driving: Is the 0.05% blood alcohol concentration limit justified? *Drug and Alcohol Review, 10*(2), 151-166. doi: 10.1080/09595239100185211

Huth, V., Sanchez, Y., & Brusque, C. (2015). Drivers' phone use at red traffic lights: A roadside observation study comparing calls and visual–manual interactions. *Accident Analysis & Prevention, 74*, 42-48. doi:10.1016/j.aap.2014.10.008

Influence Central (2016). Smartphones and the dramatic reshaping of American families. *Influence Central, 2016*. Retrieved from: http://influence-central.com/smartphones-the-dramatic-reshaping-of-american-families/

Jamson, A. H. & Merat, N. (2005). Surrogate in-vehicle information systems and driver behaviour: Effects of visual and cognitive load in a simulated rural driving. *Transportation Research Part F: Traffic Psychology and Behaviour, 8*(2), 79-96. doi: 10.1016/j.trf.2005.04.002

Jamson, A. H., Merat, N., Carsten, O. M., & Lai, F. C. (2013). Behavioral changes in drivers experiencing highly-automated vehicle control in varying traffic conditions. *Transportation Research Part C: Emerging Technologies, 30*, 116-125. doi: 10.1016/j.trc.2013.02.008

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data. Retrieved from: https://vtechworks.lib.vt.edu/bitstream/handle/10919/55090/DriverInattention.pdf?sequence=1

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using control. *Journal of Experimental Psychology: General, 128*(1), 78-87. doi: 10.1037/0096-3445.128.1.78

Kyriakidis, M., Happee, R., & de Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour, 32*, 127-140. doi: 10.1016/j.trf.2015.04.014

Lamble, D., Kauranen, T., Laakso, M., & Summala, H. (1999). Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving. *Accident Analysis & Prevention, 31*(6), 617-623. doi:10.1016/S0001-4575(99)00018-4

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors: Journal of the Human Factors and Ergonomic Society, 46*(1), 50-80. doi: 10.1518/hfes.46.1.50_30392

Levinson, J., Askeland, J., Becker, J., Dolson, J., Held, D., Kammel, S., … & Sokolsky, M. (2011, June). Towards fully autonomous driving: Systems and algorithms. In *Intelligent Vehicle Symposium (IV), 2011 IEEE* (pp. 163-168). IEEE. Retrieved from: https://pdfs.semanticscholar.org/ba62/b106c43927e3fcea1bde8736d6cdc53b7a69.pdf

Merat, N., Jamson, A. H., Lai, F. C., & Carsten, O. (2012). Highly automated driving, secondary task performance, and driver state. *Human Factors: Journal of the Human Factors and Ergonomics Society, 54*(5), 762-771. doi: 10.1177/0018720812442087

Merat, N., Jamson, A. H, Lai, F. C. H., Daly, M., & Cartsen, O. M. J. (2014). Transition to manual: Driver behaviour when resuming control from a highly automated vehicle.

Transportation Research Part F: Traffic Psychology and Behaviour, 27(B), 274-282. doi: 10.1016/j.trf.2014.09.005

Merat, N. & Lee, J. D. (2012). Designing highly automated vehicles with the driver in mind. *Human Factors, 54*(5), 681-686. doi: 10.1177/0018720812461374

Moskowitz, H. & Florentino, D. (2000). *A review of the literature on the effects of low doses of alcohol on driving-related skills* (No. DOT-HS-809-028). United States. National Highway Traffic Safety Administration. Retrieved from: https://rosap.ntl.bts.gov/view/dot/1677

Myerson, J. & Green, L. (1995). Discounting of delayed rewards: Models of individual choice. *Journal of the Experimental Analysis and Behavior, 64*(3), 263-276. doi: 10.1901.jeab.1995.64-263

Nasar, J. L. & Troyer, D. (2013). Pedestrian injuries due to mobile phones use in public places. *Accident Analysis and Prevention, 57*, 91-95. doi: 10.1016/j.aap.2013.03.021

National Center for Statistics and Analysis. (2019, April). *Distracted driving in fatal crashes, 2017*. (Traffic Safety Facts Research Note. Report No. DOT HS 812 700). Washington, DC: National Highway Traffic Safety Administration. Retrieved from: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812700

National Highway Traffic Safety Administration (2008). *National Motor Vehicle Crash Causation Survey*. U.S. Department of Transportation, Report DOT HS 811 059.

National Highway and Traffic Safety Administration (2013). Preliminary statement of policy concerning automated vehicles. *Washington, DC,* 1-14. Retrieved from: http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf

National Highway and Traffic Safety Administration (2016). Traffic Safety Facts-Drunk Driving. *National Highway and Traffic Safety Administration.* Retrieved from: https://www.nhtsa.gov/risky-driving/drunk-driving

Newport, A. L. (2004). *U. S. Patent No. 6,754,564.* Washington, DC: U.S. Patent and Trademark Office.

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., & Bonner, R. L. (2015). Exposure and use of mobile media devices by young children. *Pediatrics, 136*(6), 1-7. doi: 10.1542/peds.2015-2151

Parasuraman, R. & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors: Journal of the Human Factors and Ergonomics Society, 39*(2), 230-253. doi: 10.1518/001872097778543886

Patten, C. J., Kircher, A., Östlund, J., & Nilsson, L. (2004). Using mobile telephones: cognitive workload and attention resource allocation. *Accident Analysis & Prevention, 36*(3), 341-350. doi:10.1016/S0001-4575(03)00014-9

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of clinical psychology, 51*(6), 768-774. doi: 10.1002/1097-4679(199511)51:6<768:AID-JCLP2270510607>3.0.CO;2-1

Payre, W., Cestac, J., & Delhomme, P. (2016). Fully automated driving: Impact of trust and practice on manual control recovery. *Human Factors: Journal of the Human Factors and Ergonomics Society, 58*(2), 229-241. doi: 10.1177/0018720815612319

Petry, N. M. (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and control. *Psychopharmacology, 154*(3), 243-250. doi: 10.1007/s002130000638

Pew Research Center (2013, September). *Internet and American Life Project*. Pew Research Center. Retrieved from: http://www.pewinternet.org/2013/02/28/how-teachers-are-using-technology-at-home-and-in-their-classrooms/

Pew Research Center (2015, Spring). *Global Attitudes Survey*. Pew Research Center. Retrieved from: http://www.pewglobal.org/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/

Pew Research Center (2016, November). *Social Media Update 2016*. Pew Research Center. Retrieved from: file:///C:/Users/ashtr/Downloads/PI_2016.11.11_Social-Media-Update_FINAL.pdf

Postman, N. (1986). *Amusing ourselves to death: Public discourse in the age of show business.* Penguin.

Ranney, T. A., Harbluk, J. L., & Noy, Y. I. (2005). Effects of voice technology on test track driving performance: Implications for driver distraction. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 47*(2), 439-454. doi: 10.1518/0018720054679515

Reed, D. D., Becirevic, A., Atchley, P., Kaplan, B. A., & Liese, B. S. (2016). Validation of a novel delay discounting of text messaging questionnaire. *The Psychological Record, 66,* 253-261. doi: 10.1007/s40732-016-0167-2

Rezvani, Z., Jansson, J., & Bodin, J. (2015). Advances in consumer electric vehicle adoption research: A review and research agenda. *Transportation Research Part D: Transport and Environment, 34*, 122-136. doi: 10.1016/j.trd.2014.10.010

Richter, F. (2013). Mobile Devices-The 21st Century Nanny. *Statista: The Statistics Portal.* Retrieved from: https://www.statista.com/chart/1499/mobile-device-use-of-american-parents/

Roberts, J., Pullig, C., & Manolis, C. (2015). I need my smartphone: A hierarchical model of personality and cell-phone addiction. *Personality and Individual Differences, 79*, 13-19. doi: 10.1016/j.paid.2015.01.049

Roberts, S. (2017, March). *The science of scare tactics.* Talk presented at the Lifesavers Conference for Highway Safety Priorities, Charlotte, NC.

Rosenbloom, T. (2006). Driving performance while using cell phones: an observational study. Journal of *Safety Research, 37*(2), 207-212. doi:10.1016/j.jsr.2005.11.007

Rudin-Brown, C. M. & Parker, H. A. (2004). Behavioural adaptation to adaptive cruise control (ACC): Implications for preventative strategies. *Transportation Research Part F: Traffic Psychology and Behaviour, 7*(2), 59-76. doi: 10.1016/j/trf.2004.02.001

Rumschlag, G., Palumbo, T., Martin, A., Head, D., George, R., & Commissaris, R. L. (2015). The effects of texting on driving performance in a driving simulator: the influence of driver age. *Accident Analysis & Prevention, 74*, 145-149. doi:10.1016/j.aap.2014.10.009

Rychel, A. (2017, March). Sensors: How driverless cars will sense. *2025AD, The Automated Driving Community.* Retrieved from: https://www.2025ad.com/latest/driverless-cars-infographic-sensors/

Saffarian, M., de Winter, J. C. F., & Happee, R. (2012). Automated driving: Human-factors issues and design solutions. *Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting, 56*(1), 2296-2300. doi: 10.1177/1071181312561483

Santos, J., Merat, N., Mouta, S., Brookhuis, K., & de Waard, D. (2005). The interaction between driving and in-vehicle information systems: Comparisons of results from laboratory, simulator and real-world studies. *Transportation Research Part F: Traffic Psychology and Behaviour, 8*(2), 135-146. doi: 10.1016/j.trf.2005.04.001

Schoettle, B. & Sivak, M. (2014). *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia*. Michigan, USA. Retrieved from: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf

Shchetko, N. (2014). Laser eyes post price hurdle for driverless cars. *The Wall Street Journal, 21.* Retrieved from: http://www.luxresearchinc.com/sites/default/files/WSJ_7-21-14.pdf

Schroeder, P., Wilbur, M., & Peña, R. (2018, March). *National survey on distracted driving attitudes and behaviors – 2015* (Report No. DOT HS 812 461). Washington, DC: National Highway Traffic Safety Administration. Retrieve from: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13123-2015_natl_survey_distracted_driving_031418_v5_tag.pdf

Shweder, R. A. (1990). Cultural psychology—What is it? In Stigler, J. W., Shweder, R. A., Herdt, G., (Eds.), Cultural Psychology: Essays on comparative human development (pp. 1-43). New York: Cambridge University Press.

Smith, A. & Williams, K. D. (2004). R U there? Ostracism by cell phone text messages. *Group Dynamics: Theory, Research, and Practice, 8*(4), 291-301. doi: 10.1037/1089-2699.8.4.291

Stanford, M. S., Mathias, C. W., Dougherty, D. M., Lake, S. L., Anderson, N. E., & Patton, J. H. (2009). Fifty years of the Barratt Impulsiveness Scale: An update and review. *Personality and Individual Differences, 47*(5), 385-395. doi: 10.1016/j.paid.2009.04.008

Stewart, J. (2018). People keep confusing their Teslas for self-driving cars. *Wired*.

Strayer, D.L., Cooper, J.M. , McCarty, M.M., Getty, D.J., Wheatley, C.L., Motzkus, C.J., Mackenzie, K.L., Loveless, S.M., Esplin, J., Goethe, R.M. & Biondi, F. (2018). Visual and Cognitive Demands of Using Apple CarPlay, Google's Android Auto and Five Different OEM Infotainment Systems. AAA Foundation for Traffic Safety.

Strayer, D. L., Cooper, J. M., Goethe, R. M., McCarty, M. M., Getty, D., & Biondi, F. (2017). Visual and Cognitive Demands of Using In-Vehicle Information Systems. *AAA Foundation for Traffic Safety*.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. Human factors, 48(2), 381-391. doi: 10.1518/001872006777724471

Strayer, D. L., Drews, F. A., & Johnston, W. A. (2003). Cell phone-induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied, 9*(1), 23-32. doi:10.1037/1076-898X.9.1.23

Strayer, D. L. & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science, 12*(6), 462-466. doi: 10.1111/1467-9280.00386

Strayer, D. L., Turrill, J., Coleman, J. R., Ortiz, E. V., & Cooper, J. M. (2014). Measuring cognitive distraction in the automobile II: Assessing in-vehicle voice-based interactive technologies. Retrieved from: https://www.aaafoundation.org/sites/default/files/Cog%20Distraction%20Phase%202%20FINAL%20FTS%20FORMAT_0.pdf

Takao, M., Takahashi, S., & Kitamura, M. (2009). Addictive personality and problematic mobile phone use. *Cyber Psychology and Behavior, 12*(X), 1-7. doi: 10.1089/cpb.2009.002

Tesla (2018). Tesla Autopilot. Retrieved February 9, 2018.

Tesla Motors (2016). Model S Owner's Manual. Retrieved February 9, 2018.

Tison, J., Chaudhary, N., & Cosgrove, L. (2011). *National phone survey on distracted driving attitudes and behaviors.* (No. HS-811 555). Retrieved from: https://trid-trb-org.www2.lib.ku.edu/view/1127395

Thapa, R., Codjoe, J., Ishak, S., & McCarter, K. S. (2015). Post and During Event Effect of Cell Phone Talking and Texting on Driving Performance—A Driving Simulator Study. *Traffic Injury Prevention*, *16*(5), 461-467. doi:10.1080/15389588.2014.969803

Traffic Safety Facts (2013). *Traffic Safety Facts, 2013*. U.S. Department of Transportation, Washington, D.C., DOT HS 811 753.

Tran, A. V. (2017). *Understanding willingness to respond to messages and its relationship to driving performance.* (master's thesis). University of Kansas, Kansas, United States of America.

Treno, A. J., Grube, J. W., & Martin, S. E. (2003). Alcohol availability as a predictor of youth drinking and driving: A hierarchical analysis of survey and archival data. *Alcoholism, Clinical and Experimental Research*, *27*(5), 835-840. doi: 10.1097/01.ALC.0000067979.85714.22

Tugend, A. (2013, April 19). *The anxiety of the unanswered e-mail.* The New York Times. New York, NY. Retrieved from: http://www.nytimes.com/2013/04/20/your-money/the-anxiety-of-the-unanswered-e-mail.html

Turrill, J., Coleman, J. R., Hopman, R. J, Cooper, J. M, & Strayer, D. L. (2016) The residual costs of multitasking: Causing trouble down the road. *Proceedings of the Human Factors* *and Ergonomics Society 2016 Annual Meeting, 60*(1), 1967-1970. doi: 10.1177/1541931213601448

Twenge, J. M. (2017). *iGen: Why Today's Super-Connected Kids Are Growing Up Less Rebellious, More Tolerant, Less Happy—and Completely Unprepared for Adulthood—and What That Means for the Rest of Us.* Atria Books. Retrieved from: https://www.theatlantic.com/magazine/archive/2017/09/has-the-smartphone-destroyed-a-generation/534198/

Vanlaar, W., Simpson, H., Mayhew, D., & Robertson, R. (2008). Fatigued and drowsy driving: A survey of attitudes, opinions and behaviors. *Journal of Safety Research, 39*(3), 303-309. doi: 10.1016/j.jsr.2007.12.007

Virginia Tech Transportation Institute (2009). New Data from VTTI Provides Insight into Cell Phone Use and Driving Distraction. Blacksburg, VA: Virginia Tech Transportation Institute. Retrieved from: http://www.vtti.vt.edu/PDF/7-22-09-VTTI-Press_Release_Cell_phones_and_ Driver_Distraction.pdf

Volvo Cars Corporation (2018). Volvo Autonomous Driving Guide. Retrieved February 9, 2018.

Wilson, F. A. & Stimpson, J. P. (2010). Trends in fatalities from distracted driving in the United States, 1999 to 2008. *American Journal of Public Health, 100*(11), 2213-2219. doi: 10.2105/AJPH.2009.187179

Wise, A. V. T., Atchley, P., & Salehinejad, M. A. (in press b) IVIS increase driver willingness to respond to messages while driving. Submitted.

Wise, A. V. T., Atchley, P., & Salehinejad, M. A., (in press a). The function of information immediacy and smartphone addiction. Submitted to *Media Psychology.*

World Health Organization. (2015). *Global status report on road safety 2015.* World Health Organization. Retrieved from: http://www.who.int/violence_injury_prevention/publications/en/

Wood, J. M. (2002). Aging, driving and vision. *Clinical and Experimental optometry*, *85*(4), 214-220. doi: 10.1111/j.1444-0938.2002.tb03040.x

Zador, P., Krawchuk, S. A., & Voas, R. B. (2000). *Relative risk of fatal crash involvement by BAC, age, and gender* (No. DOT-HS-809-050). United States. National Highway Traffic Safety Administration. Retrieved from: https://rosap.ntl.bts.gov/view/dot/1674

Ziegler, C. (2015, October 14). *Tesla's cars can drive themselves starting tomorrow*. The Verge. New York, NY. Retrieved from: https://www.theverge.com/2015/10/14/9533539/teslas-cars-can-drive-themselves-starting-tomorrow

Figures

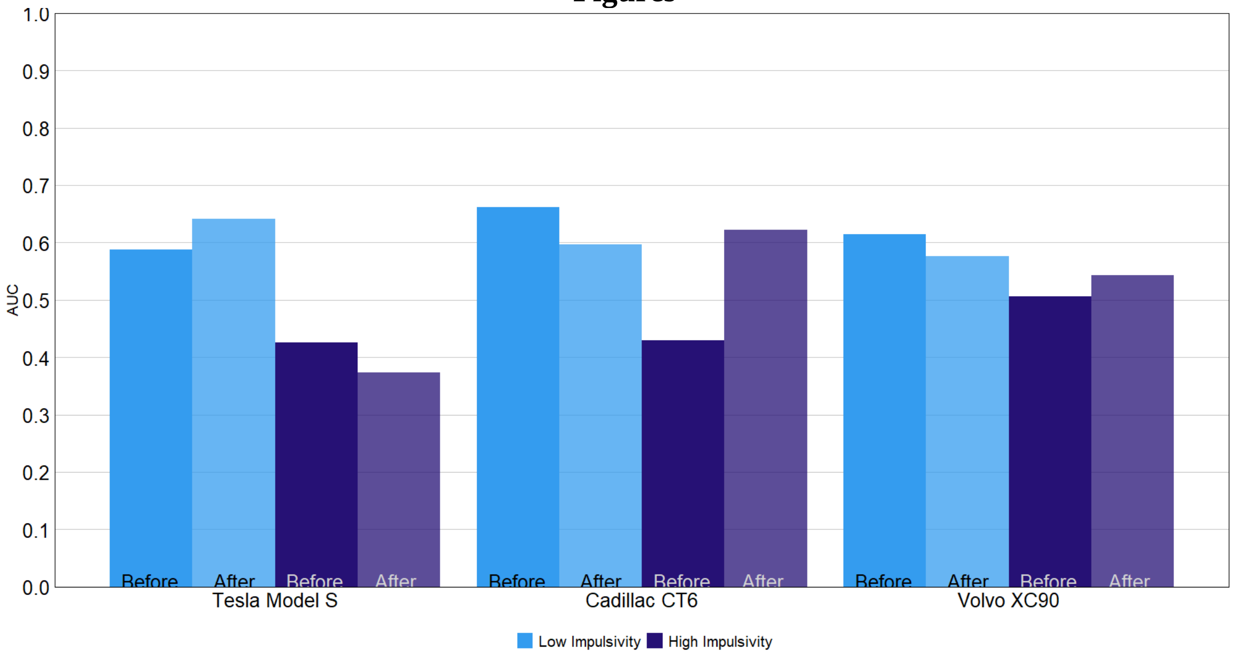

Figure 1. Main effect for impulsivity group and time.

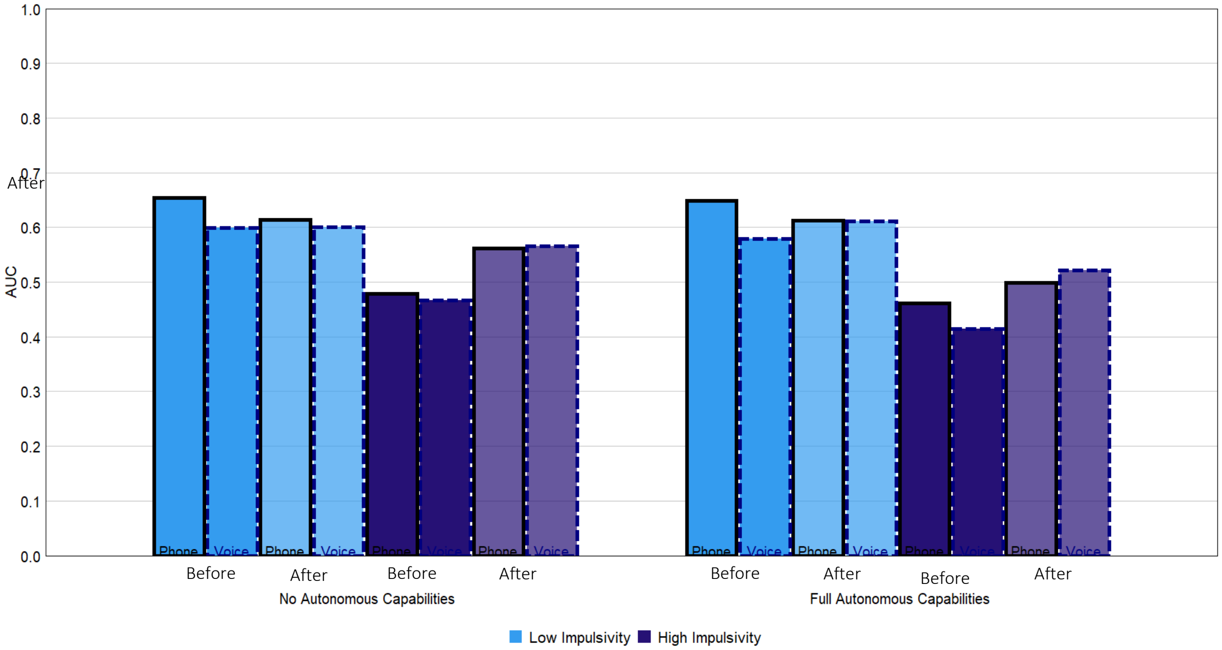

Figure 2. Main effect for impulsivity group, time, and autonomous capability and an interaction between message modality and time.

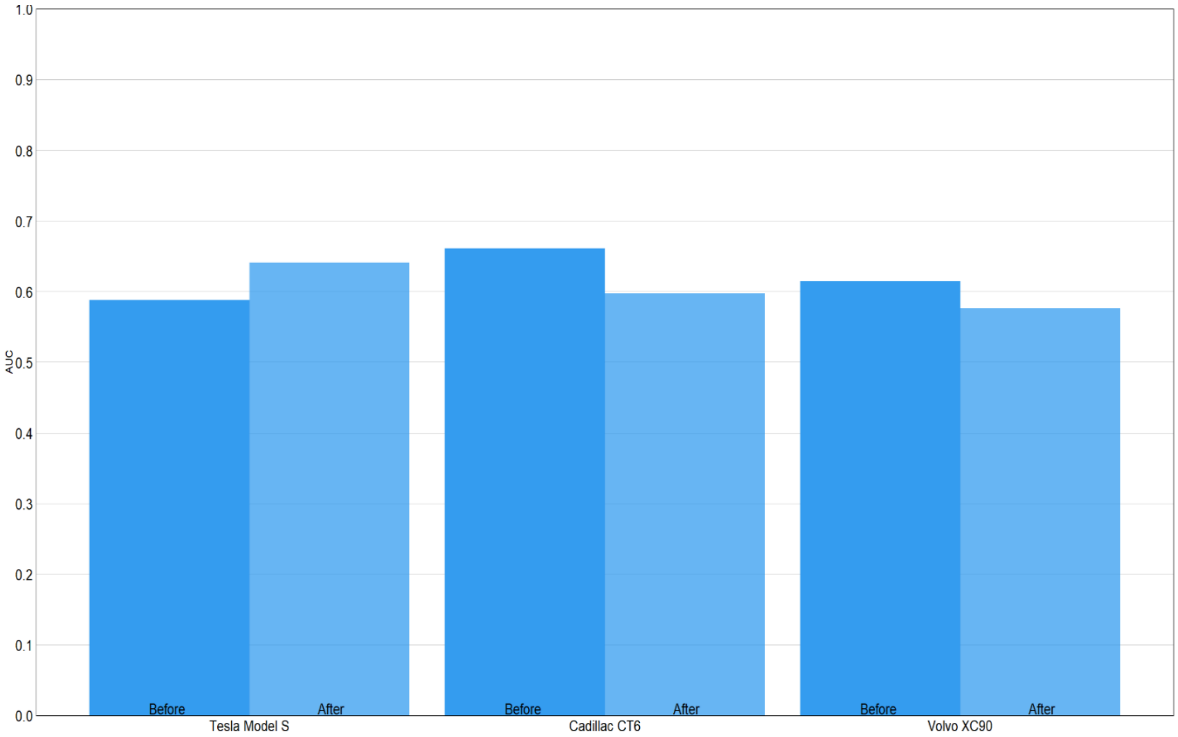

Figure 3. Interaction between vehicle and time among the low impulsivity group.

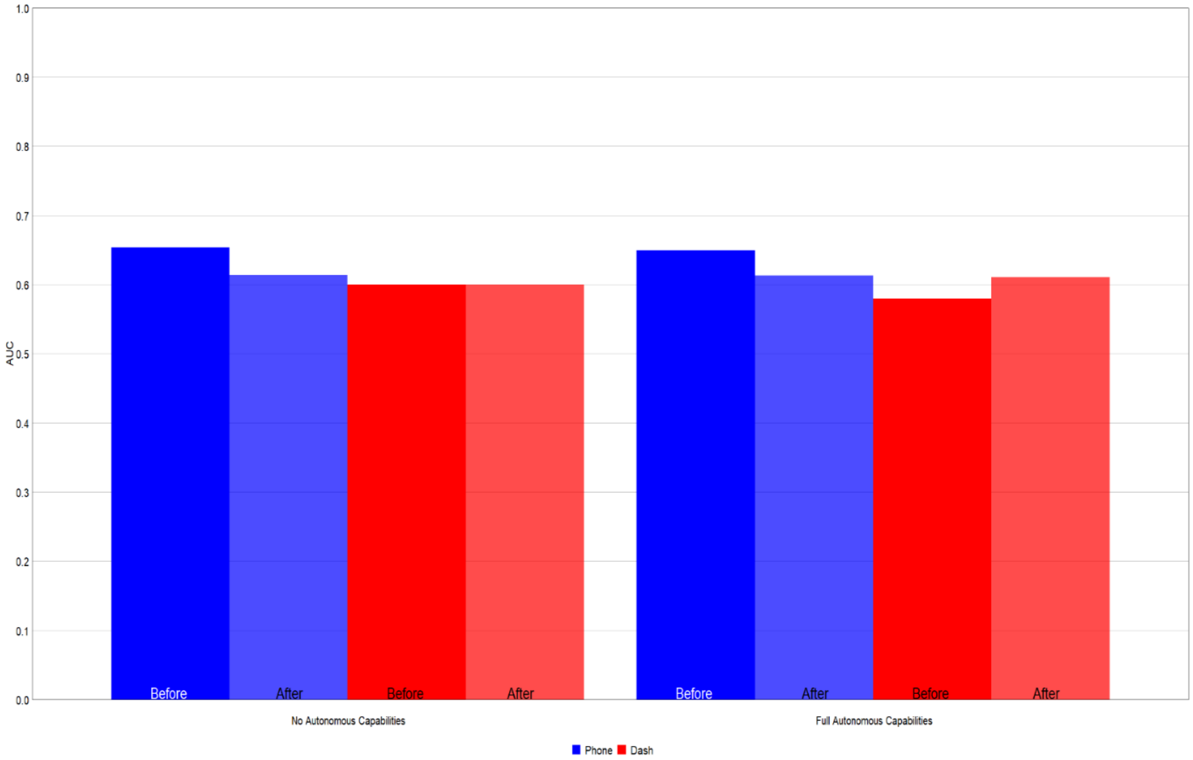

Figure 4. Main effect for message modality and interaction of message modality and time among the low impulsivity group.

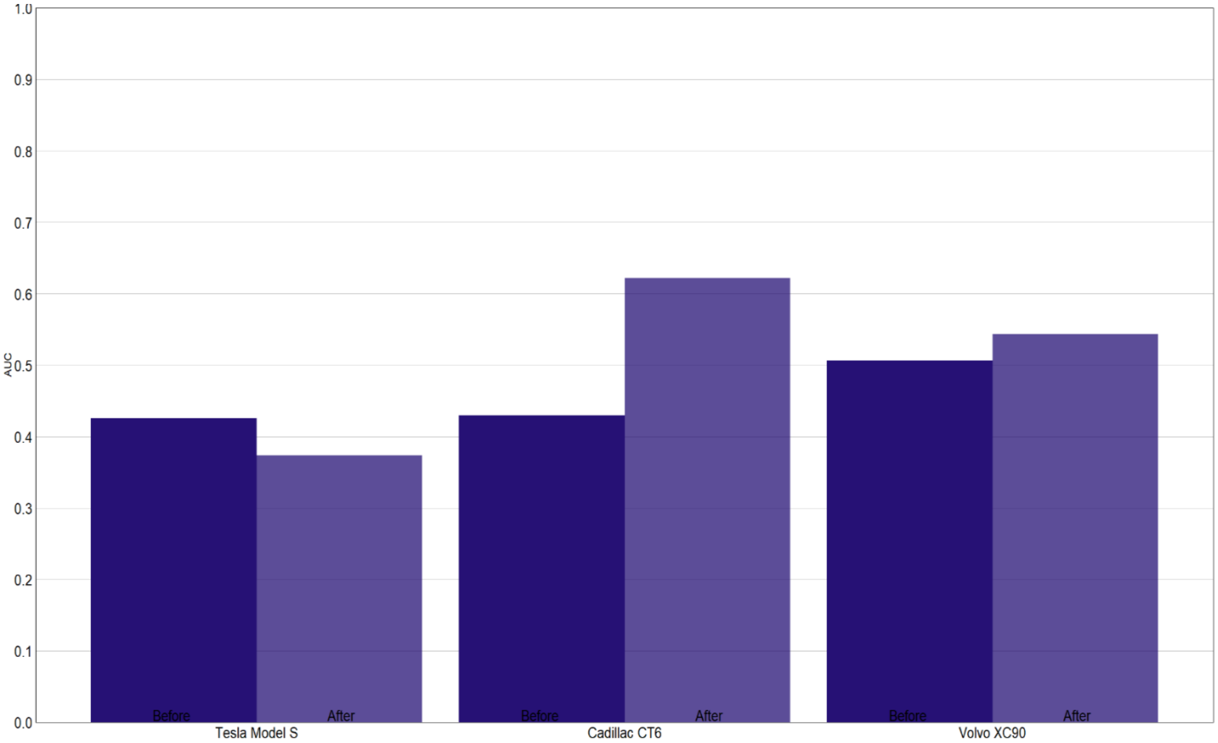

Figure 5. Main effect for time and interaction of time and vehicle for the high impulsivity group.

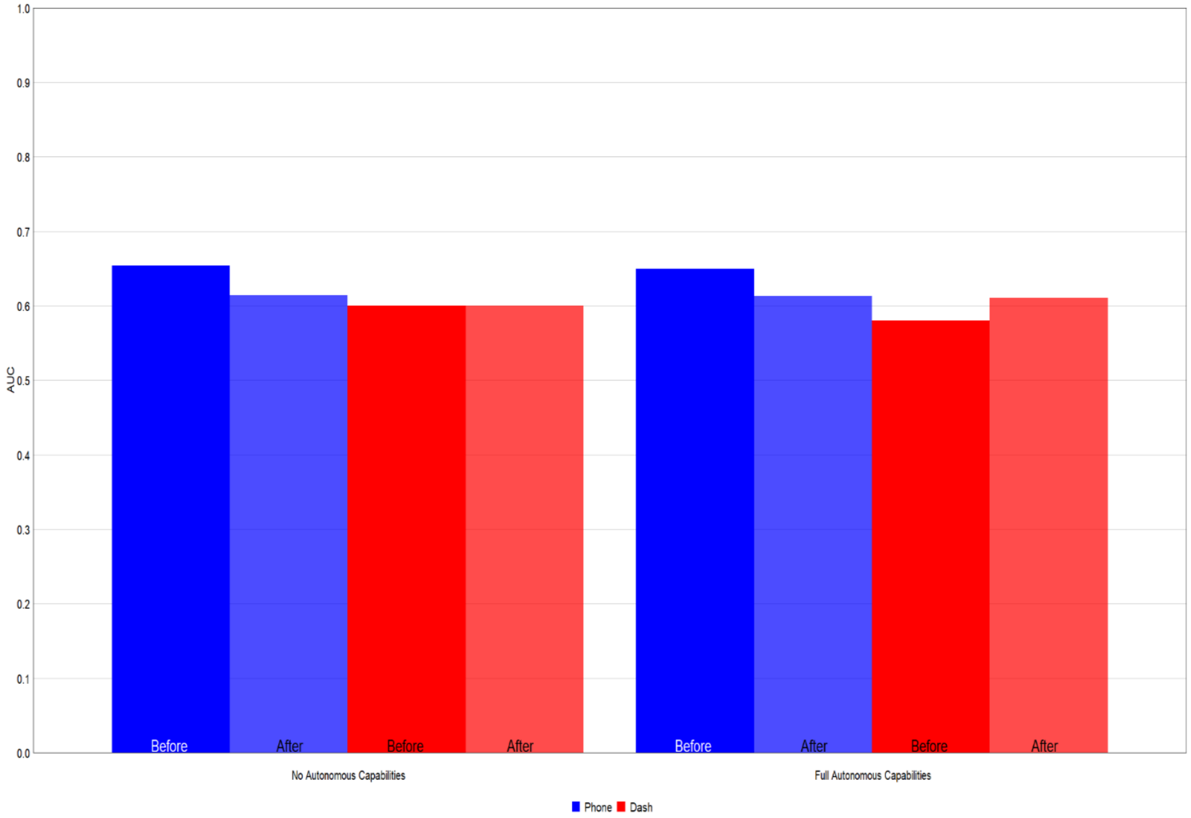

Figure 6. Main effect for time and autonomous capabilities among the high impulsivity group.