Understanding Willingness to Respond to Messages and its Relationship to Driving Performance

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Abstract

Research has demonstrated that distracted driving degrades performance. Factors influencing the decision to drive distracted were investigated. In experiment one, participants completed a discounting task where they chose between a smaller reward immediately or a delayed larger reward paired with the opportunity to text. Participants indicated willingness to wait to respond to a text in four scenes: two weather conditions and two modalities of the message. Willingness to wait to respond was related to modality but not weather. Individuals were placed into groups based on responses and differed in waiting preferences in all scenes. In experiment two, the discounting task was used and participants completed six drives consisting of three secondary tasks in two traffic levels. Participants completed the DRT measure of workload and rated driving performance. Drivers differed in driving performance and rating of driving performance for the tasks. These results have implications understanding the decision to drive distracted.

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Introduction

Distracted driving is not a new issue and has been understood to degrade driving performance since the first study conducted in 1965 (Brown, 1965). Since then, the number of conducted studies has exponentially increased and the issue has come to be thoroughly investigated. Aggregated results are overwhelmingly consistent that driving performance is degraded as the product of distraction (Atchley, Tran, Salehinejad, 2017). When the results are examined by method, we find that despite the different methods used to study distracted driving, whether it be a driving simulator or naturalistic observation, the proportions of results are consistent in finding that driving performance is negatively impacted by distraction. More importantly, when we examine the impact of distractions we find that more often than not, driving performance is worsened by distraction. When looking at the relative proportions of outcomes of each distraction type, there are some findings that do indicate that distraction can, in certain situations under certain measurements, improve driving performance. However, when looking at the different distraction types, we see there are no measurements that found driving performance to be improved when investigating the impact of text messaging on driving or non-vehicle related manual distraction (Atchley et al., 2017).

Regardless of the method used to study distracted driving, the findings are generally consistent. However, the many notable findings have highlighted the extent of the danger of driving distracted beyond crash incidence rates. When comparing a driver using a cell phone to an intoxicated driver, those using a phone while driving were understood to be involved in more collisions, have a slower brake reaction time, and a higher variance in following distance compared to both intoxicated drivers and drivers in the baseline condition (Strayer, Drews, & Crouch, 2006). Further, using a case-crossover design in which participants included in the sample had recently been in a crash, and the time of the crash was compared to the phone records of the participants, driver's use of phones resulted in an increased likelihood of involvement in a collision. Specifically, using a phone within ten minutes before a crash was associated with a fourfold increased likelihood of crashing (Redelmeier, D. A. & Tibshirani, R. J., 1997; McEvoy et al., 2005).

Generally, distracted driving can be classified as cognitive, visual, or manual. Arguably, the most dangerous of these distractions are those in which multiple types of distraction are combined, but particularly when all three, cognitive, visual, and manual, are combined. Though different distractions can be classified into these components, there are critical processing differences that further express the danger of distracted driving. Language comprehension performed concurrently with driving draws mental resources away from driving. Functionally, this means that attention is reduced which lead to an increased crash risk. Specifically, the parietal lobe activation associated with spatial reasoning decreased by 37 percent in the presence of conversation when studied using fMRI techniques (Just, Keller, & Cynkar, 2008). Further, when using the phone while driving, the functional field of view becomes limited. If this phone use existed in a vacuum, the change in functional field of view would not be a problem. However, spatial attention is critical for safe driving and divided attention is an important mechanism that is associated with an increased crash risk (Atchley & Dressel, 2004). Both of these notable findings do not also include a visual and manual component, suggesting that the changes in processing would be intensified with each addition of a different component of distraction and crash risk would further be increased.

Researchers have long understood the risks of distracted driving, and more recently those risks have been highlighted by the tragedies of victims and advocates popularized through the media and social media. Distracted driving is considered to be a risky behavior, compared to behaviors such as drunk driving and smoking. Similar to these other behaviors, politicians have taken an interest and created changes in legislation in an attempt to protect the public. For comparison in 2014 in the United States, 9,967 people were killed in alcohol-impaired driving crashes, 480,000 deaths each year were related to cigarette smoking, and 3,154 people were killed in crashes involving a distracted driving (Center for Disease Control and Prevention, 2017; Center for Disease Control and Prevention, 2017; Center for Disease Control and Prevention, 2016). These similar other risky behaviors are continually performed by people despite knowledge of the risks. Though driving while intoxicated first was made illegal in 1910, it wasn't widely enforced with strong consequences until over 100 years later (Munson, 2014). These changes have arguably been somewhat successful, as eight percent of drivers have admitted to driving intoxicated within the past year; this figure is down from the reported rates in the 1980s (NHTSA, 2008). Though smoking has been regulated by the government since 1965 when an estimated 42 percent of the population were considered to be smokers, smoking rates have been on a steady decline ever since with the latest estimate at 12 percent of the population, though it is not completely banned from any state for adults over 18 years of age (Center for Disease Control, 2016). Comparatively, texting while driving was first prohibited in 2007, but is not yet banned by all 50 states, but was admitted to by 92 percent of a sample in a recent survey (Atchley, et al., 2011).

Naturalistic Driving findings

Since the impact of distracted driving has been previously examined and understood, and more recently highlighted in the popular press, investigation is needed to understand why distracted driving, specifically texting and driving still continually occurs. To understand this, there are a few reasonable hypotheses to be examined. One possible hypothesis is that distracted driving is not actually a problem that needs to be dealt with because driving while distracted helps to reduce risk overall while driving. This hypothesis is supported primarily by the coding of crashes and "safety-critical events" recorded in a naturalistic driving. These findings have reported odds ratios that driving while talking on the phone are greater than one, implying that driving while completing a demanding secondary task actually improves driving performance (Olson, Hanowski, Hickman, & Bocanegra, 2009; Fitch et al., 2013). Unfortunately, these findings have been used to create policies that have allowed drivers, specifically commercial drivers, to use phones while driving despite over 50 years of research, which has found consistently contradictory results to these. Further, the methods used in these findings have been suggested to be unrealistic, and the findings need to be interpreted as such (Knipling, 2015). However, recent findings using the naturalistic driving method have reported odds ratios that suggest there to be an increase in risk due to conversation and an increase in risk due to phone use (Dingus et al., 2016). Because of this contradictory findings, further research is necessary to better understand existing findings.

Awareness of the risks of distracted driving

Another possible hypothesis is that drivers do not realize the dangers of driving distracted. As a result, drivers choose to drive distracted because they simply do not know better. However, a survey of U. S. college students found that all drivers were at least aware that texting while driving is dangerous, though the actual risk did not match the perceived risk (Atchley, Atwood, & Boulton, 2011). Despite the common knowledge that distraction does degrade driving performance, 70 percent of respondents of the same survey reported that they had initiated texts while driving, while 81 percent reported replying to text messages, and 92 percent reported reading text messages while driving. Further, when stopped in traffic, a shocking 98 percent of participants reported text messaging, resulting in only two percent who did not text and drive in any capacity despite knowledge of the risk (Atchley, et al., 2011). All participants understood there to be at least some risk involved with texting and driving, yet still chose to continue the behavior. These findings suggest that the general public is aware that texting and driving is dangerous which may relate to individual differences among the drivers themselves.

Compensatory driving behaviors

Drivers are generally aware the distraction does change their driving performance. One way drivers make an attempt to resolve the dissonance between their knowledge of the danger of driving distracted and actually driving distracted is by engaging in compensatory driving behaviors to reduce overall workload. Compensatory behaviors can take a variety of forms, including strategic or operational compensations. Further, these behaviors can either be conscious or nonconscious. Strategic compensations include the choice to not engage with their phone while driving. For example, older drivers are more negatively impacted by the use of mobile phones, one would predict they are more likely to engage in compensatory behaviors at the highest level, including choosing to not engage with mobile phones in the first place (Young & Regan, 2007; Alm & Nilsson, 1995; Lamble, Rajalin, & Summala, 2002).

Operational compensatory behaviors are typically concerned with decreasing interactions with other vehicles, changes in attention, or accepting temporary degradation in certain driving tasks. In decreasing interactions with other vehicles, the outcomes could be both intentional or not and can include reducing speed (Alm & Nilsson, 1995; Burns, Parkes, Burton, Smith, & Burch, 2002; Haigney, Taylor, & Westerman, 2000; Rakauskas, Gugerty, & Ward, 2004; Young & Regan, 2007) and increasing inter-vehicular distance (Jamson, Westerman, Hockey, &

Carsten, 2004; Strayer & Drews, 2004; Strayer, Drews, & Johnston, 2003). Further, whether conscious or not, drivers will allow for a decrease in attention and expectations in certain driving tasks, such as checking mirrors less often (Brookhuis, de Vries, & De Waard, 1991; Harbluk, Noy, & Eizenmann, 2002; Young & Regan, 2007). Though these compensatory behaviors are the product of awareness of distracted driving, they still exist as the product of the choice to drive distracted and the lack of the highest-order compensation of not choosing to drive distracted, leaving an incomplete answer as to why drivers still drive distracted and pointing to an area where further investigation is needed.

Calibration of driving skills

Compensatory behaviors can either be conscious or non-conscious, suggesting that drivers must have some sort of awareness of the impact distraction must have on their driving performance. However, these compensatory behaviors alone only begin to modify the driving situation if the driver is aware enough of the changes in driving performance to engage in the necessary behaviors. If drivers are not aware of the changes or unaware of the extent of the change, they may have a poor calibration of their driving skills. An accurate calibration of skills would include factors of both situational awareness as well as self-awareness, but it is broadly defined as the determination of the accuracy of an instrument by measurement of its variation from a standard (Horrey, Lesch, Mitsopoulos-Rubens, & Lee, 2015). However, based on this definition, calibration is understood to be a biased and imperfect process consisting of missed information and errors, especially when regarding the calibration of human skills. Regardless of these faults of calibration, the calibration of one's skills has important implications to guide accurate judgments to direct decision making and behavior. Typically, people tend to view their own skill and abilities optimistically, regardless of the reality (DeJoy, 1989; Zell & Krizan, 2014). The misalignment of skill, especially in a more optimistic manner can be particularly dangerous as it relates to those who are less skilled but tend to overestimate their skills more than those who are more skilled, which has come to be referred to as the Dunning-Kruger effect (Kruger & Dunning, 1999).

Though calibration failures can have relatively little to no consequences, such as cases in which students overestimate their knowledge of a particular subject and consequently receive a low score on an exam, there are instances in which calibration failures have higher stakes and potentially put themselves and others at risk, such as driving. For example, if drivers have a misalignment of their calibration of driving skills, they may potentially perceive themselves as better drivers who can handle the load of a secondary task, when in reality, they may be an inherently poor driver, and the secondary task may cause so many attentional failures they fail to notice they have drifted out of their lane and into the vehicle next to them. A biased self-view of driving ability creates a significant barrier to the attempts to counter distracted driving made by legislatures, law enforcement, advocates, and their campaigns. When asked about how their driving performance compares to others, most report that drivers tend to rate themselves as more skilled than other drivers (Svenson, 1981; McKenna, Stanier, & Lewis, 1991; DeJoy, 1989; Brown & Groeger, 1988; Horswill, Waylen, & Tofield, 2004). If all drivers were great drivers, there would be far fewer crashes due to human error, and recorded crashes would be primarily due to mechanical or technical failures. However, we realize that this is not the case as 94 percent of crashes are due to human failures (Singh, 2015). The optimistic view of driving abilities translates to a failure in calibration with dangerous implications for willingness to engage in secondary tasks, especially when the secondary tasks are highly valued. Consequently, the failures in calibration, especially in cases in which the drivers are distracted, remains a hypothesis for further investigation into answering why drivers choose to drive distracted.

The need to attend to a message

A final possible hypothesis as to why drivers choose to drive distracted is that the value of the secondary task outweighs the risk of driving distracted. Though the DSM-V has yet to include internet or phone addictions as a disorder, the term "behavioral addiction" has been recently introduced. An important aspect of this potential addiction is the underlying process of dependence. Dependence can be conceptualized as a behavior in which the individual surrenders some level of control and becomes reliant on an external substance or presence for a stimulus (De-Sola, Rodríguez, & Rubio, 2015). Scales have been developed to measure text message dependency. One of these scales is the Self-Perception of Text-message Dependency Scale (SPTDS) has been used to measure dependency of phone use as it relates to three specific factors: excessive use, emotional reaction, and relationship maintenance. Further, these factors have been understood to predict health-related outcomes. For example, Liese et al. (submitted) found that an increase in dependence was related to an increase in likelihood of motor vehicle collisions, which are not restricted to any specific age groups. Through highly accessible technology, specifically handheld smartphones, an individual can easily receive almost instant gratification regardless if they desire to talk to someone right away, look up information, or simply see what someone else is up to. In an evaluation of most common reasons to text while driving, status updates, instant gratification, to get directions, and contact a significant other were the most frequently reported reasons (Atchley et al., 2011). The immediacy of the desired response creates dopamine loops that rival those associated with highly addictive other behaviors, such as sex (Weinschenk, 2012). Once these pathways are created, the need for more dopamine is also created despite the initial desire being fulfilled. When the device or phone "dings," we are cued to know that something is going to happen. We are not sure what type of message is received, whom it is from, or what it will be concerning. These unpredictable factors create a variable reinforcement schedule, which adds to the power associated with a simple text message (Weinschenk, 2012).

In addition to the dependency on text messaging, text messaging behaviors also may done without conscious intention. Habitual orientation, or automaticity has been understood to predict text messaging while driving. Without meaning to, people instinctively and immediately attend to their phone when they are alerted of an incoming text message (Bayer & Campbell, 2012). Previous work has understood that frequency of behavior can lead to habitual processes; however, past frequency does not differentiate between conscious and nonconscious decisions (LaRose, 2010). When past texting frequency is controlled for, automaticity is still a significant predictor of text messaging while driving (Bayer & Campbell, 2012).

The delay discounting method

Text messaging while driving is also compelling because information has immediate value (Atchley & Warden, 2012). Atchley and Warden (2012) used the delay discounting method to examine the underlying dynamics of the decision making process. Through the use of the delay discounting method, we are able to understand the decrease in subjective value of an object over time compared to money. In this method, participants are asked to indicate their preference between a smaller reward paired with a stimulus available immediately and a larger reward paired with the same stimulus available after a delay. Participants repeatedly indicate their preference between these two options across increasing levels of reward and across several time periods. At the presentation of the two options, people automatically attribute a subjective value to each options and select the option with the most attributed subjective value. This attribution of value may not be a conscious process but allows us to understand how a stimulus is valued over time.

Using the delay discounting method, it has been understood that while money loses 25 percent of its value in two weeks, a reward that includes texting loses 25 percent of its value in a matter of minutes. These results suggest that the immediacy associated with a text message are highly valuable and that there is a value associated with the message itself. When social distance was manipulated, the greater the social distance, the faster the less willing an individual was to wait to respond to that person (Atchley & Warden, 2012). For example, there was a higher urgency to respond to a text message received from a significant other compared to an acquaintance. The subjective value placed on these messages indicate that many feel a strong need to attend to their phone while driving. Further, when younger drivers were surveyed, it was suggested that younger drivers who experience anticipation of messages from their phones and have emotional attachment to their phones have a "compulsion" to use their device leading to an increased crash risk (Whitehill, O'Connor, King, & Ebel, 2012).

Technological solutions to the problem of distracted driving

Given the compelling nature of phones and the compulsion to respond to it, it comes as no surprise that there is a technological solution. One of the potential solutions is an app on the phone. These apps come with a variety of features, each with their own set of pros and cons, as well as from a variety of interested parties. Using the GPS sensors in smartphones, some apps "lock out" the user by requiring the user to go through several unlocking steps to access their phone when in motion. Other apps simply silence any incoming notifications or select notifications, while others offer users potential rewards for distraction-free drives or report to loved ones when a phone is used while driving (DMV.org, 2017). While insurance companies, phone networks, and other third parties have taken a variety of approaches, these apps have yet to be widely accepted. It is estimated that over $25 million has been spent developing these apps, and yet these apps have been criticized because it has been argued that the individuals who are likely to download one of these apps are the same individuals who would not use their phone while driving (Amalberti, 2017). Though some respond better to the reward or "carrot" solution, others need the "stick" or potential punishment approach; however, a single app cannot be a solution for the differing types of reward sensitivity found in a single population despite the wishes of parents and app developers alike. So while the concept of using the phone to prevent the use of the phone is indeed appealing, it does not appear to be a feasible solution to the problem of distracted driving.

However, there has been another method to use technology to limit the risk of phones: building phone features into the vehicles themselves. Though rumors of automated vehicles with remarkably advanced technology are common conversations, advanced technologies are already commonly being sold in vehicles. In addition to Bluetooth hands-free phone systems, vehicles commonly come equipped with some sort of text messaging system built into the in-vehicle infotainment system (IVIS). These systems are typically either a vehicle voice response system in which the text message received is read aloud to you and with the press of a few conveniently placed buttons, you can dictate a response without having to manipulate the phone directly. Other less common systems allow users to read the text message either on the screen on the center console display or on a small display screen next to other critical driving information, such as the odometer and gas level gauge. Users are then able to select from pre-determined responses presented on the same screen. These systems, regardless of their specific outfitting, were described to the author by a salesman as a "safe way to text while driving."

The alarming phrase that a highly demanding distraction may be described to car buyers as a safe alternative begs the question of how these systems are marketed and described to less informed car buyers. Upon the examination of the manuals from three comparable systems from three different car manufacturers, the features of these systems are explained in the same section as equipment necessary for the safety of vehicles, such as windshield wipers and blinkers. The placement of the IVIS systems with other necessary vehicle features implies two things to consumers: using these systems must not be associated with additional risk if there is not a separate section in the manual for it, and the car manufacturers found it safe enough to be included in the car, and it therefore must be safe for use. Not found in this section of the manual are the risks involved with using these IVIS systems to send and receive text messages while driving. Though most users are required to acknowledge the risk of using an IVIS system while driving, few conceptualize the actual risk.

Though continued use of IVIS systems to send and receive text messages may somewhat improve comfortably of use with these systems, experience does not decrease the magnitude of their impact (Strayer, Cooper, Turrill, Comeman, & Hopman, 2015). In an evaluation of ten different vehicles' IVIS, participants completed a variety of tasks, and cognitive workload was reported and objectively measured. This evaluation found that though the IVIS systems may indeed be hands-free, they are still associated with high levels of cognitive demand. Further, these cognitive demands have residual costs even after the IVIS interactions were completed (Strayer et al., 2015). Realistically, IVISs are not the highly sought-after solution to distracted driving they were intended to be. In fact, these systems may have actually made the distracted driving problem worse by encouraging drivers to attend to distraction more immediately with the incorrect notion that these systems are acceptable to use while driving.

Rather than being a safe alternative to carry-on or nomadic phone systems, built-in technologies may represent a new distraction to drivers. These technologies might add to the list presented here (improper risk perception, compensatory behaviors, calibration failures or improperly valuing the secondary communication tasks) for why drivers drive distracted. If drivers think built-in technologies are safer, it might increase their use of those systems. Further, differences between drivers in their willingness to put off responding to information prompts might differentially influence their driving ability. Some drivers may be better equipped to understand how they are affected by technology and compensate appropriately. The current work has two aims. First, it seeks to understand willingness to respond to text messages presented over a vehicle's voice response system compared to a text message presented on the screen of a smartphone. Rather than using a traditional survey method in which participants typically indicate socially desirable responses, the delay discounting method will be used. In this method, participants are asked to indicate their preference between receiving a smaller reward immediately or a larger reward after a delay. These options are paired with a specific stimulus, in this case, the opportunity to respond to the text message. Using this method we are able to understand how the value of the message is valued over time and the time point at which participants are willing to engage in the behavior. This measurement is opposed to a traditional survey method, in which participants would likely indicate on a Likert scale how frequently they have done the behavior in the past. Using this method, we are able to understand the subjective perception of safety of IVIS based on how long participants feel they can wait to respond to the message as a reflection of their perceived risk. Second, the research seeks to understand how those with differing perceptions of risk might drive differently and have different evaluations of their driving performance, or differences in calibration. The second experiment will pair a driving simulation approach with measurements of individual differences in willingness to respond to a message assessed using the delay discounting method to examine the effect of these variables on calibration and driving performance. Calibration was examined with different distracted driving tasks to understand if drivers are more or less aware of their driving performance in the presence of distraction.

Experiment One

Overview

The first experiment was designed to determine if response medium and the perception of risk influence the decision to respond to a message in driving situations. When a message is received while driving, it could be answered through different response mediums such as a cell-phone text message or car in-dash systems. A message could also be received in different weather conditions such a sunny typical day or a severe snowy day. The focus of this experiment was to investigate whether receiving messages from built-in systems are perceived as being more or less important that those from a personal cellular device and if an increase in perceived risk due to poor weather conditions changes the way in which the importance of responding to messages is perceived and if this interacts with the medium of the message.

Participants

A total of 92 participants were recruited using Amazon's Mechanical Turk. Ten participants were excluded due to a failure to complete the survey or failure to show any effect for delay for any of the conditions. The final sample included 39 males and 43 females with a mean age of 38.79, ranging from 19-72 years. The age mean and range were similar for both genders. All participants reported having a U.S. driver's license and 35 states were represented in the sample. Participants were paid $0.60 for the completion of a 15-minute survey. Prior to beginning the survey, participants completed an informed consent form digitally.

Materials

Monetary-Choice Questionnaire

The Monetary-Choice Questionnaire (MCQ) or temporal discounting task is a 27-item self-administered questionnaire designed to measure delay discounting rate of participant's responses to monetary choices (Kirby, Petry, & Bickel, 1999). This questionnaire is designed for participants of 13 years of age or older. For each item, the participant chooses between a smaller, immediate monetary reward and a larger, delayed monetary reward. The protocol is scored by calculating where the respondent's answers place him/her amid reference discounting curves, where placement amid steeper curves indicates higher levels of impulsivity. A computerized version of this questionnaire was used in this study via Qualtrics Survey Software. The program presents participants with a smaller, immediate monetary reward and a larger, delayed monetary reward to choose between.

A participant's discounting curve may be calculated according to the following function: $V = A/(1+kD)$. V is 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 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). This questionnaire was presented to the participants prior to the experimental task to measure participant's general discounting rate tendency.

The process that underlies delay discounting method implies that when a choice is made there is an automatic attribution of values for both the choice of the immediate value and the choice of the delayed value (da Matta, Gonçalves, & Bizarro, 2012). These values are subjective and the degree of this subjective value is supposed to be associated with self-control (Petry, 2001). The present value of delayed rewards decreases as a function of 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). The inability to wait for a larger/later reward is associated with impulsive behavior, such as drug and alcohol use, gambling, smoking and other impulsive behavior disorders.

Hypothetical delay discounting task

A computerized hypothetical choice-making task was used to measure participant's temporal discounting rate for each response medium in different weather conditions. The task was programmed to present participants with four randomized hypothetical reward scenarios blocked by reward type and delay time. In each scenario participants repeatedly chose between one of two rewards presented on the screen: (a) a variable smaller reward available immediately or (b) a fixed larger reward available after some variable delay. The amount of fixed larger reward was always $100 and five different delays were examined during each scenario including 1, 5, 30, 60 and 480 minutes. These values were adopted based on previous work by Atchley and Warden (2012).

At the beginning of the process, when people are offered the smallest reward immediately opposed to waiting for a short delay with a much larger reward, people almost always select the option with the large reward, as the delay is reasonable to them. However, at some point for each delay, the smaller value offered immediately will have increased, and the delay will have also increased, and people will switch from selecting the larger delayed amount to the smaller and immediate amount. This is understood to be the point at which the subjective value attributed to both options is equal and is referred to as the indifference point. The indifference point is identified for each of the delays and are plotted to indicate the area under the curve (AUC), which is the reward indicated to be the preferred amount for that delay out of the total possible reward.

The plotted indifference points and corresponding AUCs provide us with insight of the value of a stimuli after a variety of factors have been considered. A lower AUC would indicate that the stimuli does not hold its value over time because it is preferred to be attended to sooner opposed to a larger AUC, which 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 are able to understand the value of the behavior as a function of the value of the behavior and the risk of that behavior. If an individual were given the options of receiving $15 and responding to a text message immediately or 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. Notably, 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. 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 therefore are willing to put off responding and the implications associated with that because of the risks.

In each of four scenarios the participants were asked to think about receiving a message from a significant other (participants without a significant other were asked to consider being in a committed relationship when thinking about the choice). The message could be received either through a smart phone or via a car in-dash system in a normal or severe weather condition while driving depending on the scenario presented on the screen. The four scenarios included receiving a message on a smart phone when driving in a sunny normal day, receiving a message through car in-dash systems when driving in a sunny normal day, receiving a message on a smart phone when driving in a severe snowy weather condition, and receiving a message through car in-dash system when driving in a severe snowy weather condition. An example of one scenario is as follows: "You are driving home on a long road trip in a typical sunny day. You have not been able to communicate with your significant other for several days. On your way you receive a message from your significant other appearing on your car dash screen, which reads 'Contact me when you can.'" Pictures were paired with each of the four scenarios to establish consistency for each of the four scenarios. These pictures are presented in Figures 1-4.

Then participants were repeatedly asked to choose their preferred hypothetical rewards. The smaller reward was available immediately (11 values ranging from $5 to $95) and the fixed larger reward ($100) was available after five different delays (1, 5, 30, 60 and 480 minutes). For example, participants were presented with such hypothetical choice after one trial: "Would you rather receive $5 and reply immediately or receive $100 and reply in 8 hours." The texting delays were chosen based on what was suggested in younger adult opinions whom were asked to estimate short to long texting delays (Atchley & Warden, 2012).

Barratt Impulsiveness Questionnaire (BIS-11)

The Barratt Impulsiveness Questionnaire (BIS-11) is the most widely used impulsivity scale that is 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) and three second-order factors (e.g., attentional, motor, and non-planning impulsiveness) (Patton et al., 1995). Patten et al (1995) reported the internal consistency range for BIS-11 from 0.79 to 0.83 for under-graduates, substance-abuse patients, general psychiatric patients, and prison inmates. Items are presented on a 4-point Likert scale with point 1 = Rarely/Never, point 2 = Occasionally, point 3 = Often and 4 = Almost always/Always.

The BIS-11 was administrated after participants finished their computerized hypothetical choice task. We included this questionnaire in the experiment to determine a possible relationship between individual differences in impulsiveness scales and participants' discounting rate for each messaging scenario. Studies showed that BIS-11 questionnaire factors, specifically attentional impulsiveness factor, are associated with executive function and decision making in the general population (Stanford et al., 2009). The participants' pattern of responses and discounting rate were not the same, which could reflect different behavioral and cognitive impulsive patterns. This was the rationale to use a questionnaire measuring impulsiveness construct in the experiment. The participants who score higher in BIS-11 are expected to have higher discounting rate in general which could account for their higher temporal discounting.

Procedure

A Human Intelligence Task (HIT) was posted on Amazon's Mechanical Turk offering participants $0.60 for their participation in a 15-minute survey. Once participants accepted the

HIT, they followed a link to the Qualtrics survey. First, participants completed a digital informed consent. They then provided basic demographic information. Participants then completed the MCQ portion of the experiment, followed by the Hypothetical delay discounting task. In the Hypothetical delay discounting task, the order of the four scenarios were randomly presented to participants to ensure there were no order effects. Next, participants completed the BIS-11. Finally, participants were thanked for their participation and given the opportunity to provide any feedback to the experimenter. Participants received their reward within three days after completion of the entire survey. To ensure no crossover, participants who completed this study were not eligible to have completed other similar studies posted by the Kansas University Visual Information Processing lab.

Results

In the first experiment the role of response medium of message while driving (cell-phone vs. car in-dash system) and the role of different weather conditions (normal vs. severe) were investigated. Figure 5 presents indifference points and the hyperbolic fit of these points for each scenario. As Figure 5 indicates there is difference among AUCs of each scenario suggesting different temporal discounting rates for each scenario. Area under the curve was calculated for each set of indifference points of each scenario. To see if there is significant difference on the AUC for different scenarios a 2 (response medium: cell-phone and in-dash car system) x 2 (weather: normal and severe) ANOVA was computed.

The results show that there is no interaction between weather condition and response medium on AUC $F(1, 324) = 0.19$, *n.s*. Further, the main effect of weather condition on AUC is also not significant $F(1, 324) = 1.33$, *n.s*, ($M_{\text{Sun}} = 0.67$, $M_{\text{Winter}} = 0.71$) indicating that people are equally willing to reply to a text message in a driving situation when the weather condition is normal compared with a severe weather condition, and this decision does not depend on whether the message is received via cell-phone or car in-dash system. Moreover, the effect of devices or response medium on people's decision to respond to a text while driving was significant on AUC $F(1, 324) = 12.32$, $p < 0.001$, ($M_{\text{Voice System}} = 0.63$, $M_{\text{Phone Screen}} = 0.75$). The results show people are more likely to respond to a text message when it is received through a car in-dash system whether they are driving in a normal weather condition or in a severe weather condition.

Individual difference analysis

Participants were divided into two groups of the heavy discounters and the low discounters based on a mean split of their scores on MCQ and the same analysis was done. The purpose of this analysis was to see if heavy discounters, who are more impulsive, show the same impulsiveness in responding to a message received from different mediums in different weather situations. Figures 6-9 shows indifference points and the hyperbolic fit of these points for the scenarios. AUC was calculated for each set of indifference points of each scenario. A two-way ANOVA on the AUC was computed, and results show there is no interaction between weather condition and response medium $F(1, 112) = 0.01$, *n.s* for heavy discounters. The main effect of weather condition was also not significant on AUC $F(1, 112) = 1.25$, *n.s.* ($M_{\text{Sun}} = 0.65$, $M_{\text{Winter}} = 0.72$). However, the effect of devices or response medium on people's decision to response to a text while driving was significant on AUC $F(1, 112) = 4.44$, $p < 0.05$, ($M_{\text{Voice System}} = 0.61$, $M_{\text{Phone Screen}} = 0.76$). Indeed, people with a higher level of impulsivity based on MCQ scores are more impulsive in responding to a text message when it is received through a car in-dash system whether they are driving in a normal weather condition or in a severe weather condition. Although the main effect of weather condition was not significant, we can see more impulsivity in responding to a message in different weather condition in heavy discounter participants compared to low discounter participants.

The same analysis was done for the low discounter participants. Figures 6-9 shows indifference points and the hyperbolic fit of these points of the scenarios for the low discounters. Area under the curve was calculated for each set of indifference points of each scenario. A two-way ANOVA on the AUC was computed and results revealed that there is no interaction between weather condition and response medium $F(1, 208) = 0.23$, *n.s*. The main effect of weather condition was also not significant on AUC $F(1, 208) = 0.36$, *n.s*. ($M_{\text{Sun}} = 0.69$, $M_{\text{Winter}} = 0.69$). However, the effect of devices or response medium on people's decision to respond to a message while driving was significant on AUC $F(1, 208) = 7.75$, $p < 0.01$, ($M_{\text{Voice System}} = 0.65$, $M_{\text{Phone Screen}} = 0.73$).

Discussion

The present experiment was conducted to see if the devices by which people receive messages (handheld phone compared to built-in technology) and risk of the primary tasks of driving influenced the decision to respond to a text message in the driving situation. The way participants received the message did have an effect on the decision about responding to a message. Participants showed greater temporal discounting, or less willingness to put off, a message received through a car in-dash system rather than through a cell phone regardless of whether the message was received in normal or severe weather conditions. Interestingly, weather condition did not have an effect on the way people decided to respond to a text message in a driving situation. Regardless of whether the message was received through the car in-dash system or on the handheld phone screen, people showed no differences in temporal discounting when the weather was normal or severe. Not surprisingly, drivers see driving in bad weather conditions as more dangerous compared to driving in normal weather conditions (Zhang, Huang, Roetting, Wang, & Wei, 2006). However, despite this risk, the value of the text message was still able to supersede this risk subjectively to participants. This is consistent with previous research, which has suggested that willingness to engage in distraction was related to general driver attributes of driving intensity and distraction (Lerner & Boyd, 2005).

These findings suggest that participants find built-in technologies to be safer compared to using a carry-on phone to send messages. In the current method, the willingness to delay an otherwise compelling message (Atchley & Warden, 2012) because it is delivered via a handheld phone indicates that drivers perceive handheld as a riskier option than built-in. If participants find these systems to be safer, one would predict participants to be equally as likely to use them as handheld devices. Using an external system does not reduce the value of the message, just the presentation of the message. It is important to note that if the systems are no safer than handheld, this possible increase in risk exposure could lead to greater risk on the part of the drivers.

The next step is to understand if those who are less willing to put off responding to a text message drive differently and perceive their driving performance differently than those individuals who are quite willing to postpone a text message. It is hypothesized that those who are high discounters are the same individuals who will have a poorer calibration of driving skills. Specifically, those who are less willing to put off responding to a text message will perceive their driving performance as better compared to those who are willing to wait to respond. On the other hand, those who are more willing to wait to responding to a text message will have a more accurate subjective perception of their driving performance. Further, it is hypothesized that those who are less willing to put off responding to a text message will have an objectively worse driving performance and will be more negatively impacted by distractions. We predict that drivers who perceive risks of texting as higher will have a more realistic perception of their driving performance, especially in the midst of a distraction. Further, those who have higher perception of the risks of distracted driving are likely embody this perception and driver more conservatively.

Experiment Two

Overview

The second experiment was designed to extend the findings in experiment one to driving performance in a simulator and drivers' perceptions of driving performance. As in the first experiment, we examined the willingness to respond to a text message as well as a measure of impulsivity. In this experiment, drivers were also asked to drive a series of simulated drives with low and high traffic conditions and to rate their driving performance following each trial. Drivers were required to drive distracted in some scenarios.

Method

Participants

Participants were recruited through an online advertisement. To be eligible for participation, participants were required to be between the ages of 21-55, be native English speakers, have low susceptibility to motion sickness, have normal or corrected-to-normal far vision acuity, have a valid U.S. driver's license, and be right-handed. Participants were balanced by gender and age. Participants were paid $30 for each hour of participation. The final sample size was 22 participants, but two participants did not complete the study due to simulator sickness leaving a final sample size of 20 (M_{age} = 39.4). There was an even split between males (M_{age} = 39.3) and females (M_{age} = 39.5). Participants reported an average of 22.85 years of driving experience and an average of 20,975 miles driven annually.

Materials

Driving Simulator

The Liberty Mutual Research Institute for Safety (LMRIS) driving simulator is a fixed-base simulator that consists of an open-cab vehicle mock-up, including an accelerator and brake pedals, steering wheel, dashboard, instrument panel, and center console. The instrument panel and center console are "glass panel" displays that can be reconfigured according to the requirements of the study.

The driving environments are presented on three 46-inch widescreen LCD displays that, from the driver's eye point, subtend 200° of forward visual angle. Embedded inlay displays simulate rear view mirrors. The simulator control dynamics are modeled after a typical four-door sedan and are coordinated through RTI SimVehicle software. The various driving environments and traffic scenarios were generated using RTI SimCreator and SimVista software.

Detection Response Task

The Detection Response Task (DRT) is a measure of cognitive workload. A headband with an LED light on the end of a flexible arm is placed on the participant's head. The light is positioned to be in the participant's left peripheral field of vision following ISO standards and a microswitch is attached to the participant's left thumb (ISO, 2012). A red light is presented to the participant every three to five seconds, in which they are to respond as soon as they detect the light using the microswitch on their thumb.

The DRT has been established as a sensitive measure of cognitive tasks. This measure has been used along with previously established measures, including both the subjective and physiological measures, of cognitive workload and has been shown to be an accurate measure of workload (Strayer, Turrill, Coleman, Ortiz, & Cooper, 2014). As difficulty in cognitive tasks or driving demand increases, response time for the DRT increases. This task is notably sensitive as a measure of cognitive demand but is not a reliable measure of visual-manual tasks (Bruyas & Dumont, 2013). The DRT measure has also been used to measure a variety of tasks while driving, including text messaging and in-vehicle devices, and it has consistently shown there is an increase in workload when completing secondary tasks while driving (Cooper, Ingebretsen, & Strayer, 2014).

Monetary-Choice Questionnaire

The description of the Monetary-Choice Questionnaire (MCQ) is provided in the experiment one materials (Kirby et al., 1999). The same questionnaire was used but was administered first using Qualtrics Survey Software on a tablet.

Hypothetical delay discounting task

A computerized hypothetical choice making task was used again to measure participant's temporal discounting rate for each response medium in different weather conditions. The scenario given to participants was similar to the previously described scenario in experiment one. In this experiment, participants were again asked about responding to a message either presented on their handheld smart phone screen they would have to read or via a car in-dash system, in which their message would be read aloud to them, and their response would be dictated. The weather outside of the car was again either a sunny and clear day or a severe winter storm.

Participants were asked repeatedly to choose their preferred hypothetical rewards from a smaller reward available immediately (11 values ranging from $5 to $95) and the fixed larger reward ($100) which was available after five different delays (1, 5, 30, 60, and 480 minutes.)

Barratt Impulsiveness Questionnaire

The description of The Barratt Impulsiveness Questionnaire (BIS-11) is provided in the experiment one materials (Patton et al., 1995). To preview, we do not present analysis using the BIS-11, as those results converge with the results of the delay discounting procedure.

Procedure

Upon arrival, participants were given an informed consent and audio/visual release and were then given a vision test to ensure they had at least 20/40 vision (normal or corrected). Next, participants completed a questionnaire consisting of demographic information, including driving experience and history, and the delay discounting questionnaire.

Upon completion, participants were given an introduction to the driving simulator. Participants first completed a drive to familiarize themselves with the simulator, the driving scene, and the calibration paradigm. The scenarios were modeled after earlier studies (Horrey, Lesch, & Liang, 2016). The driving scene consisted of a straight roadway in a rural area with lateral wind gusts. The wind gusts were randomized but presented an equal number of gusts from both directions with a balanced number of stronger and weaker gusts, but all gusts were between 150 to 450 Newtons or 650 to 950 Newtons in strength, which was sufficient to push the vehicle off-course, prompting a corrective steering response. The total duration of each gust was 25 seconds and was marked by an audio prompt for participants to rate their driving performance. There was a five second gap between the end of each wind gust and the beginning of the next gust, for a total of thirty seconds. This thirty-second window was referred to as a "trial." In this calibration framework, participants were asked to rate their driving performance aloud, following each trial along a continuum ranging from 1 (worst performance) to 100 (perfect performance). They were given no instruction on which aspects of their driving should be considered in their rating as it was intended to be purely subjective. The results of their driving performance based on the data provided by the driving simulator were then compared in proportion to their subjective rating. Participants completed 18 trials and therefore rated their driving performance 18 times, for a total time of nine minutes for each drive.

After familiarizing themselves with this calibration framework and the driving scene, participants then completed a series of practice drives to familiarize themselves with the secondary tasks. Typically, each practice drive lasted for three trials unless the participant indicated that they felt they needed more practice. The first secondary task was the DRT measure of cognitive workload. Participants first practiced the DRT task without driving, then practiced the task while driving. The light stimuli began at the same time as the first wind gust trial. Next, participants completed the *n*-back task. In this task, participants were instructed that they would be read aloud a string of single-digit numbers every few seconds, and they were to repeat the number read two numbers prior (Mehler, Reimer, & Dusek, 2011). For example, if the numbers "one...seven...three...nine" were read aloud, the number "one" would be repeated aloud by participants when they heard the number "three" and "seven" when they heard "nine." Once participants felt comfortable with the task, they then did a practice task while driving and rating their driving performance. The end of the string of numbers to repeat was marked by the audio prompt to rate their driving performance. Finally, participants were introduced to the text messaging task. Participants were sent a text message on an Apple iPhone 5 every thirty seconds. Participants were instructed to use the last letter of the prompt word texted to them to begin a text message response. For example, if participants were texted the word "pen," they could hypothetically respond with the word "nose." Once participants were comfortable with this task, they then practiced the text messaging task while driving and rating their driving performance.

Participants then completed six drives, utilizing a two by three factorial design. These drives consisted of two levels of ambient traffic, either high or low traffic. The drives also consisted of three different tasks: the *n*-back, the text messaging task, and a control drive with no secondary task. Participants completed the DRT task in all six drives to have a measure of cognitive workload for each task. Before each drive, participants were told that driving safe was always their main priority, they were to stay in the right lane unless the needed to pass a car then to return to the right lane, and to maintain a speed of 65 mph. The purpose of telling participants that driving safe was their main priority was to give participants the option of not completing the secondary tasks if they felt it was unsafe for their driving performance. Participants were given a short break between the third and fourth drive. Because truly counterbalancing all six drives would require 720 participants, a balanced Latin square design was used to assign the order of each drive to participants.

Upon completion of all six drives, participants completed a brief survey. Participants were then debriefed and paid for their participation in the study. The total duration for the study was about 2.5 hours for each participant.

Results

Delay Discounting

Overall, there was a significant difference in AUC between all four scenarios $F(1, 78) = 98.33$, $p<0.001$. Once the groups were divided, we ran an ANOVA to examine if high and low discounters differed in their willingness to wait to respond to text messages by examining differences in their AUC for the four different scenarios, see Figures 10-13. In the sunny and clear weather condition in which the participants were making the decision to respond to the text message using the vehicle's voice response system, there was a significant difference in AUC between high and low discounters $F(1, 18) = 21.55, p<0.001$ ($M_{\text{High}} = 0.25$, $M_{\text{Low}} = 0.82$). In the sunny and clear weather condition in which the participants were making the decision to respond to the text message using the handheld phone keyboard, there was a significant difference in AUC between high and low discounters $F(1, 18) = 9.58, p<0.01$ ($M_{\text{High}} = 0.36$, $M_{\text{Low}} = 0.79$). In the winter storm weather condition in which the participants were making the decision to respond to the text message using the vehicle's voice response system, there was a significant difference in AUC between high and low discounters $F(1, 18) = 48.92, p<0.0001$ ($M_{\text{High}} = 0.25$, $M_{\text{Low}} = 0.72$). In the winter storm weather condition in which the participants were making the decision to respond to the text message using the handheld phone keyboard, there was a significant difference in AUC between high and low discounters $F(1, 18) = 44.13, p<0.001$ ($M_{\text{High}} = 0.34$, $M_{\text{Low}} = 0.88$). Due to a lack of power, the individual differences analyses conducted in the previous experiment were not conducted in this experiment. Instead, differences in each scenario were examined.

DRT Performance

The response time for the DRT was collected as the number of microseconds between the onset of the light in the participant's peripheral vision and the participant's press of the thumb switch. The results were converted to milliseconds and are reported as such. There was an increase in response time for the varying levels of tasks $F(2, 107) = 18.54, p<0.001$ ($M_{\text{Control}} = 614.84$, $M_{\text{N-back}} = 859.86$, $M_{\text{Texting}} = 892.68$), see Figure 14. Tukey HSD pairwise comparisons revealed significant differences between the *n*-back condition compared to the control condition as well as the text messaging condition compared to the control condition at $p <.001$. The Tukey HSD test did not reveal a difference between the text messaging condition and the *n*-back condition at $p <.05$. However, there was not a significant difference in response time for traffic level *F*(1, 107) = 1.24, *n.s* (M_{High} = 764.92, M_{Low} = 811.67) (see Figure 15) and no significant interaction between task condition and traffic level *F*(2, 107) = 0.49, *n.s*. Additionally, there was no significant difference in response time for those in the high discounter or low discounter groups *F*(1, 108) = 0.44, *n.s* (M_{High} = 776.33, M_{Low} = 802.28) (see Figure 16) and no significant interaction between discounting group and task condition *F*(1, 108) = 0.19, *n.s*.

The hit rate for the DRT was defined as the number of misses divided by the total number of presented stimuli. There were no differences in response hits for the varying levels of tasks *F*(2, 107) = 1.39, *n.s* (M_{Control} =0.92, $M_{\text{N-back}}$ = 0.90, M_{Texting} = 0.88) (see Figure 17) or for the levels of traffic *F*(1, 107) = 0.19, *n.s* (M_{High} = 0.90, M_{Low} = 0.89) (see Figure 18) and the interaction between task and traffic was also not significant *F*(2, 107) = 0.04, *n.s.* Interestingly, there was a significant difference in hit rates for those in the high discounters or low discounter groups *F*(1, 107) = 4.14, $p<0.05$ (M_{High} = 0.88, M_{Low} = 0.92) (see Figure 19) and no significant interaction between discounting group and task condition *F*(2, 108) = 0.02, *n.s*.

Driving Performance

Lane maintenance was examined by looking at participants' variance (squared standard deviation) in meters. Though we could examine the raw data of lane position, examining lane stability or maintenance in the presence of the wind gusts provides a better measure of the driving situation. There was a significant difference in lane maintenance for the task levels *F*(2, 111) = 20.97, $p<0.001$ (M_{Control} =0.14, $M_{\text{N-back}}$ = 0.12, M_{Texting} = 0.21) (see Figure 20). A Tukey HSD pairwise comparison revealed there to be a significant difference between the text messaging task and the control task as well as between the text messaging task and the *n*-back task but not between the *n*-back task and the control condition, all at a $p<0.05$ level. There was not a significant difference in lane maintenance for the high and low traffic levels *F*(1, 111) =

0.01, *n.s* ($M_{\text{High}} = 0.16$, $M_{\text{Low}} = 0.16$) (see Figure 21), and the interaction between task and traffic was also not significant $F(2, 111) = 0.07$, *n.s*. Further, there was no significant differences in lane maintenance by discounting group $F(1, 111) = 1.61$, *n.s* ($M_{\text{High}} = 0.15$, $M_{\text{Low}} = 0.16$) (see Figure 22).

Speed maintenance was also examined as a measure of driving performance. Speed maintenance was measured by participants' variance (squared standard deviation) in miles per hour. There was not a significant difference in speed maintenance for the task levels $F(2, 111) = 0.83$, *n.s* ($M_{\text{Control}} = 14.99$, $M_{\text{N-back}} = 17.57$, $M_{\text{Texting}} = 19.67$) (see Figure 23). There was a significant difference in speed maintenance for the high and low traffic levels $F(1, 111) = 22.76$, $p<0.001$ ($M_{\text{High}} = 24.23$, $M_{\text{Low}} = 10.67$) (see Figure 24) and the interaction between task and traffic was also not significant $F(2, 111) = 0.07$, *n.s*. Further, there was no significant differences in speed maintenance by discounting group $F(1, 111) = 3.32$, $p=0.071$ ($M_{\text{High}} = 19.77$, $M_{\text{Low}} = 15.43$) (see Figure 25).

Rating of Driving Performance

Participants were to rate their driving performance on a scale of one to one hundred. If participants called out a zero, it was assumed that they intended the lowest possible rating and that rating was entered as a one. There was a significant difference in driving performance ratings for the task levels $F(2, 114) = 29.40$, $p<0.001$ ($M_{\text{Control}} = 79.63$, $M_{\text{N-back}} = 73.40$, $M_{\text{Texting}} = 53.90$) (see Figure 26). A Tukey HSD pairwise comparison revealed there to be a significant difference between the text messaging task and the control task as well as between the text messaging task and the *n*-back task and between the *n*-back task and the control condition, all at a $p<0.05$ level. There was not a significant difference in driving performance ratings for the high and low traffic levels $F(1, 114) = 0.18$, *n.s* ($M_{\text{High}} = 68.38$, $M_{\text{Low}} = 69.57$) (see Figure 27), and the interaction between task and traffic was also not significant $F(2, 114) = 0.138$, *n.s*. Further, there were no significant differences in driving performance by discounting group $F(1, 118) = 1.61$, *n.s* ($M_{\text{High}} = 70.91$, $M_{\text{Low}} = 66.61$) (see Figure 28).

Discussion

To further our understanding of the problem of distracted driving, possible explanations into the decision of driving distracted were investigated. First, we sought to understand how a message is valued over time and across different levels of risk. We expected to find that in situations of higher risk, or in more dangerous weather situations, participants would be less willing to respond to messages sooner and would prefer to wait until the risk was decreased. We further expected that the modality in which the message was presented would influence the immediacy at which the participant attended to the message. In other words, we thought that when the message was presented through the IVIS, the participants would perceive the message with less associated risk than when the message was presented on the handheld phone screen and would therefore be willing to respond to the message presented over the IVIS sooner. These findings would inform us as the perceived risk of different message modalities and its relationship with external risk. Though we know that using in-vehicle systems is associated with increased cognitive workload, these findings would inform us if consumers perceive them the same way and treat them appropriately.

After increasing our understanding of the perception of risk, we sought to understand perception of driving as it relates to perception of risk in different scenarios. We expected to find that those who perceive a greater risk from driving distracted would have a more accurate perception of their driving performance compared to those who perceive less of a risk. Those individuals who perceived less of a risk and were willing to attend to text messages sooner were expected to have an inflated perception of their driving performance. These results would inform us about the relationship between driving performance skills calibration as it is related to a willingness to be distracted.

In the first experiment, we used the delay discounting method to examine willingness to respond to a message as an indicator of perceived risk. Using this method, we found that the modality that the message is presented on is the most important factor. Participants were more willing to put off responding to a text message presented on their smartphone screen opposed to a message presented over the IVIS. There was no interaction found between modality and weather situation, and weather was not a significant factor when deciding to respond to a message. These findings were also found for both high and low discounters in the individual analysis. However, there was a stronger effect for modality low discounters than high discounters.

These results suggest that a received message on the IVIS might be seen as part of car in-vehicle technology, which is supposed to facilitate driving performance rather than threatening driver's safety. There are studies supporting the idea that in-car systems may be perceived to increase driver's safety or improve driving performance (Kim, Kwon, Heo, Lee, & Chung, 2014; Kim & Song, 2014; Takayama & Nass, 2008). Drivers also reported that they use in-vehicle technologies, especially auditory in-vehicle technologies, while driving, showing that their attitude is not negative about using in-vehicle technologies and even see these technologies facilitating of deriving performance (Kidd, McCartt, & Oesch, 2014; Varden & Haber, 2009; Viborg, 1999). Therefore, a received message through car in-dash system may be seen as a safety-improving in-vehicle technology despite contradictory evidence (Strayer et al., 2015).

A possible explanation for the preference in responding to text messages using an IVIS is concerned with the immediacy and availability of the information received through a car in-dash system message. A received message on the car in-dash system is more quickly and easily available. Drivers see the message on their car interface system quickly available whereas the message received on a cellphone is not as easily visible as a car in-dash system message. The increase in the immediacy may increase the value of the information. This is something worth exploring in future research.

Further, the influence of advertisement from car manufacturers about advantages of in-vehicle technologies may have a pronounced impact of driver's perception of these technologies, especially with respect to driver's safety. We see many advertisements in the media about new cars with facilitating in-vehicle technologies, and a recent survey of public opinion in the U.S, the U.K, and Australia about connected vehicles showed that the general public feel positive about connected vehicles, have optimistic expectations of the benefits and generally desire connected-vehicle technology when it becomes available (Schoettle & Sivak, 2014). This positive public opinion about in-vehicle technologies may contribute to why people prefer to respond to a message while driving using a car in-dash system.

The lack of an effect for weather was an unexpected finding. Previous research has demonstrated that drivers do feel their driving behavior is impaired by bad weather conditions, especially so when compared to normal weather conditions (Abdel-Aty, Ekram, Huang, & Choi, 2011; Konstantopoulos, Chapman, & Crundall, 2010; Ma & Kaber, 2005; Zhang et al., 2006). However, the current study found that this associated risk is devalued when presented with the option to send and receive text messages. This finding is contradictory to a similar study, which used a similar paradigm and scenario. In this study, there was still no interaction between weather condition and message modality, but there was an effect for both the weather condition and the message modality. However, there was a larger effect for message medium compared to the effect for weather (Salehinejad & Atchley, 2015). Though this risk may be considered, the value of the message supersedes the risk in this case, especially so when the message is presented in such an immediate and rewarding way, such as over the IVIS. This effect is more apparent in the present study. One possibility for the devaluation of the risk of weather may be the location of participants. Participants were recruited from mTurk, and 35 of 50 states were represented. The location of participants can possibly provide two explanations. One, explanation is that winter storms are common, and drivers are used to driving in the winter and see winter weather as less risky. On the other hand, participants may be from states in which winter storms are not common and are therefore not perceived as a threat because of their rarity. We had no coding scheme to examine this hypothesis in the current work but it is worth considering in future studies that are able to sample form a broad geographic area.

In experiment two, the differences between high and low discounters were examined as well as differences in calibration and driving performance in both distracted situations and for the differing groups of high and low discounters. Similar to experiment one, there was a difference between all four scenarios. In this experiment effects for weather and modality in individual analyses could not be examined like they were in experiment one because of low power. However, we found that high and low discounters did differ in AUC across all four scenarios. When examining the effect size, the largest effect across all four scenarios was when the message was presented on the handheld phone screen when the weather was a winter storm, which was associated with the largest difference between AUC of low discounters and high discounters. These results are not surprising that those who are high and low discounters would differ the most in their willingness to respond in the scenario associated with the most risk. Interestingly, we see that there was the smallest effect for the scenario in which the text message was also presented on the handheld phone screen when the weather was sunny and clear. This scenario is associated with less risk because the weather is less of a factor. However, this finding was surprising because there is still a high level of risk involved with responding to a message on the handheld phone opposed to over the IVIS.

In the DRT measure of cognitive workload, there were differences in reaction for the different secondary tasks while driving, such that the text messaging and the *n*-back task were each different from the control condition, but there was no difference between the texting task and the *n*-back task. These findings suggest that the text messaging task and the *n*-back are indeed highly cognitively demanding. There were no differences in reaction time for the varying traffic levels. This finding is not surprising as driving in traffic is common and may not be highly demanding for experienced drivers and the traffic flow in the simulation was intended to flow naturally and did not involve any unexpected events requiring careful maneuvering. Likewise, there were no differences for DRT hit rate for the varying traffic levels. However, unlike the reaction time, there were no differences in hit rate for the three different secondary tasks. This finding is particularly interesting because drivers were still able to respond to the DRT at the same rate but had slower response times as the product of a cognitively demanding secondary task. Further, when differences in hit rate were examined between high and low discounters there was a significant difference in that low discounters, or those who were considered to be less impulsive, had a higher hit rate than those who were considered highly impulsive. There were no differences in response times for high and low discounters. These findings suggest that when using the DRT as a measure of cognitive workload the response time may be related to the task while the hit rate may be a better measure of individual differences. The differences between these measures are important because individual differences are often lost when attempting to also examine differences related to the task.

When driving performance was examined, there was more variance in lane position for the differing secondary tasks. Wind gusts were included as part of the driving scenario and maintaining a stable position was challenging but possible. Lane position was equally stable for both the differing traffic levels and between high and low discounters. Text messaging resulted in more variable lane position compared to both the *n*-back task and the control condition. However, the *n*-back task did not differ compared to the control condition. Interestingly, though not significantly different, there was increased stability in the n-back condition compared to the variance of the control condition. This finding is surprising because the *n*-back task reaction time is just as cognitively demanding as the text messaging task. However, text messaging does include both a manual and a visual component, which are absent in the other two tasks, which may potentially explain why the extra demands of the task result in more variable lane keeping. The increased stability associated with the *n*-back task may be related to the auditory nature of the task. Consequentially, participants cannot rely on the audio cues of traffic and therefore must more heavily rely on visual cues of the driving scene. As a result, there were fewer changes in lane position because of the intensified focus on the roadway. Another possible explanation for why lane position variability decreases as cognitive workload increases is due to eye movements. Generally, drivers tend to gaze in the direction that they intend to steer but also steer where they tend to gaze (Readinger, Chatziastros, Cunningham, Bülthoff, & Cutting, 2002; Rogers, Kadar, & Costall, 2005; Wilson, Chattington, & Marple-Horvat, 2008). However, under cognitive workload, drivers fixate less on their mirrors and dashboard and more on objects immediately in front of them (Recarte & Nunes, 2000; Tsai, Viirre, Strychacz, Chase, & Jung, 2007; Victor, Harbluk, & Engström, 2005; Medeiros-Ward, Cooper, & Strayer, 2014). This hypothesis does not fully explain the decrease in variability in lane position as a result of cognitive workload as a function of eye movement as cognitive workload has been understood to influence lane variability independent of eye movements (Cooper, Medeiros-Ward, & Strayer, 2013). Further, maintaining lane position is understood to become an automated process more prevalent in experienced drivers opposed to novice drivers (Yang, Jaeger, & Mourant, 2006). However, this hypothesis does not necessarily apply to the current sample, as the mean age was about 40, suggesting that a majority of the participants were at least moderately experienced drivers. Regardless of the mechanism, a strategically placed congruent secondary cognitive task can improve lane position variability (Atchley & Chan, 2010).

Speed variance did not significantly differ for each of the differing tasks levels. This finding is interesting because a reduction of speed was noted as one of the primary compensatory driving behaviors when distracted (Alm & Nilsson, 1990; Burns et al., 2002; Haigney et al., 2000; Rakauskas et al., 2004; Young & Regan, 2007). However, this may be because drivers were already expressing a change in their driving performance by rating their driving performance and therefore expectations for their driving were already altered and therefore, possibly nonconsciously, drivers may not feel the need to engage in compensatory driving behaviors. Speed did vary more in the high traffic conditions compared to the low traffic conditions. This finding is expected, as drivers have to respond to the patterns of traffic around them, including reducing and increasing speed. Finally, there were no significant differences in speed maintenance for the high and low discounters. However, the differences in speed variance were approaching significance in a reasonable direction that high discounters, or the more impulsive group, were more variable in their speed.

When drivers were asked to report their subjective rating of their driving performance, we found that they did realize their driving performance was indeed impacted by the secondary tasks. Participants reported their driving performance ratings to be lowest in the text messaging condition and best in the control condition. There were no differences in rating in the differing traffic levels or between high and low discounters.

The dissonance between driving performance ratings and the measures used to quantify driving performance suggest that drivers are not actually aware of their driving performance. Though drivers did indeed realize that their driving performance was the worst when completing the secondary texting task, they reported that their driving performance was also impacted negatively by the *n*-back task. However, when completing the *n*-back task, lane keeping was more stable, even when compared to the control condition. Though drivers may believe they are reporting their driving performance, it appears they actually may be reporting their level of cognitive workload. As the reaction time increased, it appeared that ratings of driving performance decreased. This suggests that drivers are not aware of their driving performance and are instead just aware of their cognitive effort.

Though the main hypothesis that drivers who are less willing to respond to text messages were more likely to drive differently was not confirmed, the results were in the correct direction as the high discounters were noted to have more variance in their speed. Unfortunately, the study may have been limited in power. Though the intended effect did not emerge, the area is worth continued exploration. Previous research has demonstrated that those higher in impulsivity are less likely to detect threats while driving and this effect will be continually investigated in future investigations with more power (Castro, Gugliotta, & Jose, 2017).

Further, the same drivers who were less willing to put off responding to a text message had a decreased ability to attend to multiple tasks, as evidenced by a decreased number of hits on the DRT measure. It was hypothesized that these same individuals would rate their driving performance lower as a way to resolve the cognitive dissonance between the willingness to wait to respond to a message and actually attending to a distraction while driving. However, this result was not found. Those less willing to wait to respond to a message scored higher on the impulsivity scale given, which is an expected finding that high discounters would also be highly impulsive (Bickel, Odum,& Madden, 1999). One key component of impulsivity is that behavior is done without regard for negative consequences, among other behaviors (Patton, et al., 1995). This disregard for future consequences in this case does not require individuals to resolve the cognitive dissonance, as there are lesser amounts of cognitive dissonance.

The findings in the current work have implications for how in-vehicle technologies are marketed and described to car buyers. Consumers need to be fully aware of the risk involved with using an IVIS system. Though it may be sold as part of the car and drivers have the option of using their devices without having a manual component, there is still a risk involved (Strayer, et al., 2015). However, the dissemination of this information falls on both car manufacturers as well as consumers. Understanding the risk before participating in a behavior is an important issue to address. Further, the current work has implications for perceptions of the safety of in-vehicle technology beyond those findings of a traditional survey method.

The current work also has implications for how those with different personality factors may be influenced by distraction. Though the highly impulsive individuals were just as aware as the impact distraction had on their driving performance as those who were low impulsive, they still reported a greater willingness to attend to distraction while driving. Further work is needed to understand what other personality aspects may be related to willingness to drive distracted and what may have an impact on perception of driving performance.

Using the delay discounting method to examine differences between high and low discounters and splitting participants into groups based on a mean or median split has been a common practice (Salehinejad, 2015). Though this approach has previously been used, if a large sample is not used, it may not be the most meaningful way to examine the data. Future research will examine different ways to split participants into groups of high and low discounters. These directions will include examining the distribution participants and looking at those in the highest and lowest quartiles. Another future approach is examining groups using a scree plot, which would plot participant responses and point us to where a more meaningful difference is between participants opposed to the seemingly arbitrary method of mean or median split.

The delay discounting method is an arguably more precise measure of impulsivity as it relates to a specific behavior of interest, yet it is a hypothetical scenario. Though this is indeed a limitation of the method, it also presents an interesting research question. Future research is needed to investigate the same effects in a more ecological setting in which drivers have to choose between responding to a message immediately or later. Further, more research is needed to understand differences in those who are more and less willing to wait to respond to text messages as it may relate to other safety behaviors.

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Figure 1: Message received on the handheld phone while driving through a winter storm.

Figure 2: Message received through the vehicle's voice response system while driving through a winter storm.

Figure 3: Message received through the vehicle's voice response system while in sunny and clear weather.

Figure 4: Message received on the handheld phone while driving in sunny and clear weather.

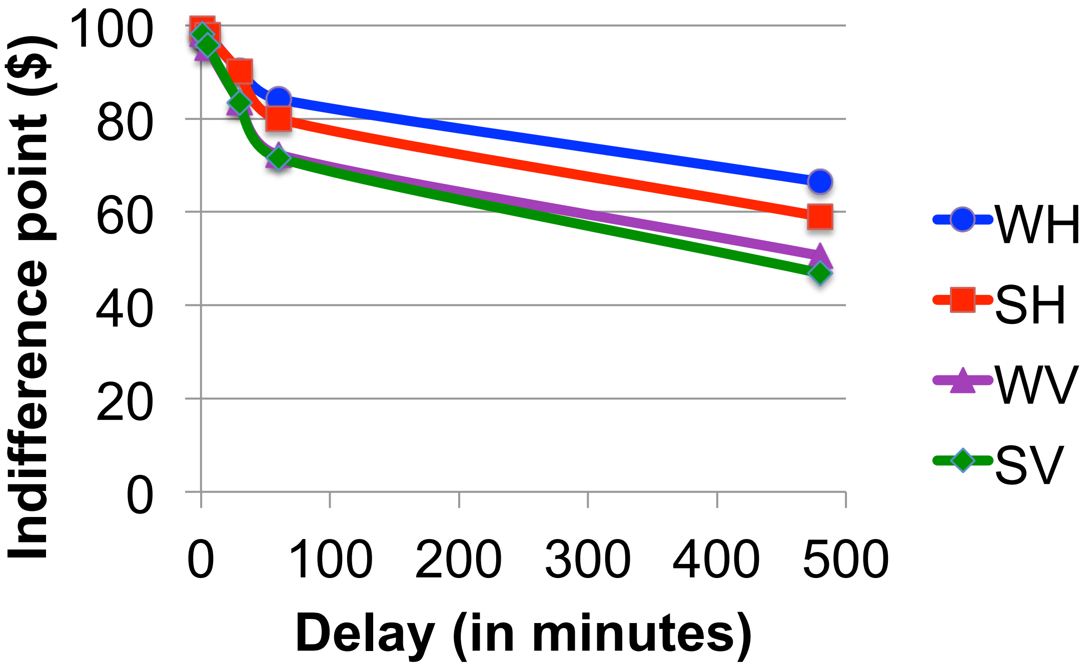

Figure 5 Mean indifference points of the scenarios across 5 delay points in experiment 1.

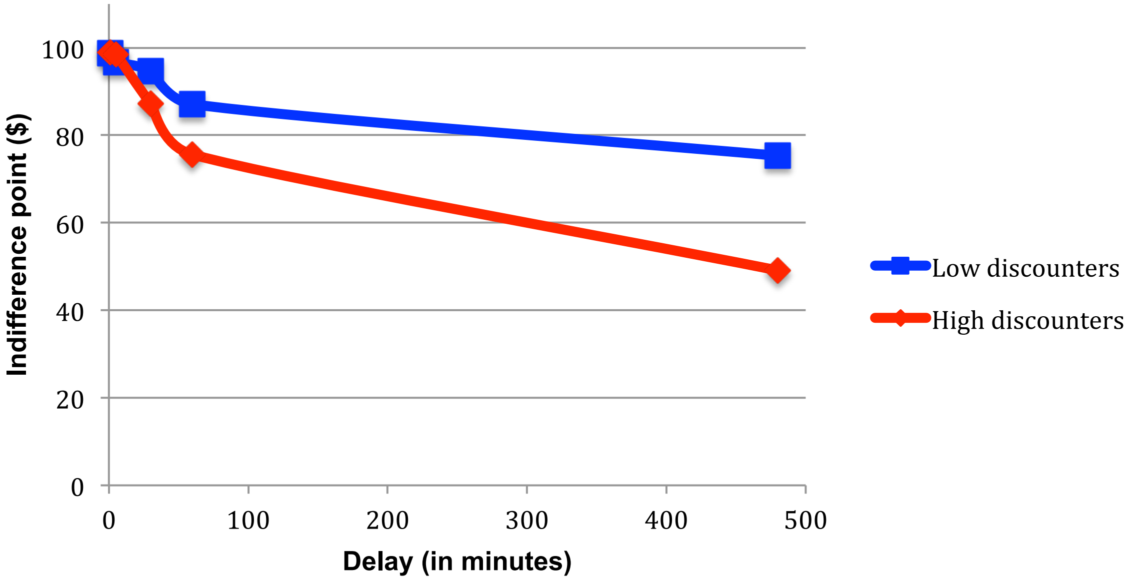

Figure 6 Mean indifference points for high and low discounters when message was presented on the handheld phone screen in sunny and clear weather in experiment 1.

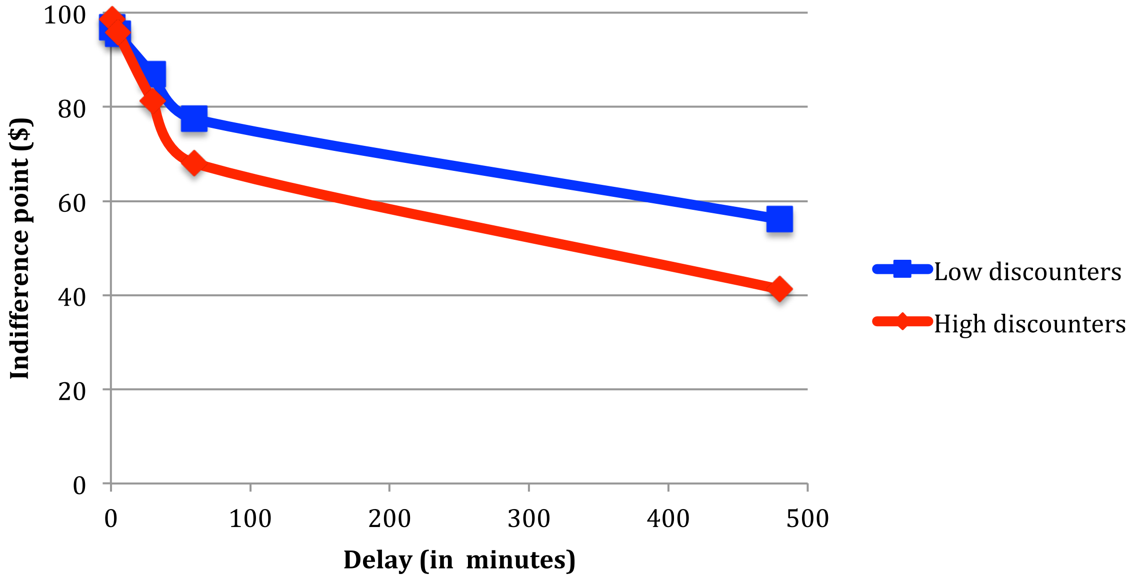

Figure 7 Mean indifference points for high and low discounters when message was presented over the vehicle's voice response system in sunny and clear weather in experiment 1.

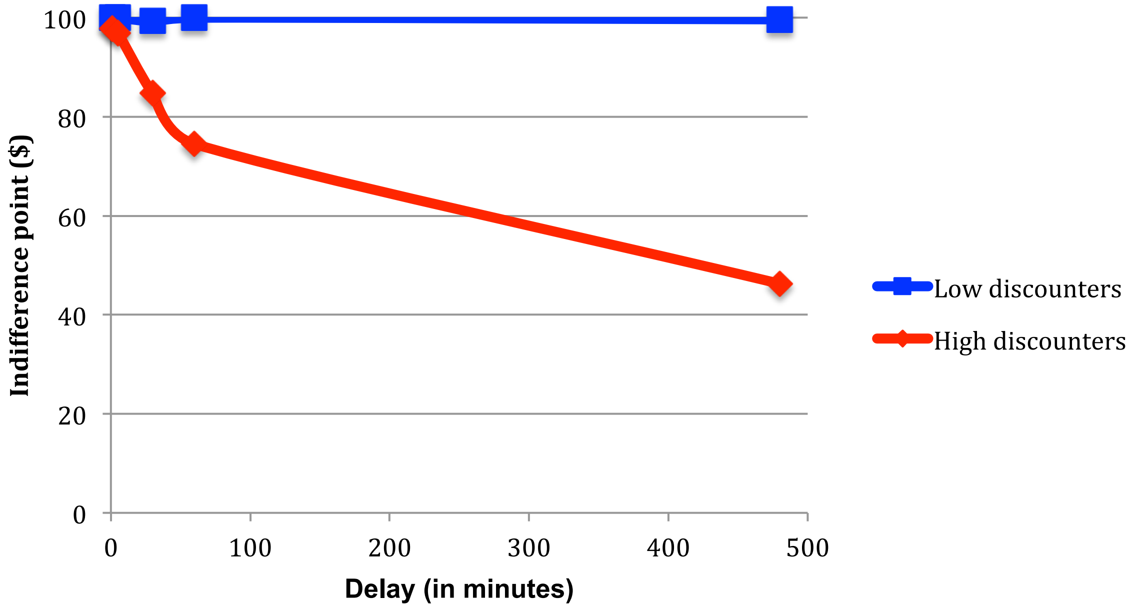

Figure 8 Mean indifference points for high and low discounters when message was presented on the handheld phone screen in a winter storm in experiment 1.

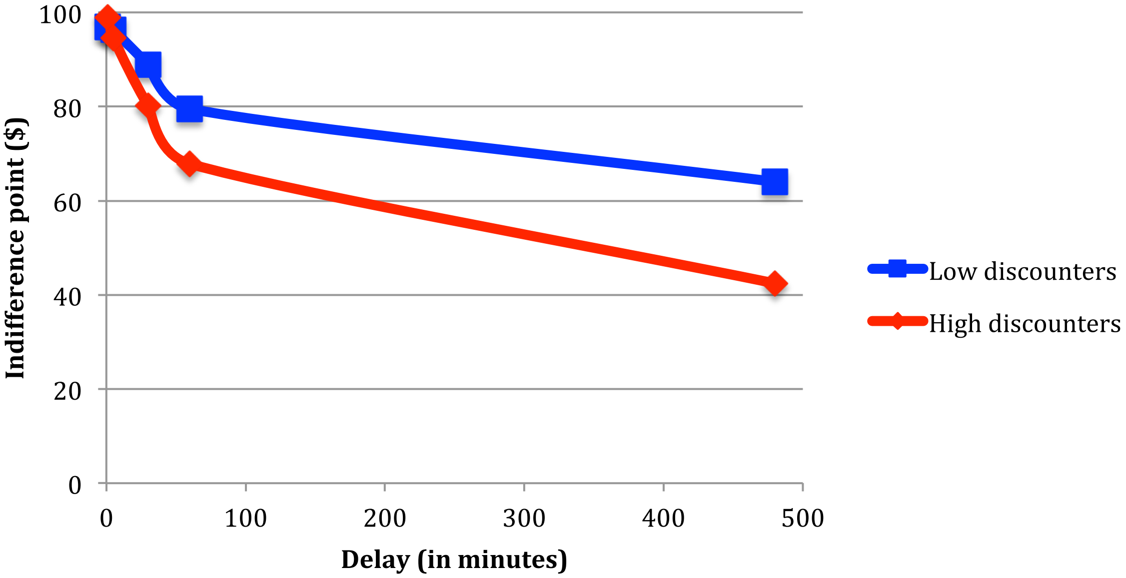

Figure 9 Mean indifference points for high and low discounters when message was presented over the vehicle's voice response system in a winter storm in experiment 1.

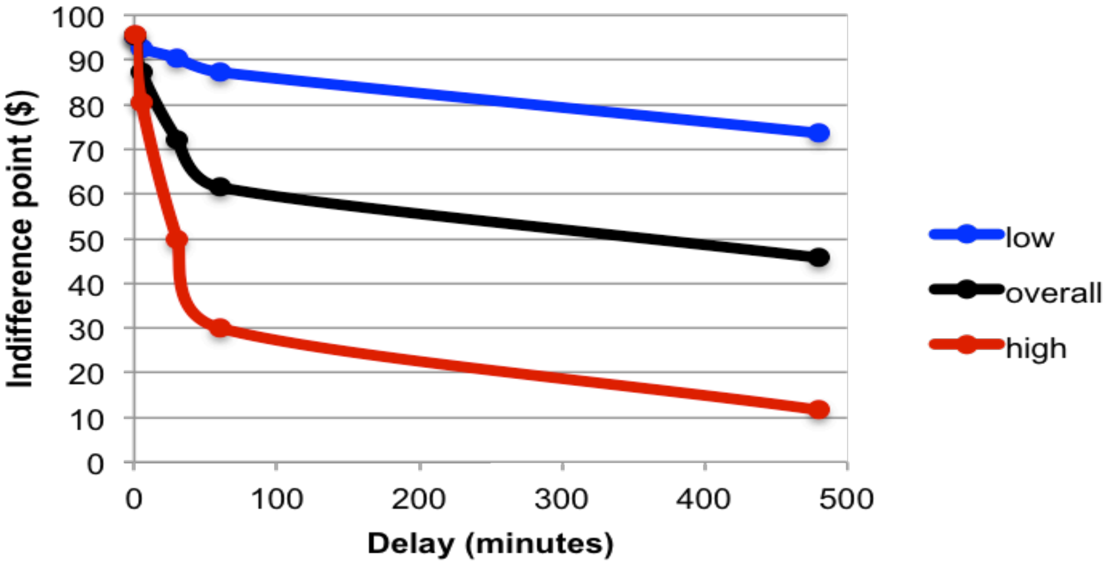

Figure 10 Mean indifference points for high and low discounters when message was presented over the vehicle's voice response system in sunny and clear weather in experiment 2.

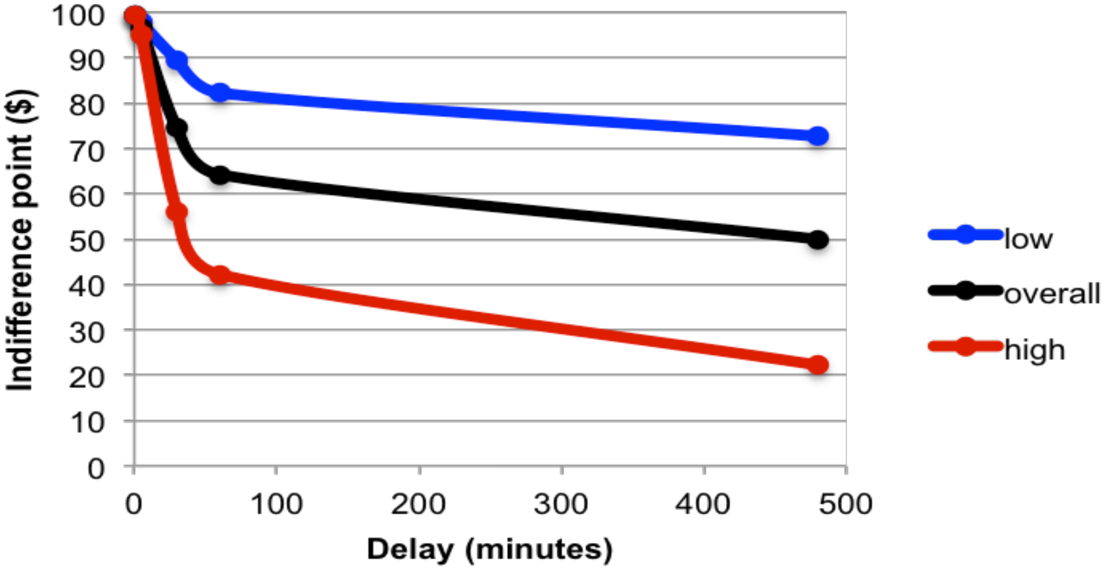

Figure 11 Mean indifference points for high and low discounters when message was presented on the handheld phone screen in sunny and clear weather in experiment 2.

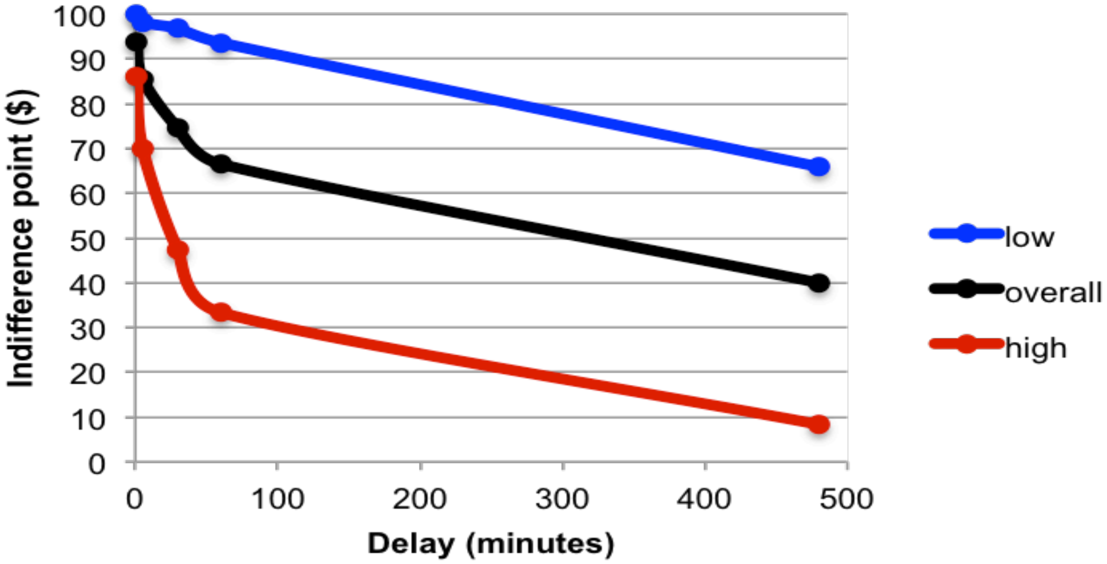

Figure 12 Mean indifference points for high and low discounters when message was presented over the vehicle's voice response system in a winter storm in experiment 2.

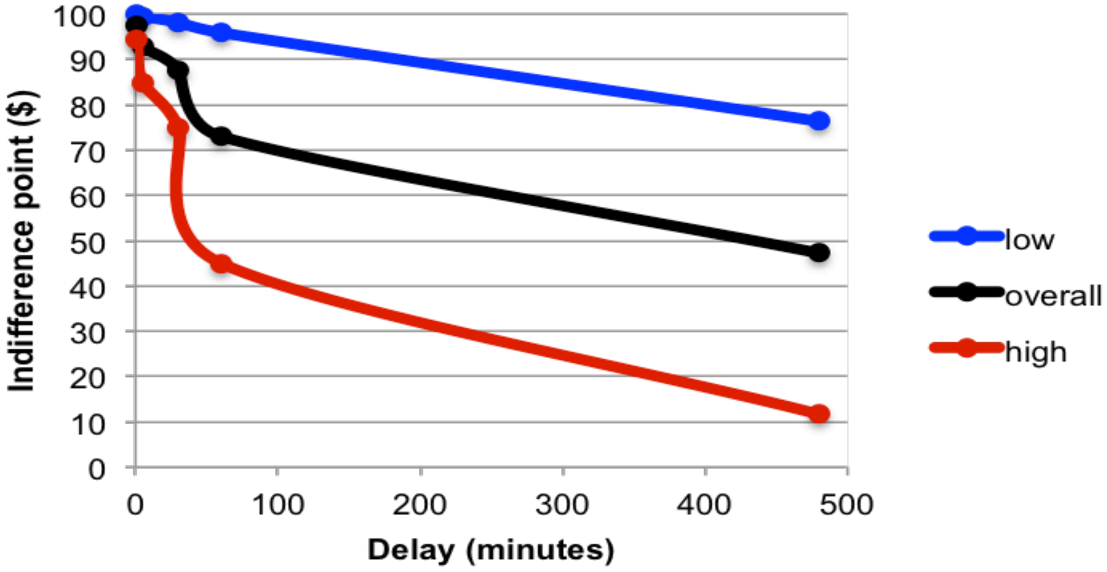

Figure 13 Mean indifference points for high and low discounters when message was presented on the handheld phone screen in a winter storm in experiment 2.

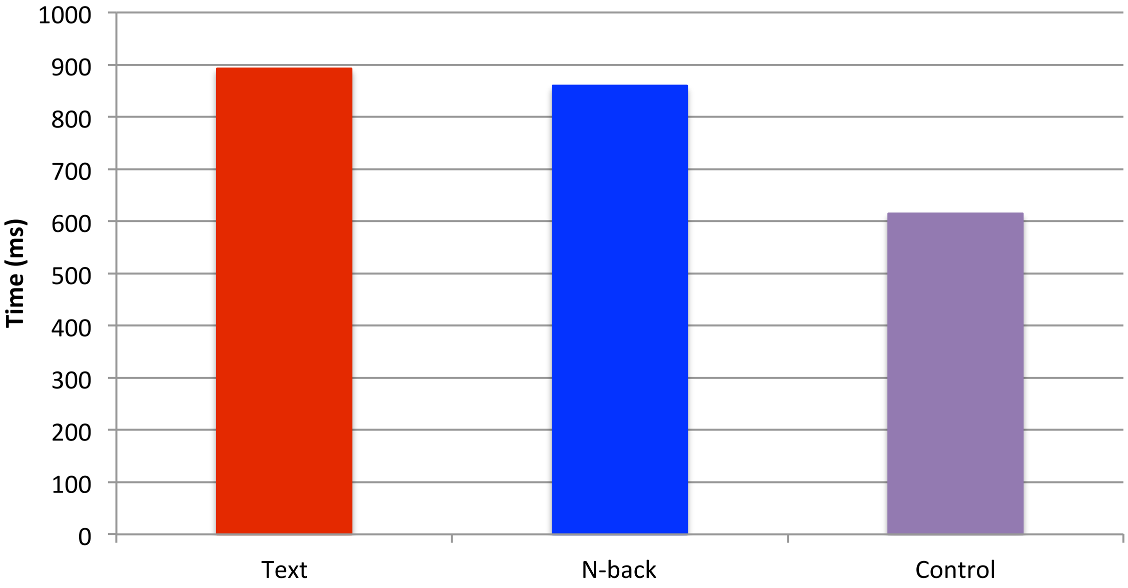

Figure 14 Average response time for the DRT measure of cognitive workload for the secondary tasks in experiment 2.

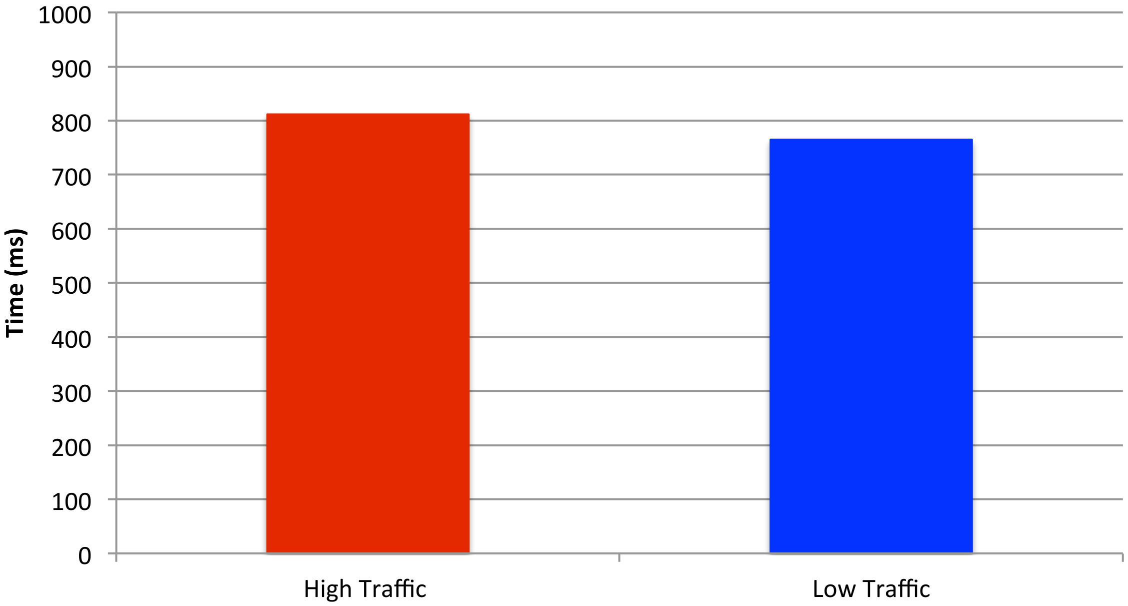

Figure 15 Average response time for the DRT measure of cognitive workload for high and low traffic levels in experiment 2.

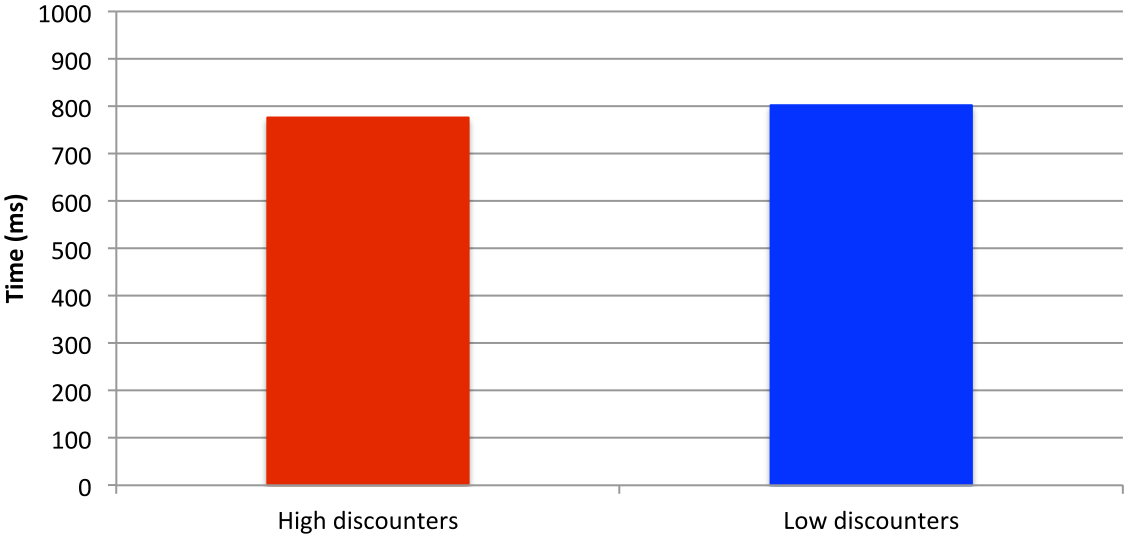

Figure 16 Average response time for the DRT measure of cognitive workload for high and low discounters in experiment 2.

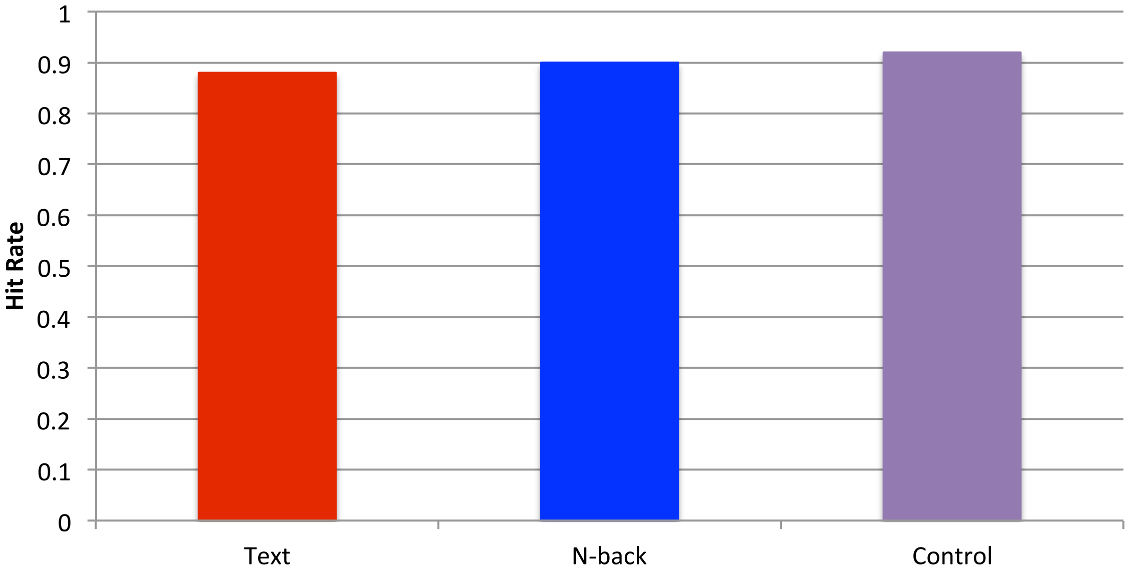

Figure 17 Average hit rate of the DRT measure of cognitive workload for the secondary tasks in experiment 2.

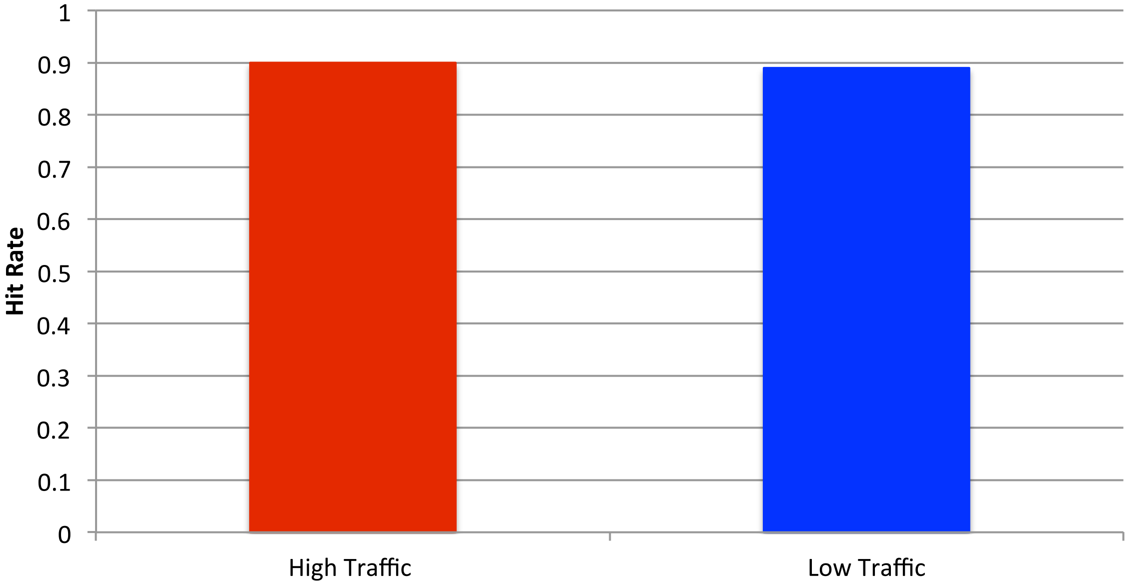

Figure 18 Average hit rate of the DRT measure of cognitive workload for high and low traffic in experiment 2.

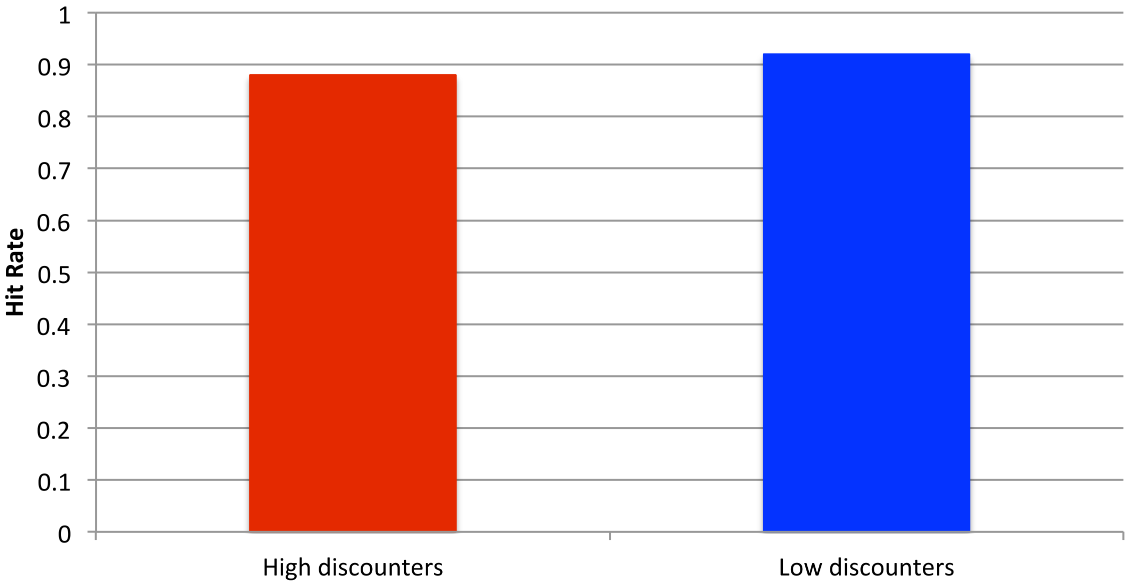

Figure 19 Average hit rate of the DRT measure of cognitive workload for high and low discounters in experiment 2.

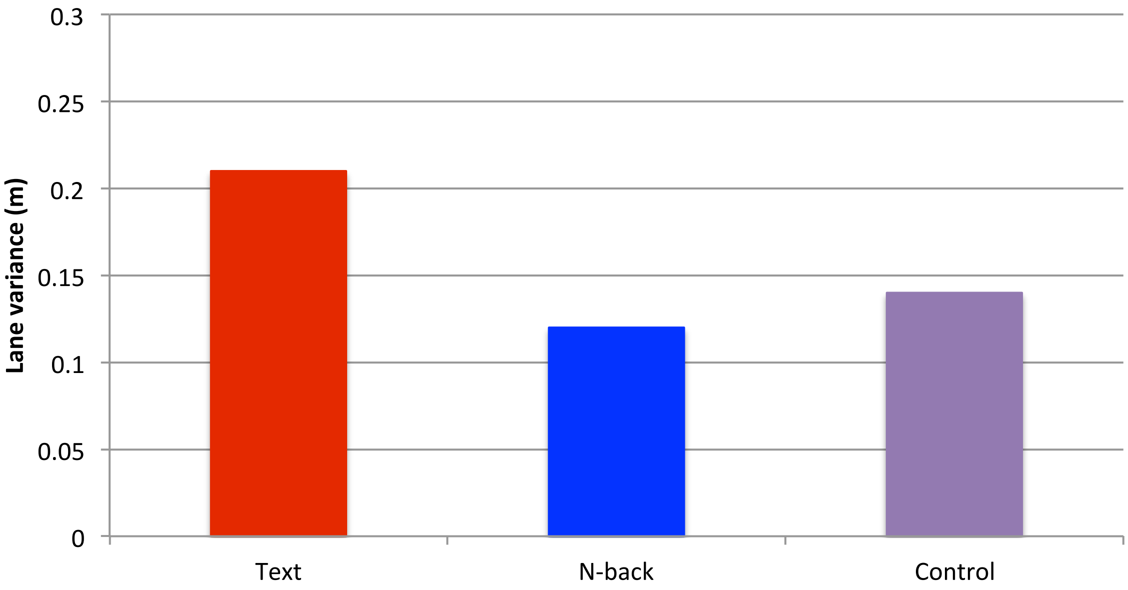

Figure 20 Average lane variance for the secondary tasks in experiment 2.

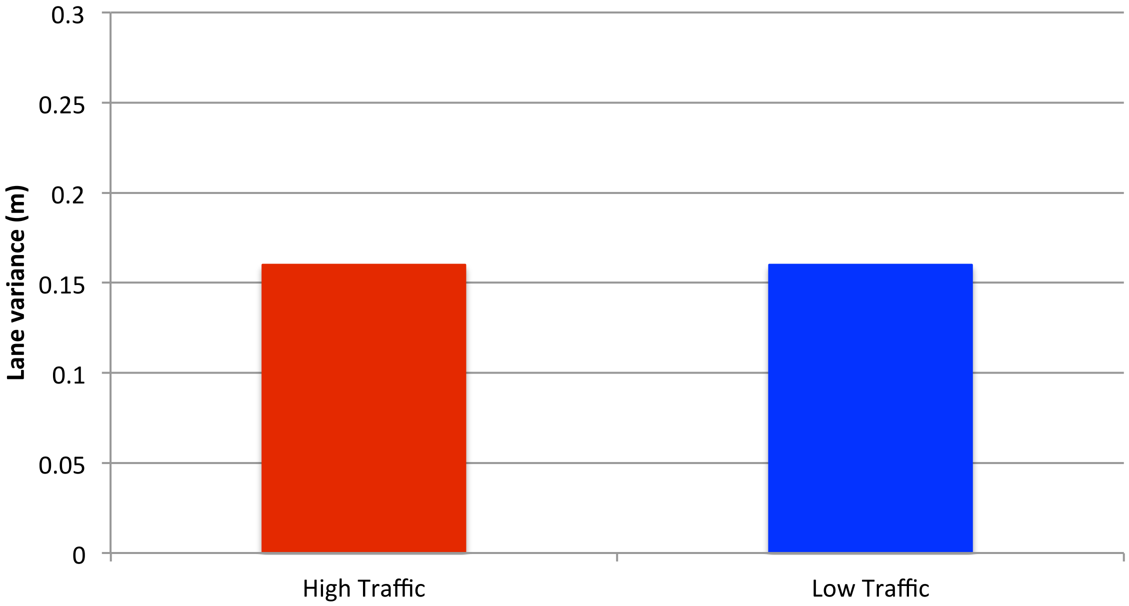

Figure 21 Average lane variance in high and low traffic in experiment 2.

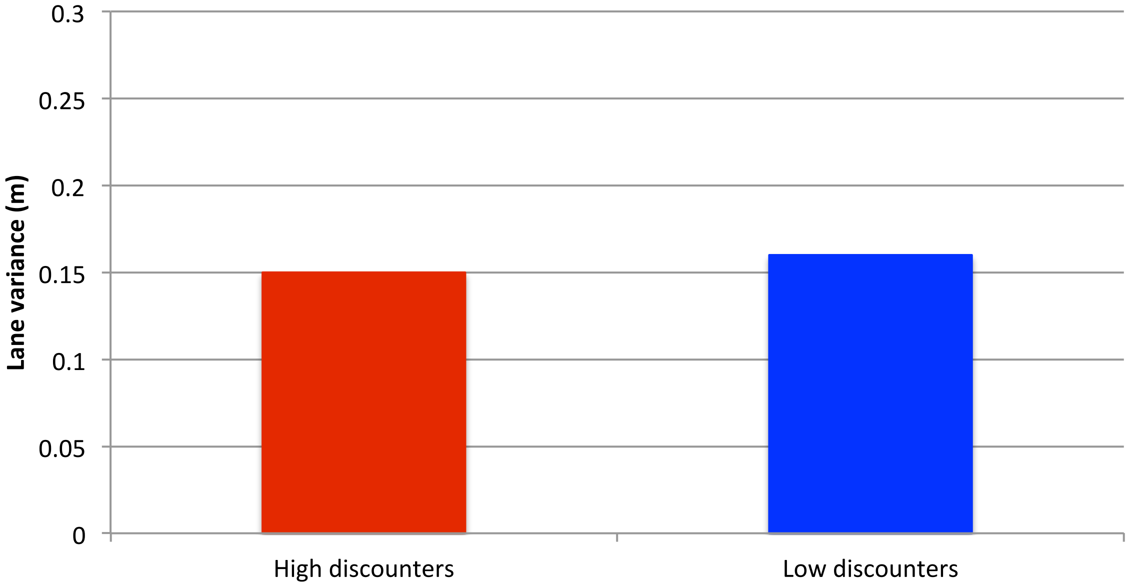

Figure 22 Average lane variance for high and low discounters in experiment 2.

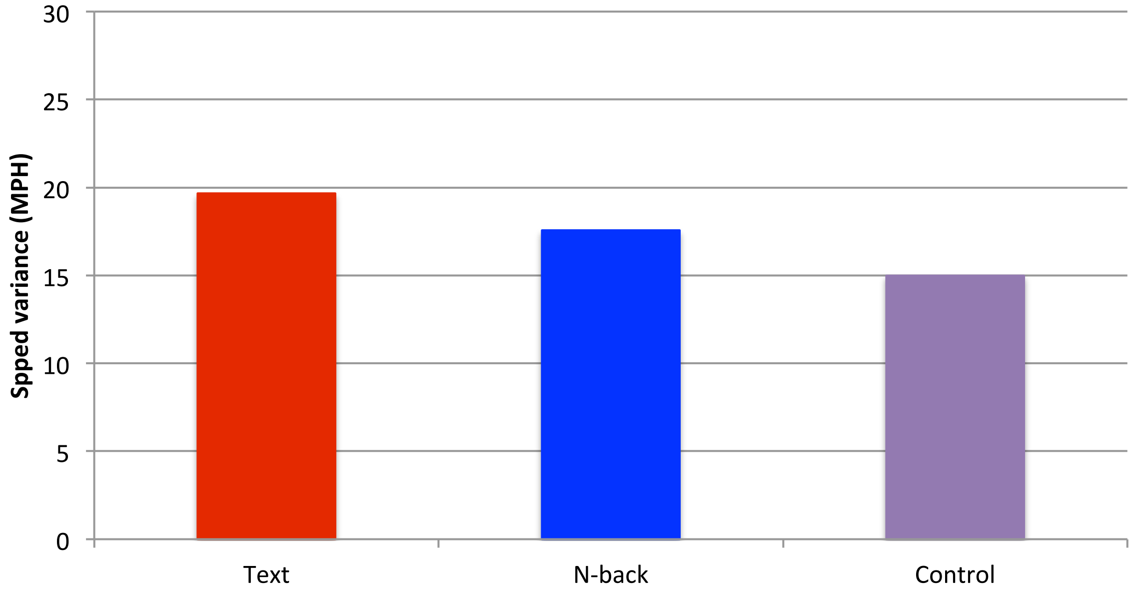

Figure 23 Average speed variance for the secondary tasks in experiment 2.

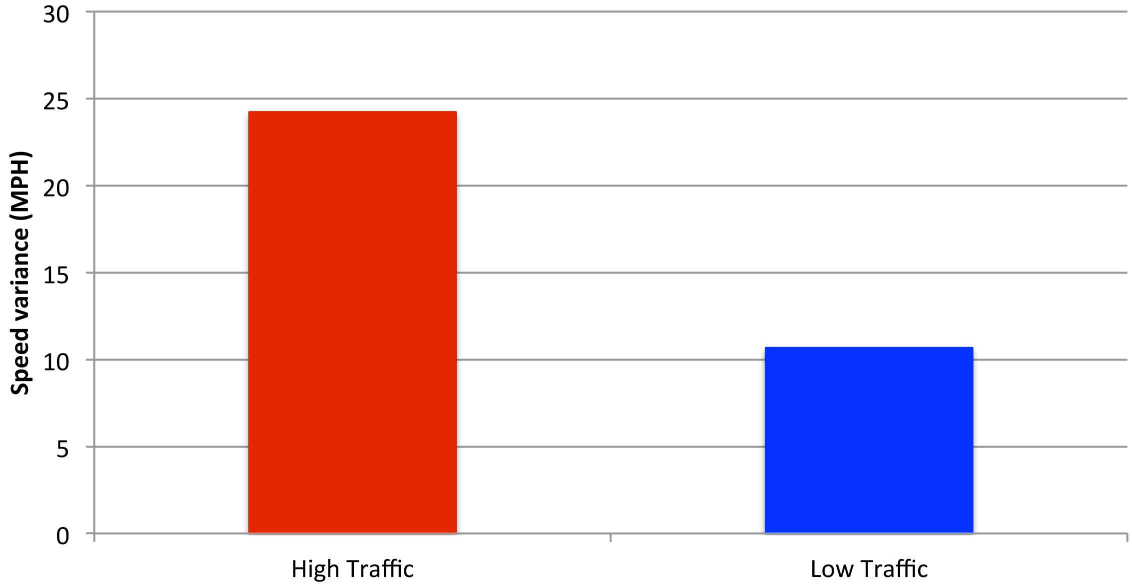

Figure 24 Average speed variance in high and low traffic in experiment 2.

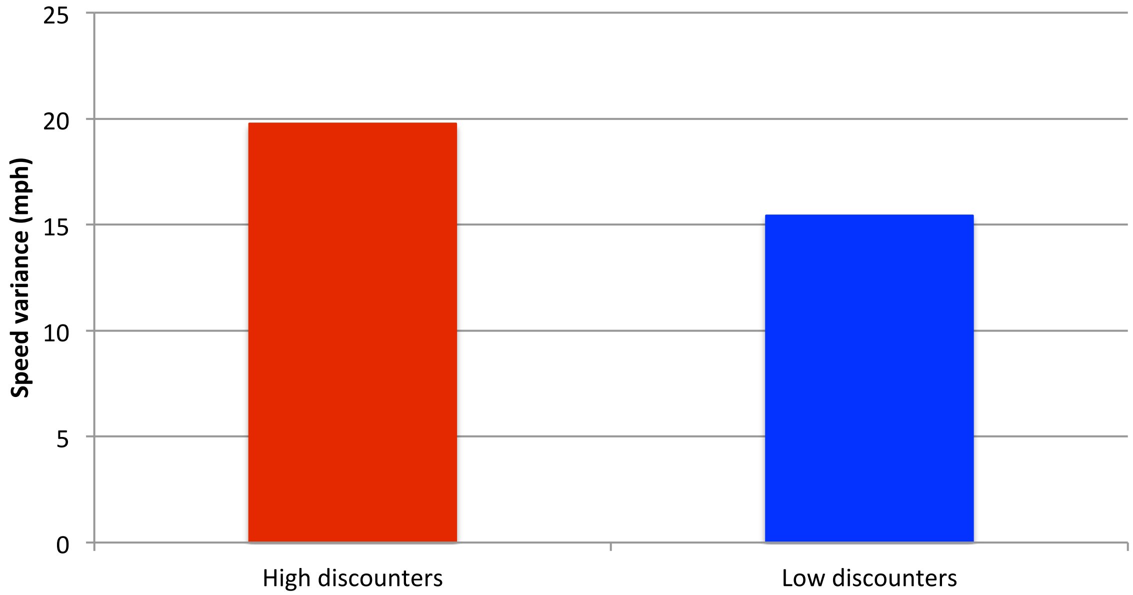

Figure 25 Average speed variance of high and low discounters in experiment 2.

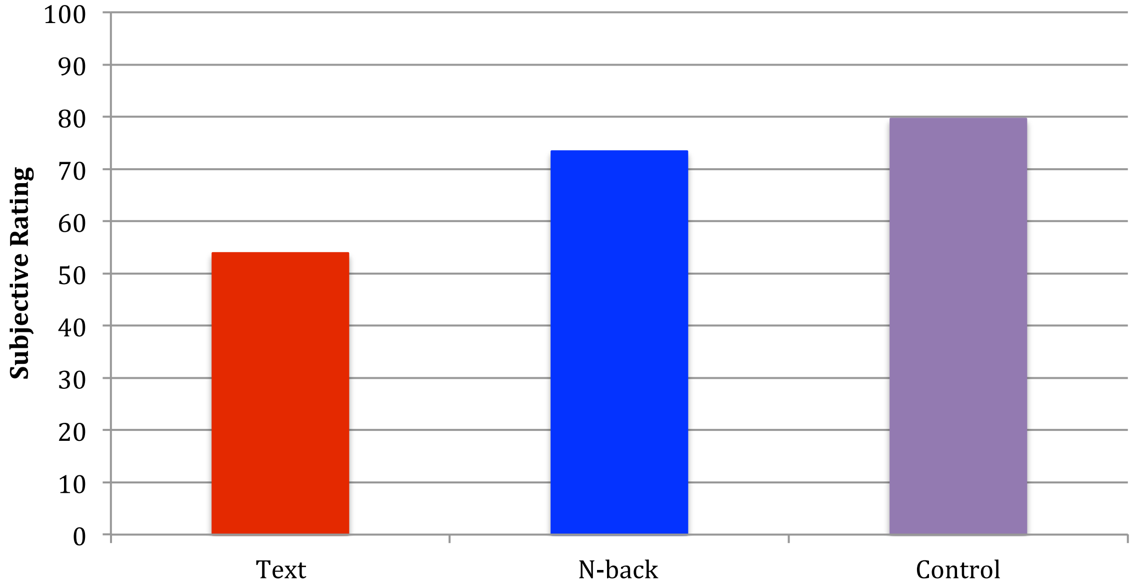

Figure 26 Average rating of driving performance for secondary tasks in experiment 2.

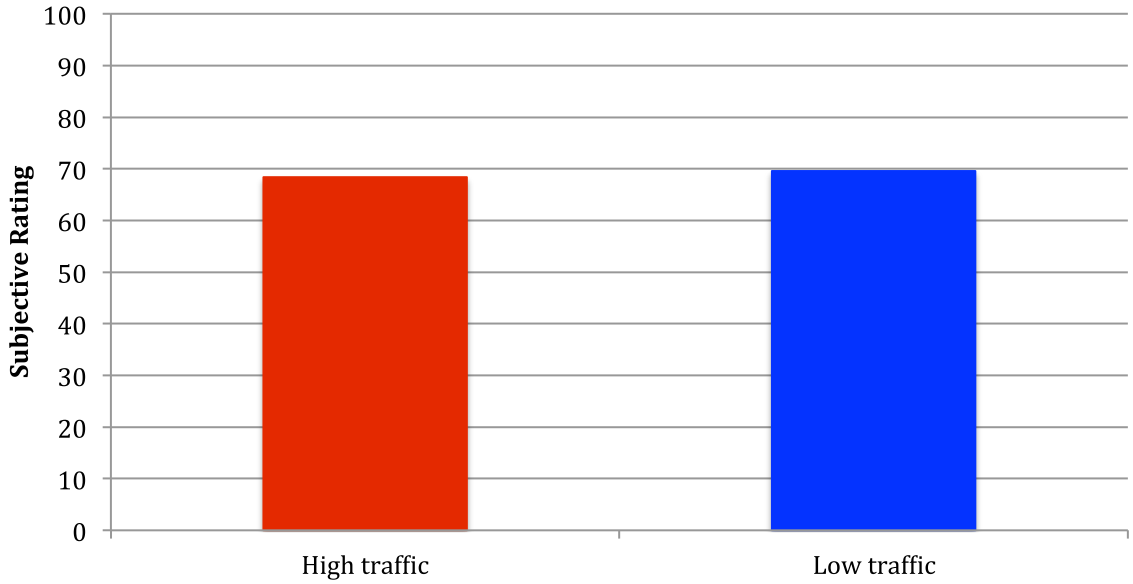

Figure 27 Average rating of driving performance in high and low traffic in experiment 2.

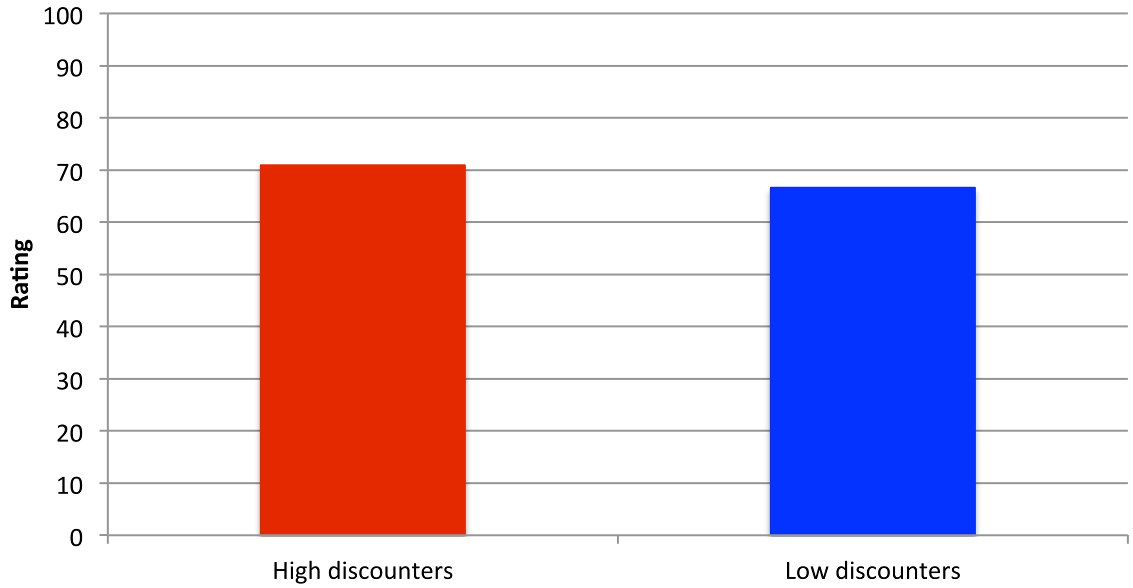

Figure 28 Average rating of driving performance between high and low discounters in experiment 2.

Appendix A. Monetary-Choice Questionnaire

For each of the next 27 choices, please circle which hypothetical reward you would prefer: the smaller reward today, or the larger reward in the specified number of days. While you will not actually receive the rewards, pretend you will actually be receiving the amount you indicate and answer honestly.

Would you rather have?

54 dollars today,	OR	55 dollars 117 days from now
55 dollars today,	OR	75 dollars 61 days from now
19 dollars today,	OR	25 dollars 53 days from now
31 dollars today,	OR	85 dollars 7 days from now
14 dollars today,	OR	25 dollars 19 days from now
47 dollars today,	OR	50 dollars 160 days from now
15 dollars today,	OR	35 dollars 13 days from now
25 dollars today,	OR	60 dollars 14 days from now
78 dollars today,	OR	80 dollars 162 days from now
40 dollars today,	OR	55 dollars 62 days from now
11 dollars today,	OR	30 dollars 7 days from now
67 dollars today,	OR	75 dollars 119 days from now
34 dollars today,	OR	35 dollars 186 days from now
27 dollars today,	OR	50 dollars 21 days from now
69 dollars today,	OR	85 dollars 91 days from now
49 dollars today,	OR	60 dollars 89 days from now
80 dollars today,	OR	85 dollars 157 days from now
24 dollars today,	OR	35 dollars 29 days from now
33 dollars today,	OR	80 dollars 14 days from now
28 dollars today,	OR	30 dollars 179 days from now
34 dollars today,	OR	50 dollars 30 days from now
25 dollars today,	OR	30 dollars 80 days from now
41 dollars today,	OR	75 dollars 20 days from now
54 dollars today,	OR	60 dollars 111 days from now
54 dollars today,	OR	80 dollars 30 days from now
22 dollars today,	OR	25 dollars 136 days from now
20 dollars today,	OR	55 dollars 7 days from now

Appendix B. Barrat Impulsiveness Questionnaire

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and put an X on the appropriate circle on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

1	2	3	4
Rarely/Never	Occasionally	Often	Almost Always/Always

1	I plan tasks carefully.	1	2	3	4
2	I do things without thinking.	1	2	3	4
3	I make-up my mind quickly.	1	2	3	4
4	I am happy-go-lucky.	1	2	3	4
5	I don’t “pay attention.”	1	2	3	4
6	I have “racing” thoughts.	1	2	3	4
7	I plan trips well ahead of time.	1	2	3	4
8	I am self controlled.	1	2	3	4
9	I concentrate easily.	1	2	3	4
10	I save regularly.	1	2	3	4
11	I “squirm” at plays or lectures.	1	2	3	4
12	I am a careful thinker.	1	2	3	4
13	I plan for job security.	1	2	3	4
14	I say things without thinking.	1	2	3	4
15	I like to think about complex problems.	1	2	3	4
16	I change jobs.	1	2	3	4
17	I act “on impulse.”	1	2	3	4
18	I get easily bored when solving thought problems.	1	2	3	4
19	I act on the spur of the moment.	1	2	3	4
20	I am a steady thinker.	1	2	3	4
21	I change residences.	1	2	3	4
22	I buy things on impulse.	1	2	3	4
23	I can only think about one thing at a time.	1	2	3	4
24	I change hobbies.	1	2	3	4
25	I spend or charge more than I earn.	1	2	3	4
26	I often have extraneous thoughts when thinking.	1	2	3	4
27	I am more interested in the present than the future.	1	2	3	4
28	I am restless at the theater or lectures.	1	2	3	4

29 I like puzzles.	1	2	3	4
30 I am future oriented.	1	2	3	4

Patton, Stanford, Barratt (1995). *J Clin Psy*, vol. 51, pp. 768-774