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A Field Experiment to Test the Effects of Automated Feedback and Monetary Incentive on Speeding Behavior

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ABSTRACT

A FIELD EXPERIMENT TO TEST THE EFFECTS OF AUTOMATED FEEDBACK AND MONETARY INCENTIVE ON SPEEDING BEHAVIOR

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This field experiment tested the effects of two systems on speeding, mental workload, and driver acceptance of the systems. Using GPS technology integrated with GIS referenced speed limit information, eight vehicles were instrumented in a manner that allowed real time knowledge of vehicle speed relative to the speed limit. Fifty participants drove these vehicles, with each individual driving his or her assigned vehicle for a four week trial. During one week, 40 participants experienced an automated feedback system, which provided visual and auditory alerts when they sped five or more mph over the limit. Twenty of these 40 individuals experienced a monetary incentive system during their second and third weeks of driving. Ten participants were in a control group that experienced neither system. Results indicated that the incentive system resulted in dramatic reductions in speeding over the posted limit, and the feedback system led to modest reductions in speeding. In the condition in which drivers experienced the feedback and incentive, reductions in speeding were similar to those found during the incentive only condition. Drivers perceived that both systems increased mental workload. Ratings of trust and acceptance were generally positive, although drivers reported the feedback system was annoying and displeasing. The

results indicate that these systems could significantly benefit traffic safety by reducing crashes caused by speeding.

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INTRODUCTION

Each year, traffic crashes claim 1.2 million lives across the world (World Health Organization, 2004) and more than 40,000 lives in the United States (National Highway Traffic Safety Administration (NHTSA), 2007). These events are the number one cause of death for Americans under age 35 (Centers for Disease Control, 2006). Crashes occur for a variety of reasons, including distraction, speed, aggressive driving, impaired driving, perceptual errors, and fatigue. Many emerging in-vehicle technologies are designed to improve safety by preventing contributing factors from occurring or minimizing the adverse effects of their occurrence. For example, adaptive cruise control (ACC) reduces tailgating (Rudin-Brown & Parker, 2004). With the system engaged, drivers maintain following distances based on distances to lead vehicles. Although the safety advantages of such automation are clear, systems require thorough testing to validate benefits and assess unintended negative consequences such as over-reliance on the system (Lee & See, 2004; Parasuraman & Riley, 1997). Rudin-Brown and Parker reported that the tested adaptive system reliably increased following distance, yet drivers were more likely to engage in a distracting secondary task when driving with ACC than driving without it. The focus of the current project, Intelligent Speed Adaptation (ISA), is similar to ACC because it reacts to the environment in a dynamic manner to reduce an unsafe driving behavior. However, the basic notion of ISA is dynamic reaction to changes in speed limits, whereas ACC adapts to the speed of a lead vehicle. ISA uses Global Positioning Systems to compare the speed of the vehicle to the speed limit of the roads on which the driver is travelling. In areas where databases of speed limits exist, ISA systems are feasible, and the systems provide an opportunity to reduce speeding by informing the driver about speed, introducing mechanical resistance to make speeding quite effortful, or preventing the driver from speeding (Carsten & Tate, 2005).

There is empirical support for the effectiveness of ISA (Regan, et al., 2006; Várhelyi, Hjälmdahl, Hydén, Draskóczy, 2004), but some researchers have noted the potential for driver habituation (Dingus, Klauer, Neal, Petersen, & Lee et al. 2006). A possible factor related to this habituation is an inadequate feedback structure (Toledo & Lotan, 2006). For example, feedback provided by the system only when the driver chooses to access it may receive initial attention by the driver and then a gradual decrease in attention as time progresses. The current project evaluated a strategy for decreasing speeding behavior by manipulating auditory and visual feedback and behavior-based incentives. The feedback and incentive schedules were structured so that drivers experienced real-time warnings, received an economic incentive, or received warnings and the incentive for keeping within preset speeding parameters. The speeding of these drivers was compared to a control group that experienced neither warnings nor economic incentives. In addition to speeding behavior, driver workload and acceptance of the system was analyzed. Acceptance and workload are important: if drivers dislike the system they will be unlikely to use it voluntarily. Alternatively, if some aspect of workload, such as temporal demand, increases when driving with ISA, then a reduction in speeding may be offset by a negative behavioral adaptation, such as tailgating. Theoretically, there is concern among human factors researchers that exposure to automation may lead to unintended behavior change (Comte, 2000; Parasuraman & Riley, 1997).

ISA systems are a relatively new technology. They have been field tested in Europe and Australia, but not in the United States. Evaluations indicate that the systems are promising, but the benefit may not generalize to the United States driving population. In addition to the applied nature of the study, theoretical perspectives helped to guide the proposed feedback and incentive structures, to make predictions about potential negative consequences such as increased mental workload, and to explain why drivers speed.

Speeding

Speeding appears to be a universally accepted behavior in several Westernized countries. Shinar, Schechtman, and Compton (1999) analyzed self-report data that were collected annually over 11 years. The sample size of adults from the United States was relatively large, 1,250 respondents per year, and the questions asked related to general health behaviors such as diet and smoking and to traffic safety behaviors such as wearing seat belts, drinking and driving, and speeding. In general, the authors reported that the respondents in the later years of the study period placed more importance on health habits than respondents in the first years of the study period. Similarly, the respondents indicated the importance of buckling seatbelts and driving sober increased over time. However, the respondents' attitude toward speeding did not follow this pattern. At the beginning of the measurement period, respondents indicated that speeding was less of a threat to safety than driving while impaired or unbuckled.

Moreover, Shinar et al. (1999) report that the perceived relevance of speeding to safe driving continued to decrease as the 11 year period progressed. In a separate analysis of self report data Blincoe, Jones, Sauerzapf, & Haynes (2006) collected over 500 surveys of English drivers who were ticketed for speeding through an area with an automated speed camera. One line of questioning concerned reasons for speeding. Frequent answers were that speeding was not dangerous and that "everybody else speeds." Similarly, self report data collected by Fleiter and Watson (2006) indicate that Australian drivers view speeding as acceptable. They asked drivers to indicate the extent to which they speed on urban and "open" roads with respective speed limits of 60 and 100 kilometers per hour. A third of the sample indicated that they speed on the slower road, whereas more than half indicated that they choose to speed on the faster road. Fleiter and Watson (2006) also asked drivers to indicate what speed should be permissible at both limits. The drivers overwhelmingly selected speeds that were greater than the posted limit. Similar findings are reported by Shinar (2001), who asked drivers to indicate what speed they typically drove on roads with different speed limits. Based on the hypothesis that different conditions affect speed choice, Shinar asked drivers to indicate the speed they would choose to drive when they were driving in situations such as driving alone, driving with family, or driving for fun. Drivers consistently indicated that the speed they drive when alone was higher than posted limits, and the "fun" speed was generally greater than the typical speed.

These findings were based primarily on self-report data, and the validity of subjective results is always a concern. However, the work of Haglund and Aberg (2000) indicates that there is value to self report data. These researchers tested the relationship between observed speed and drivers' self reports by using a hidden speed camera and an interview that occurred down road from the camera. Researchers asked the drivers, who were unaware that speed was recorded, to indicate how fast they were driving before they were stopped and how fast they would normally drive on the road. The correlations between observed and reported speed and observed and normal speed were .58 and .5, respectively. These data indicate that drivers' estimates were in general agreement with observed speeds. However, other researchers report more moderate relationships between observed and reported speed (see Corbett, 2001).

In contrast to debate about the relationship between observed and reported speed, there is little doubt that drivers choose to speed in free flow traffic, particularly where the roads are in good repair and enforcement is absent. For example, Freedman, De Leonardis, Polson, Levi, and Burkhardt (2007) completed an evaluation that measured the effect of rational speed limits. The notion behind rational speed limits is that the overwhelming majority of drivers rationally select safe speeds based in part on road design, and therefore, speed limits should correspond to these selected speeds. Typically, the rational speed is defined as the speed at which 85% of the traffic selects during free flow conditions. Freedman et al. divided several roadways into 7 mile sections that contained multiple speed limit changes, and then measured the speeds that drivers selected in free flow traffic, defined as flow conditions in which five seconds separated the own vehicle from a lead vehicle. When driving in free flow, the authors found that 50 to 90% of drivers exceeded the speed limits before speed limits were changed to the rational speed. After implementing the rational speed limit program, as many as 50% of drivers still violated the speed limit. In addition, the average speed did not change --- drivers were traveling as fast after the limits increased as they were before they were changed. They simply were not violating the speed limit as frequently because the limit increased. In sum, an abundance of self report data indicates that speeding is commonplace, and high correlations between observed and reported speed suggest that self report data are indicative of drivers' true speed. Finally, the Freedman et al. study indicates that exceeding the speed limit may be the norm in certain locations. Several questions follow from these findings about the prevalence of speeding: 1) Who is speeding? 2) Why are they speeding? 3) Is speeding truly dangerous? and 3) If it is dangerous, why?

Who is speeding? From a demographic perspective, there are several driver characteristics that covary with speeding. Many authors report that younger drivers are more likely to speed than older drivers (Quimby, Maycock, Palmer, & Buttress, 1999; Wasielewski, 1984), as suggested by fatality statistics (NHTSA, 2007.) Other individual difference variables include income level, with wealthier drivers speeding more frequently than their less wealthy counterparts; sex, with males driving faster than females; and vehicle size, with drivers of large vehicles driving faster than those with smaller vehicles (Shinar, 2007.)

Why are drivers speeding? Explaining why individuals speed is vexing because drivers speed for different reasons, and there is considerable within group variance. An individual may speed in a certain condition on one day (being late for work) but choose not to speed the next time the condition is present. Drivers may be rushing to work, speeding because they are within a group of drivers who are exceeding the limit, or speeding for emotional reasons (thrill or anger) (McKenna, 2005). McKenna describes these willful acts of speed as “rebellious” or “pragmatic” speeding. In addition to willful speeding, drivers may not be aware that they are speeding. That is, they may have a lapse of attention during which their speed may increase without their knowledge. A second cause of unintended speeding may be perceptual speed adaptation. Unintended speeding may also result from a failure to see a speed limit sign. When trying to explain these reasons more completely, researchers have applied theories from social psychology, sensation and perception, and information processing.

From an information processing approach, speeding increases risk because of time pressure. Researchers quantified the time needed to sense, perceive, decide, and act to various stimuli using methods such as the additive method (Sternberg, 1969). In fact, researchers succeeded in parsing out the processing time associated with certain stages and factors that affect processing in laboratory settings. When movement through space becomes a factor, the equation *Distance = Rate * Time* dictates that an individual driving at a faster speed has less time to react to a given stimulus than an individual driving at a slower speed who encounters the same stimulus. In addition to the distance equation, stopping distance increases exponentially with speed. Finally, environmental factors such as darkness, weather, and roadway characteristics can add further constraints on the amount of time that drivers have to process and react. However, humans do not make decisions based on the computation of complex formulas, and it is reasonable to assume part of the speeding problem is a result of naivety about the true risks. This situation may be further compounded by perceptual speed adaptation.

Perceptual Effects on Speed - Speed Adaptation. This theoretical perspective is helpful for understanding why some violations are committed unknowingly. The vestibular system is attuned to sudden changes in movement; however, humans quickly adapt to steady movement. When angular or rotational acceleration occurs, fluid shifts in the vestibular canals, and the moving individual experiences the sensation of acceleration. When movement through space is at a constant velocity, the vestibular fluid will not shift, and individuals adapt to the speed at which they are moving.

When individuals adapt to a set speed, e.g., 45 mph, and suddenly change to a new constant velocity, e.g., 25 or 65 mph, what they experience differs from what they would have perceived had they not adapted to 45 mph velocity. However, individuals experience significantly different perceptions depending on whether the new constant velocity is greater or less than the adapted speed. When individuals experience an increase in true velocity, the perceived change in velocity is greater than the true change, i.e., they feel that they are going faster. In contrast, and of particular interest to the current study, when there is a reduction from a high speed to a lower speed, individuals perceive that the reduction in speed is significantly slower than the true reduction. Psychophysical studies completed several decades ago support this perceptual phenomenon (Denton, 1966; Matthews, 1978; Schmidt & Tiffin, 1969). For example, Schmidt and Tiffin had participants make several estimates when a vehicle they were driving reached 40mph. When participants accelerated from 0 to 40, the average speed that they estimated was 41mph. However, when the individuals maintained a speed of 70mph for a period of 20 minutes and then slowed to what they perceived to be 40mph, the perceived 40mph was 50mph. Schmidt and Tiffin (1969) showed that this underestimation of perceived speed increased as a linear function of time spent at the higher constant velocity. Denton (1966) completed a similar investigation. In addition to showing that drivers underestimate reductions from a higher to a lower speed, he also showed that participants overestimated increases from lower to higher speeds. Finally, Matthews (1978) recorded radar readings of vehicles traveling on a roadway that had the same speed limit in both directions. However, in one direction vehicles traveled on a road that was 15mph higher than the test road, whereas vehicles traveling in the opposite direction had previously driven on a lower speed road. Matthews (1978) reported that drivers who traveled on the higher speed road had significantly greater travel speeds than those traveling in the opposite direction. These studies provide empirical support to the frequent anecdotal reports of perceptual speed adaptation.

Thus, the speed adaptation phenomenon may contribute to the prevalence of and dangers associated with speeding. An individual who adapts to a high speed of 70 mph and does not slow sufficiently due to faulty perception may underestimate the time available to safely respond to a hazardous event. Unfortunately, required information processing time does not change because drivers choose a higher speed. Further, individuals generally make decisions based on heuristics and past experience rather than the computations needed to determine decision time relative to stopping distance; therefore, it seems likely that drivers may underestimate the increased risks of speeding.

Decision Making: Heuristics and Prospect Theory. The classical approach to decision making would suggest that when choosing to speed or comply with the limit, drivers weigh the probabilities of costs and benefits. These costs might include lost time, lost money associated with a speeding citation, and losses associated with a crash. Drivers may use confirmation bias and the availability heuristic when determining the probabilities associated with the possible outcomes. For example, drivers may discount speed related crashes and recall only those related to impaired driving. Drivers who see a driver adhering to the speed limit may look to confirm that the driver is "old" and dismiss information that disconfirms an assumption that only certain populations drive the speed limit. Speeders may recall that they always drive over the limit and never get stopped. Drivers may further downplay the threat of sanction if a judge dismissed or reduced a ticket when they went to court. Given the low perceived probabilities of costs associated with sanctions and crashes, classical decision making theory would predict that drivers weigh the potential losses accordingly when they select speed.

The one cost that drivers might perceive as probable if they comply with the limit is the loss of time. Prospect theory explains an interesting phenomenon associated with the differences between subjective ratings of losses and gains (Kahneman, Slovik, & Tversky, 1982.) Kahneman et al. report a body of work that indicates individuals perceive a loss of a certain amount as more important than a gain of the same amount.

Prospect theory would predict that individuals who speed because they are rushing do so because they feel they are losing time rather gaining time. Prospect theory would provide an explanation for why drivers who speed for pragmatic reasons account for a significant portion of speeders, particularly given findings that indicate faster speeds do not ensure faster commutes (Regan et al., 2006).

Theory of Planned Behavior. In contrast to information processing and perceptual perspectives associated with speed, the Theory of Planned Behavior (TPB) offers an explanation as to why individuals purposefully speed. TPB is rooted in social psychology and is a frequently cited theory used to explain various behavioral phenomena. This theory was proposed by Ajzen and reviewed by De Pelsmacker and Janssens (2007). The central features of the theory include "norms", "attitudes", and "intentions." Norms refer to the rules and beliefs that an individual has about a certain behavior. These norms can be personal, normative, descriptive, or subjective. There is a "moral" component to personal norms; this component captures the extent to which the individual thinks the behavior is "right" or "wrong." A second component of personal norms described by De Pelsmacker and Janssens (2007) refers to the regret an individual would experience if the behavior were or were not manifested. Norms may also be relative or normative. Normative norms are those that describe what the individual thinks others believe about the behavior. These norms include "everyone else is doing it" reasoning for engaging in a behavior. Subjective norms refer to the extent to which the individual feels pressure from valued individuals, e.g., friends, family, peer groups, to engage in the behavior.

According to TPB, these four norm types directly affect attitudes about the behavior. Attitudes are comprised of affective and cognitive components. The affective aspect of attitudes capture the emotion associated with the behavior: "I am anxious to get home and see my family." The cognitive component describes the logic associated with the attitude: "I know that speeding is technically illegal but the police allow 10 mph over the limit." Researchers who refer to TPB suggest that attitudes directly affect intentions to engage in the behavior. Two additional important factors in this theory are "perceived behavioral control (PBC)" and "habits." PBC and habits moderate intention such that in situations when individuals believe they have behavioral control, they are more likely to realize their intention. Similarly, Azjen suggests that the intention to engage in a behavior is stronger when the behavior is relatively more habitual.

TPB may explain a variety of behaviors. With regard to speeding, De Pelsmacker and Janssens (2007) completed a study that used structural equation modeling to test a model based on the factors contained in the theory. The authors devised Likert-type survey items that were written to reflect the latent factors described above, i.e., norms, attitudes, intentions, habits, and perceived behavioral control. In addition, they asked participants to estimate how often they speed. The results of the factor analysis indicated that there were significant loadings for items associated with each latent construct. The constructs with the strongest effect size were habits, intentions, and personal norms.

TPB is reviewed here because it has received significant attention from traffic safety researchers. However, hypotheses based on the theory will not be included in the current field experiment because there seems to be little explanatory power beyond what could be gained by asking individuals about their intentions and habits. Intuitively, to the extent individuals have opportunities to manifest a behavior and intend to do so, the behavior will be realized. This is particularly so if the behavior is habitual. The results of the factor analytic study reported by De Pelsmacker and Janssens (2007) suggest that asking drivers about their intentions and habits alone would yield nearly the same power for predicting self reported speeding behavior as using the full theoretical model. A final problem with the model used by De Pelsmacker and Janssens is the failure to consider the possibility that habits influence attitudes. Clearly, attitudes toward a behavior become more favorable as the behavior becomes more habitual.

In sum, TPB describes some components involved in purposeful speeding but does not appear to sufficiently explain how or why norms are formed. The concept of habit, admittedly a strong component in an individual's decision to engage in a behavior, appears to be introduced as an afterthought. Further work may improve the explanatory power of TPB, and researchers would welcome a theory that facilitates the understanding of why drivers speed. Although some individuals indicate that speeding is not dangerous, evidence suggests speed increases the frequency and severity of vehicle crashes.

Does Speeding Affect Traffic Safety?

NHTSA publishes an annual report entitled *Traffic Safety Facts.* The document provides a wealth of data about crash related variables. The most recently published version of the document (2007) ranks a set of 16 variables by relative frequency of

"Related Factors for Drivers and Motorcycle Operators Involved in Fatal Crashes." The most frequent factors in the list of variables for fatalities occurring in 2005 were driving too fast for conditions, inattentiveness, driving recklessly, and failing to keep in the proper lane (NHTSA, 2007). "Driving too fast for conditions" is listed as a factor for 21% of traffic fatalities for 2005. This translates to nearly 12,000 deaths in one year. Further, 36% of the total fatalities in 2005 were associated with unknown or unlisted factors. Some portion of this 36% was likely due to speed, which would increase the overall number of speed related fatalities. These recent data are supported by Treat, Tumbas, McDonald, Shinar, Hume, et al., (1977) who identified speed as a serious safety matter. Treat et al. completed in-depth analyses of approximately 2,000 fatal crashes. The authors used a strict definition of "causal:" a crash would not have occurred if the factor were absent. They determined speed was the causal factor in 8% of crashes and the probable cause of an additional 15% of the crashes. The Treat et al. data are dated, but, their conclusions support the fatality statistics reported by NHTSA (2006a) and recent work that captured driver behavior in naturalistic settings.

The 100-car naturalistic driving study provides further underscores the need to establish effective speed countermeasures (Dingus et al., 2006; Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Klauer, Sudweeks, Hickman, & Neale, 2006b.) The naturalistic study was a significant endeavor. One hundred vehicles were instrumented with several video cameras and data loggers to capture images of the drivers, their vehicles, their environments, and several other parameters including acceleration, vehicle speed, yaw rate, and forward time to collision. The vehicles were tracked for one year, yielding a vast amount of data that provide valuable insight about the nature of traffic crashes. To determine the extent to which events were associated with crashes, near crashes, or incidents, Klauer et al. (2006b) calculated odds ratios for behaviors operationalized as risky. The odds ratio for speeding was statistically significant: participants in the 100 car study were nearly 3 times more likely to be involved in a crash or near crash when driving at excessive speeds relative to periods when they were driving at acceptable speeds.

Although the 100-car study and NHTSA statistics implicate driving too fast for conditions as a significant factor for collisions, several researchers found a significant positive relationship between changes in speed limit laws and crashes or fatalities. The easing and subsequent repeal of the United States' 55mph law has provided an ideal situation for examining the relationship between speed and crashes. Patterson, Frith, Povey, and Keall (2002) studied the changes in traffic fatalities associated with the easing of the national 55 mph law during the 1980s. Patterson et al. reported that states with increased limits had greater increases in traffic fatalities relative to states that kept the 55 mph speed limit. The work of Grabowski and Morrisey (2007) also suggests that increased highway speed limits increased crash risk. Those authors studied rural highways and examined the increase in fatalities that occurred when speed limits initially increased from 55 mph to 65 mph and when some limits increased from 65 to 70 mph following the official repeal of the 55 mph law. Grabowski and Morrisey found that the increase from 55 to 65 mph was associated with a 15% surge in fatalities, and in locations where the limit went to 70 mph, fatalities were more than 30% greater.

Finally, Stuster, Coffman, and Warren (1998) reviewed studies of the effect of speed limit changes and reported that 75% of studies that assessed lowered limits found a concomitant lowering of traffic fatalities, whereas nearly 75% of the evaluations of increased speed indicated that fatalities increased. As with rational speed limits, changed speed limit laws permit faster driving, so drivers were not speeding as defined by law. However, these studies show the strong relationship between increased speeds and increased fatalities.

A different approach to studying the same relationship is to select a specific section of road and investigate injury outcomes for crashes that occur at different speeds. Moore, Dolinis, and Woodward (1995) completed a case control study and found a strong relationship between speed and the occurrence of serious head injuries or fatalities for vehicles traveling, particularly in 60 km per hour zones. Moore et al. found that vehicles were approximately 8 times more likely to have a crash at speeds between 75 and 84 km per hour than vehicles traveling 55 to 64 mile per hour. Similarly, Kloeden, McLean, Moore, and Ponte (1997) reported that injury risk increased exponentially when drivers exceeded 45 kilometers per hour (approximately 30mph.) This finding might be expected given the relationship between speed and force at impact expressed in the formula for kinetic energy, $E = 1/2mv^2$, where E is energy, m is mass, and v is velocity (Shinar, 2007). This formula states that energy is a function of the square of velocity; thus an increase in of absolute speed of 10 mph will have a far more intense impact from 30 mph to 40 mph than from 20 mph to 30 mph. This physics equation is supported by the meta-analysis of Elvik, Cristensen, and Amundsen, (2004) who concluded that speed was the most significant factor associated with traffic fatalities.

Despite these studies that indicate speed is a causal factor in substantial portion of crashes, some researchers maintain that speeding in and of itself is not dangerous (see Shinar, 2007). Those who suggest that speeding alone does not elevate risk argue that drivers who travel at 65 mph in a 55 mph zone are speeding; however if they have adequate headway from a lead vehicle and refrain from weaving through traffic or making abrupt steering changes then these individuals are safe drivers. Proponents of this argument might suggest it is the presence of multiple factors that elevates risk. For example, individuals increase risk marginally when the only factor is increased speed but increase risk significantly when they drive impaired and speed (NHTSA, 2007). The position taken in the current project is in agreement with the multiple factor argument. However, physics clearly indicates that impact force increases exponentially with speed, so any given crash at a higher speed will elevate the risk of serious injury relative to the same crash that occurs at lower speeds. In sum, there is sufficient evidence to suggest that lowering speeds will increase safety, and this is the focus of the current project. Additionally, the operational definition of speeding for this project is driving over the speed limit rather than driving too fast for conditions.

From this focus, the goal of this project was to use driver monitoring technology to reduce speeding behavior by using a system that alerts drivers when they speed, that provides an incentive to promote speed limit compliance, or that combines an incentive and alert. Although speeding behavior was a central focus in the proposed study, the experimenter gave significant attention to the possibility that drivers may adapt negatively to such a system. European field studies indicate drivers may habituate to warnings, may engage in unsafe driving behaviors such as short following distances, or may fail to monitor speed when the system is removed. These adaptations could attenuate or negate the benefits of reduced speeding realized by ISA. New systems such as ISA may supplement conventional speed countermeasures only if there are minimal adverse effects.

What Countermeasures Exist for Addressing the Speeding Problem?

The traditional methods to limit speeding fall into three categories: engineering, education, or enforcement. Engineering solutions typically involve changes to the roadway that force drivers to slow down. Examples of these include speed bumps and speed tables, roundabouts, road striping that narrows lanes, and increased road curvature. These "traffic calming" approaches successfully reduce speed but are expensive and limited to specific areas. Further, some drivers become frustrated upon encountering such engineering solutions, which could lead to aggressive driving (Litman, 1999).

A second speeding countermeasure is education, which is designed to inform drivers about the importance of driving slowly. An example of the educational approach is NHTSA's (2006b) pilot test of the "Heed the Speed" safety program, which was deployed to reduce the frequency and egregiousness of speeding in neighborhoods. The educational components of this project were street and yard signs, news stories about how vehicle speed affects pedestrian injuries, and brochures about the program for residents of the target neighborhoods. Though such strategies are important, education has very limited success when not reliably linked to high visibility enforcement (NHTSA, 2008).

Enforcement is a final option for reducing speeding behavior. Anecdotally, many drivers will admit to checking their speedometers closely when they see a police cruiser or when they enter a location notorious for police "speed traps." However, this concern for obeying the speed limit is short lived. This phenomenon, reviewed by Shinar (2007) is referred to as the "halo effect." The effect describes the nearly reflexive reduction in speed that occurs from the point that a driver sees a police cruiser and remains for a certain period after passing the enforcement area. However, much like the resumption of speed by drivers who drive over a speed bump, drivers who travel past a police officer will eventually increase speed to levels that they drove prior to encountering the enforcement. A second issue that is problematic for enforcement is staffing; increasing the police force to allow for increased speed enforcement is not a feasible option. Speed cameras are effective, but there are considerable privacy concerns with this technology.

The preceding literature review presented findings that indicate speeding is widespread and problematic. Drivers knowingly, willingly, and routinely violate the speed limit (Shinar et al., 1999; Taylor, Lynam, & Baruya, 2000). Speeding causes and contributes to crashes, increases crash risk, and increases the risk of serious injury or death (e.g., Elvik et al., 2004; NHTSA, 2007). Traditional approaches to curtail speeding have limited success (Shinar, 2007.) Based on these premises, different approaches to addressing the speed problem are warranted. Intelligent Speed Adaptation (ISA, a technology that monitors driver speed, is a new approach that may help reduce speeding.

Data Recording, Driver Monitoring, & ISA

History of Data Recording in Transportation. ISA belongs to a class of technology based on operator monitoring, and its history dates to data recorders used in the aircraft industry. The aviation realm first used recorders in the late 1950s and referred to them as Flight Data Recorders (FDRs). FDRs recorded aircraft parameters such as speed and heading and were designed to survive a crash. As FDR technology matured during the latter part of the 20^{th} century, additional recordings included conversations of the aircrew and sounds of the aircraft. FDRs have been instrumental for determining the causes and correlates of aviation crashes, but a by-product of the technology was that pilots decreased risky actions because they were aware of the performance monitoring.

An automotive system analogous to FDRs is the motor vehicle event data recorder (EDRs), a device installed by original equipment manufacturers. EDRs were originally designed to trigger the deployment of air bags. When a monitored parameter such as speed, vertical and lateral acceleration, deceleration, and brake application exceeds limits, the EDR initiates air-bag deployment. However, shortly after EDRs were installed for air-bag deployment, their potential for facilitating crash investigation became evident. Since their deployment, the precision of the EDRs has improved. This improvement led to applications of EDRs to include fleet management and automatic crash notification (ACN) to emergency first responders.

This improved technology also generated interest about the use of EDRs to improve safe driving behavior in a manner analogous to FDRs. However, due to privacy concerns, the possibility of using the data and computing power of the EDRs installed by OEMs is unlikely to be realized. There are aftermarket devices that can be used in a manner analogous to FDRs. At times researchers mistakenly refer to the aftermarket devices as EDRs or "black boxes." The inappropriate use of the term "EDR" to refer to these monitoring systems has led to confusion. The federal government has a very clear definition of an EDR (Department of Transportation Final Rule, 2006), and the majority of the aftermarket systems are significantly different from the EDRs manufactured by automakers. For example, the driver monitoring system *Drivecam* records and saves video footage of the inside and outside of the vehicle when a driver exceeds a certain parameter, such as lateral acceleration. This capability is far beyond the US DOT requirements for an EDR, and the experimenter will avoid use of the term "EDR", as the focus is on aftermarket devices. Throughout this document the general class of systems designed to improve safe driving behaviors by monitoring vehicle or driver performance will be referred to as in-vehicle driver monitoring (IVDM.) In this classification scheme, ISA, is a type of IVDM. General IVDMs and ISA systems are relatively new and have undergone limited empirical evaluation. However, the evaluations that do exist suggest that the technology may reduce traffic injuries and fatalities.

Use of In-Vehicle Driver Monitoring to Change Driver Behavior. The ability of technology to monitor real time measures has led researchers to assess the extent to which IVDMs might reduce unsafe driving. For example, Wouters and Bos (2000) instrumented a fleet of vehicles and documented changes in accident involvement. The authors recorded several measures including delivery schedules, fuel consumption, sudden accelerations and decelerations, and average speed. The experimenters told drivers in the experimental group about the monitoring. Some drivers were given feedback by their managers, whereas a control group was naïve to the presence of the equipment. Wouter and Bos reported an accident rate that was 20% lower for the treatment relative to the control group. The researchers emphasized that neither feedback nor consequences were central to the study. Thus, it is conceivable that managers' interactions with drivers ranged from positive feedback to job termination. Despite this limitation, the findings of Wouters and Bos indicate that monitoring technology can positively affect safe driving.

In a manner similar to Wouter and Bos (2000), Toledo and Lotan (2006) recruited participants from a private vehicle fleet to conduct a field study with an IVDM system. However, these authors examined the role of feedback to a greater extent than Wouter and Bos. The system used by Toledo and Lotan recorded GPS location, acceleration, speed, and sudden braking. The authors then used these measures and created an algorithm that produced a single risk indicator, which ranged from cautious to risky, for each driver. Toledo & Lotan validated this index by showing a significant correlation between drivers' previous crash history and the risk score.

Toledo and Lotan (2006) then implemented their treatment, which included an explanation of the system and feedback about driving performance. The researchers defined feedback as the number of log-ins to a web-based system that provided information for each driver. Specifically, the authors rated every trip made by a driver as "cautious, moderate, or risky," and each driver was able to see how his or her performance compared to the whole fleet. Toledo and Lotan indicated that the feedback successfully for reduced the risk index but only for individuals who had relatively low risk initially. In addition, the results indicated that log-ins decreased linearly such that by the fifth month the log-in rate was reduced 6-fold. Finally, the results indicated that the risk index for whole treatment group showed a U-shaped function: the average risk index decreased initially but by the end of the feedback period, the index was slightly higher than at the onset of the study.

Given the designs used by Toledo and Lotan (2006) and Wouters and Bos (2000) it is impossible to determine whether the reported effects were a function of the drivers' awareness of the systems, the feedback provided, or the combined effects of awareness and feedback. Both research teams found that awareness of monitoring may affect behavior, and Toledo and Lotan reported that feedback may reduce risky driving. Wouter and Bos were rather cavalier in their discussion of feedback, merely stating that fleet owners may have used it, but it was not the focus of the study. In contrast, Toledo and Lotan's operational definition of feedback was concise but poorly controlled by the experimenter. In sum, the two studies tested the effects of IVDMs on risky driving in general, and both research teams obtained results that indicated potential benefits from the use of such systems. The following section documents the efforts made to test a specific type of IVDM: intelligent speed adaptation or ISA.

History of ISA Systems. Whereas general IVDMs target several unsafe behaviors, the focus of ISA systems is on speed. As mentioned previously, ISA systems require a linkage between vehicle speed, vehicle location, and speed limit information. Researchers in Europe and Australia have used two methods to meet these requirements. As reviewed by Jamson, Carsten, Chorlton, and Fowlkes (2006), the precursors to modern ISA systems were essentially a cross between speed governors and cruise control: either the system prevented the driver from speeding by setting a predetermined speed regardless of the speed limit, or the driver or passenger activated a speed limiter manually upon encountering a speed limit change. The first researchers to study true ISA used transponders affixed to speed limit signs, which sent microwave signals about the speed limit to the ISA system in the vehicle. A processor then compared the speed limit to the vehicles' travel speeds, and a user interface provided feedback to the driver (Almquist & Nygard, 1997; Brookhuis & de Waard, 1999.) Brookhuis and de Waard used this transponder system and had drivers complete baseline and ISA drives on a route that had five speed limits and took 35 minutes to drive. An in-vehicle system provided visual and vocal feedback to the driver when they exceeded the limit. The visual feedback was graded: green indicated adherence to the speed, yellow an intermediate violation, and red a violation greater than 10 kilometers per hour. The vocal feedback coincided with the red visual display. Using this system, the researchers were able to show a significant reduction in the amount of time that drivers were 10% over the limit when driving with the ISA system.

The work completed by Almqvist and Nygard (1997) also used a transponder based system. However, the system deployed in the vehicle exerted a higher level of control over vehicle speed than that of Brookhuis and de Waard. Specifically, when Almqvist and Nygard's participants entered the zone defined by the installed transponders, the fuel distributor prevented acceleration over 50kmh. As one would expect with this level of automation, the system was 100% effective in terms of compliance with the speed limit. Surprisingly, nearly two-thirds of the participants provided positive ratings about the system's usefulness in maintaining the speed, although drivers also felt that they were delaying other drivers.

A third early ISA study used an intermediate level of automation with a device referred to as the active accelerator pedal or AAP (Varhelyi & Makinen, 2001.) The AAP provides a force to the accelerator when the driver violates the speed limit, but unlike the system tested by Almquist and Nygard (1997), drivers could override the system by pressing harder on the accelerator. The premise for such a system is that drivers at times may need to exceed the speed limit, e.g., to overtake a vehicle in some emergency. Schulman (2005) first tested a similar accelerator technology in 1985. Varhelyi and Makinen tested the effect of the AAP ISA among three different European populations: Dutch, Swedish, and Spanish, using methods similar to those previously discussed. The authors reported significantly reduced speeds in each country, but the effect was strongest in Spain. The authors attributed this difference to less road congestion in Spain, which allowed drivers greater choice in setting their speed. Subjectively, there was a general acceptance of ISA. The majority of the sample indicated that they partially or entirely supported the use of such a system for situations such as dangerous road conditions.

In contrast to the speed measures that showed a positive effect on behavior, Varhelyi and Makinen (2001) reported negative subjective workload ratings. Summing across the full sample, the authors found increases in frustration and time pressure. Moreover, the authors reported closer following distances during the ISA drives relative to baseline drives. There were also important differences among the countries. For example, the increase in frustration between the ISA drive and the baseline drive was significantly greater in the Netherlands, relative to Spain and Sweden, and there were no changes in the six workload dimensions (frustration, time pressure, performance, effort, physical demand, and mental demand) among the Swedish participants. These differences indicate that cultures may differ regarding attitudes toward ISA and underscore the need to test ISA in any region prior to wide scale adoption of the automation.

At approximately the same time that Varhelyi and Makinen (2001) found potential negative behavioral adaptations, Comte (2000), used a simulator to test the effects of ISA in a more controlled setting. The researcher recorded gap acceptance, i.e., the distance between two oncoming vehicles at which participants would initiate a left turn; following distance between the participant and lead vehicles; reaction time to a sudden braking event; passing; and moving violations. Comte reported two significant behavioral adaptations. Relative to a control drive, drivers accepted shorter gaps when initiating left turns and following distances were shorter. Similar to Varhelyi and

Makinen, Comte reported that subjective workload ratings of time pressure and frustration were significantly greater when driving with ISA relative to driving without it.

The failure of Comte (2000) to show a difference in reaction time when responding to the sudden event is of particular interest, because of the concern that ISA systems, particularly those that completely control speed, may take the driver out of the loop, which could result in automation induced complacency (Sarter & Woods, 1995). Comte's (2000) results cannot support nor refute the potential for such complacency. A second finding of interest was that this simulator experiment showed no mean difference in speed when driving with the system, relative to control drives. This finding is in direct contrast with earlier field studies showing significant reductions in speed when using ISA (i.e., Brookhuis & De Waard, 1999; Varhelyi & Makinen, 2001). Two possible explanations for this result are that speeding in the virtual world and the real world are sufficiently dissimilar behaviors or that Comte's dependent variable, mean speed, was not sufficiently sensitive to detect an effect. This latter explanation has some support based on findings that show that the proportion of time over the speed limit may be a more sensitive measure than mean speed (Warner & Aberg, 2008).

These early "proof of concept" studies demonstrated that ISA systems were a feasible countermeasure for speeding. As reviewed by Carsten and Tate (2005), transponder based ISA systems such as those used by Almqvist and Nygard (1997) and Brookhuis and de Waard (1998) were deemed unreliable relative to GPS-based systems because of potential transmission or reception problems. Therefore, systems that rely on GPS capabilities are currently the preferred method of deploying ISA (for example, Adell & Varhelyi, 2008; Harms et al. 2007). GPS provides accurate latitude and longitude location and accurate travel speed. In such advanced ISA systems, a database links the GPS coordinates of speed limit signs and the speed limit indicated on each sign. The final component of a GPS based ISA system is an interface between an on-board GPS system and the speed limit GPS database. These systems react in real-time to speeding. As alluded to in review of earlier ISA work, these reactions vary with regard to the level of speed limit control experienced by the driver.

Level of ISA Automation. The types of ISA systems developed and tested can be conveniently classified by level of automation. Levels range from those that simply provide a visual, auditory or haptic signal to the drivers when they speed (e.g., the system tested by Brookhuis & De Waard, 1998), to those that exert some level of control over the vehicle that can be overridden by the driver (e.g., the AAP system used by Varhelyi & Makinen, 2001), to those that prevent driving the vehicle above the speed limit (e.g., the system used by Almqvist & Nygard, 1997.) Carsten and Tate (2005) defined these levels of ISA automation as advisory, interactive, and mandatory.

The three levels of automation defined by Carsten & Tate (2005) fit well with Sheridan's (1980) framework for classifying levels of automation. Sheridan's (1980) discussion of automation provides a means of categorizing automation as a function of which entity in the human-system relationship decides upon action. The author lists 10 levels of automation that range from complete human control of decision making determined by automation with zero input from the operator. Advisory ISA parallels the Sheridan's second level, one at which the system offers alternatives that operators may act upon if they desire. The interactive ISA would fall at some point near Sheridan's sixth level, a point at which the system decides but the user can override the automation. Mandatory ISA would fit with Sheridan's final two levels, points where the operator has no control over the decision to exceed speed limits.

Researchers in Europe and Australia tested each of these levels of ISA automation. Mandatory systems engineered to prevent exceeding the speed limit provide a consistent change in speeding behavior, as drivers are forced into compliance with the speed limit (Almqvist & Nygard, 1997; Duynstee, Katteler, & Martens, 2001.) As mentioned previously, Almqvist and Nygard were able to show the effect during a relatively short period, whereas Duynstee et al. tested a relatively large sample of drivers (480) over a test period of 8 weeks (2 week baseline period and 6 week ISA period) and showed that a mandatory ISA system was completely effective for preventing violations of the speed limit. These authors report that a majority of drivers (64%) rated this mandatory ISA system as positive. However, Duynstee et al. did not test other levels of ISA automation, so it is difficult to know how the mandatory ISA compared to advisory or interactive systems. As reported below, field studies of advisory and interactive ISA also obtained significant reductions in speeding and relatively higher acceptance ratings than more controlling systems (Biding & Lind, 2002).

The continuum of automation described by Carsten and Tate (2005) presents a dilemma. Based on the literature that indicates speed significantly increases crash severity (e.g., Elvik et al. 2004; Grabowski & Morrisey, 2007), the notion of a mandatory system that reliably prevented speeding as such automation would eliminate speeding.

Yet intuitively, such a system would lead many to react unfavorably, and perhaps even override the system. Findings indicate that commercial drivers found an interactive ISA system adverse relative to an advisory system (Biding & Lind, 2002), and drivers were reported as having sabotaged other vehicle safety systems (Van Houten & Malenfant, 2006). Moreover, Harms et al. (2007) report that younger drivers aged 18-28 rated mandatory and interactive systems less desirably than advisory ISA. As this age group speeds more often than older drivers, stakeholders may benefit from considering the preferences of this demographic. However, proponents who more staunchly support ISA may argue that the benefits of limiting speeding outweighs driver acceptance. A cost-benefit analysis completed by Carsten and Tate (2005) led the authors to conclude that mandatory ISA offered the largest benefit, although there were significant but smaller benefits for the advisory and interactive systems. Further support for mandatory ISA is found from subjective results. Almqvist and Nygard (1997) and Duynstee et al. (2001) reported that a majority of their participants reacted positively toward the mandatory ISA systems. Given any ratings that suggest mandatory ISA is acceptable, proponents of mandatory ISA might argue that drivers would eventually accept such technology.

Thus there is debate about the appropriate level of control, with supporting evidence on both sides. Moreover, there are factors that indicate that the optimal level of ISA automation is still undecided, and these factors are of particular relevance to the current project. ISA researchers have studied only drivers and geographic regions outside of the United States. The findings of Varhelyi and Makinen (2001) indicate substantial cultural differences with regard to ISA acceptance. Second, individuals who rated the more controlling systems positively were biased toward wanting such a system. Some participants were told the nature of the system prior to signing up for the study, i.e, they actively sought to participate in a study designed to reduce speeding (see Almqvist & Nygard, 1997 and Duynstee et al., 2001). Finally, results suggest more automated ISA systems have potential negative behavioral adaptations (Hjalmdahl & Varhelyi, 2004).

In sum, the ultimate goal of reducing speeding behavior would surely be met by a mandatory system. However, whether drivers, particularly United States drivers who have yet to be exposed to ISA, would accept such a system or whether there may be negative behavioral adaptations is not yet determined. With the intention of maximizing acceptance of ISA and with the goal of maintaining a fully crossed experimental design, the current project will test an advisory ISA system. Although advisory and interactive systems are a focus, systems using a higher level of automation are a significant part of a discussion about potential behavioral adaptations to ISA.

Sweden's ISA Field Study. To date, the most comprehensive ISA effort occurred in Sweden between 1999 and 2002 (Biding & Lind, 2002), with several field studies and post-hoc analyses following the original large scale evaluation (e.g., Adell & Varhelyi, 2008; Hjalmdahl & Varhelyi, 2004; Hultkrantz & Lindberg, 2003). The following summary of the Swedish National Road Administration's (SNRA) effort comes largely from the report authored by Biding and Lind. The SNRA tested four systems in four urban areas over a 2 year period. Two systems were advisory (used in the city of Umea and Borlange). A major goal for the Umea location was a wide scale deployment of the system, and because the cost of GPS based ISA was prohibitively expensive for the 4000 vehicles that took part in the study at Umea, this test area used transponder technology. The Borlange site (400 vehicles) and the remaining two sites used the GPS based ISA. These remaining two field test sites were the cities of Lund (290 vehicles) and Lidkoping (280 vehicles). Participants in Lund drove vehicles with interactive systems that used a variation of the AAP described above. Participants in the Lidkoping either drove vehicles with an advisory system or AAP plus an advisory system.

Although different variations of ISA systems were tested at the four sites, the experimental design was essentially the same at each location. Experimenters recorded baseline driving measures and subjective ratings during the first month of the trial. After recording baseline measures, the ISA systems became active and the same measures were recorded. The analyses compared the pre-ISA activation period with two post-ISA periods of one month each. The first post-period occurred immediately following system activation, and the second post-test period was approximately a year later. The ISA system was active during both post-periods. Across the four sites, there were significant reductions in the percentage of speed violations during the first post-activation period relative to the baseline period. For example on 70 km/hour roads, speed limit violations reduced 18 percentage points in Lund on 70 km/hour roads and 13 percentage points in Borlange. Overall, the reductions ranged from 10 to 20 percentage points across sites and speed limits. Effects on speed were similar for the interactive system that provided accelerator pedal feedback and the advisory system. During the second baseline period, speed violations were significantly lower than the baseline period, although the effect was attenuated. This attenuation suggests that drivers may habituate to the system.

In contrast to objective measures of speed, which indicated similar effects between the interactive and advisory systems, the ISA systems received different ratings of general acceptance. For example, prior to the onset of the field trial, participants were asked whether having an ISA system would be "good." The respondents provided ratings for each type of ISA system used in the study. There were differences between the individuals who expressed interest about participating and those who did not, with those uninterested in participation feeling less positive toward all ISA automation levels. The range of positive ratings for those not interested in participating in the ISA study was approximately 15% to 45%, whereas the range of positive ratings for those who were interested in participating was 20% to 80%. Prior to and after driving with the systems, participants rated the advisory systems more favorably than the interactive systems. Participants disliked the psychophysical parameters of the auditory warning. Twenty percent of the individuals who used the system admitted to trying to deactivate the auditory warning, and many indicated that a "softer" tone would be more acceptable. Drivers who experienced the advisory systems stated that a variable alarm pulse rate that increased as the speed violation increased would be desirable. Many of the negative ratings associated with the interactive systems were due to mechanical problems, and Biding and Lind (2002) suggested that ratings would likely have been more positive had the functional issues not surfaced. The participants also provided acceptance ratings by indicating whether or not they would keep the system.

Approximately 66% of the participants indicated that they would keep the system if given the opportunity. However, only 33% of the participants indicated that they would pay to keep the system.

The results reported by Biding and Lind (2002) also included ratings of perceived mental workload. The workload scale was similar to the NASA TLX (Hart & Staveland, 1988.) Specifically, the individuals rated the extent to which ISA affected perceived temporal demand, attentional demand and time stress. As mentioned by Comte (2000) there is concern that ISA may affect attentional resources negatively by removing the operator from the loop, increasing frustration associated with the interface, or potentially reducing workload associated by eliminating the task load associated with monitoring speed. Biding and Lind's participants rated the advisory systems as having more attentional demand than driving without the system. In contrast, participants rated the interactive systems as having less attentional demand.

In sum, the Swedish large-scale ISA field test demonstrated that ISA was effective in reducing speed, although the effect decreased in magnitude at the second post-test period relative to the first post-test period. The majority of drivers who participated in the study indicated that they would continue to use the system – provided they did not have to pay for its use. Despite the negative ratings related to frustration and feelings of being a hindrance to other drivers, which could arguably be attributed other vehicles on the road traveling faster, the participants overwhelmingly (a range of 70% to 90%) admitted that ISA was useful for maintaining speed. A final sign of ISA acceptance were participant ratings that indicated ISA should be available for certain groups, such as teen drivers, and locations, such as hospitals.

Thus, the Swedish trial was successful and suggests that ISA has promise. However, the study had limitations. For example, the participants were not representative of at-risk drivers. Across the four test sites, participants averaged approximately 50 years of age, an age at which speeding is less of a problem (Quimby et al., 2007), relative to younger age groups. Younger drivers may particularly benefit from ISA, but this age group may have a significantly different experience than participants in the Swedish field test. For example, 20% of Biding and Lind's participants admitted to trying to deactivate the advisory system; if younger drivers are less accepting this percentage could be greater. Another limitation of the sample relates to participant recruitment. Participants were fully aware of the study's purpose and goals and were willing to have their cars instrumented and driving performance recorded for the full test period. The self report data concerning ISA acceptance reported by Biding and Lind (2002) that revealed differences between field test participants and non-participants supports the notion that participants were biased toward having a positive view of ISA. Therefore, the findings may only generalize to older individuals with favorable attitudes toward automation.

Two final limitations of the study were related to the experimental design. The experimenters did not use a control group and therefore cannot rule out that differences were due to historical events. In fact, the authors mention that there were significant traffic calming and enforcement efforts during the study period. A second limitation was the absence of a post-ISA measurement period to measure driving performance after removal of the system. Therefore, it is not possible to answer whether or not permanent behavior change occurred in association with exposure to the system. Would drivers be more mindful of speed limits, or could there be some negative behavioral adaptation such as failing to monitor the speed limit because of an expectation that the system would do so? Subsequent ISA research attempted to address some of these and additional questions about how various ISA systems might affect driving behavior.

Follow-up Studies to the Sweden's Large Scale Field Test.

Removal of ISA after Long Term Use. Hjalmdahl and Varhelyi (2004) tested for the effect of ISA removal after drivers drove with the system for several months. A subsample of participants from the Lund site drove a preplanned 30km route at two different periods. The first period occurred prior to the activation of ISA, and the second period occurred after the participants had driven with ISA for six months. Half of the 30km route occurred within the digitally mapped area, and the remaining portion occurred outside of the mapped area. Thus, it was possible to compare the interaction between test period, (pre-ISA activation versus post-ISA activation), and drive segment (ISA controlled versus non-ISA controlled). Hjalmdahl and Varhelyi (2004) indicated that upon entering the non-ISA controlled route segment during the post-activation drive, several drivers failed to notice speed limit changes that occurred outside of this range. In contrast, the same drivers rarely failed to adjust their speed when they entered this region during the pre-activation drive. These results strongly suggest that drivers had a behavioral adaptation; they appeared to delegate to the vehicle the task of monitoring for and reacting to speed limit changes, whereas the drivers had sole responsibility of speed monitoring during the pre-activation phase.

This finding is compelling for theories about the effects of automation on operator performance. Specifically, Parasuraman and Riley (1997) suggest that there are several potential reactions to automation. One potential effect described by these authors is overreliance on the system. The authors site empirical work that suggests the probability for overreliance increases as a system's reliability increases. As the ISA system was reported to be reliable within the mapped area, and given that drivers failed to detect the speed limit changes, it is possible that these individuals were over relying on the system as suggested by Parasuraman and Riley. However, Hjalmdahl and Varhelyi's (2004) study looked only at a single 30km post-activation drive, and during half of this drive the participants experienced the interactive ISA. Given the authors' design, it was not possible to test if drivers would reallocate the task to themselves after realizing that the system was no longer active or how long a period of time it might take if the reallocation did occur. For example, scenarios in which drivers drive for extended periods of time with and extended periods without ISA might show allocation of speed monitoring to the vehicle during the ISA period and then a gradual reallocation to the driver during the post-ISA period. An objective of the current project is to further examine the potential for automation misuse as described by Parasuraman & Riley. To accomplish this objective, the current study tested the effects of a one week post-ISA period.

The Effect of ISA on Tertiary Measures. Post-hoc analyses of the large scale Swedish field study assessed hypothesized effects on measures that were tangentially related to speeding or speeding violations. Varhelyi, Hjalmdahl, Hyde, and Draskoczy (2004) completed several in-depth analyses from the field test site in Lund, which used the active accelerator pedal, and reported that individuals with the ISA drove with less speed variance after the ISA activated. This finding of reduced speed variance is important; as reviewed by Shinar (2007), minimizing differences in speed between vehicles on the same road reduces potential confrontations that should lead to reduced crashes. In addition to reduced speed variance, Varhelyi et al. also reported a significant reduction in emissions at approximately 40% of sample sites. Given concerns about global warming among the general public, such findings could provide another line of support for the use of ISA. Of course this assumes that the effect of ISA is permanent.

Habituation to ISA warning. The advisory ISA system that was studied at 2 of the 4 sites in the Sweden large scale study showed initial large effects on speeding, but a follow-up analysis reported by Warner and Aberg (2008) indicates that initial effects may decrease over time. Specifically, the authors examined a subsample at the Borlange site and compared speeding performance at 4 time periods from 2 to 4 weeks prior to activation to 3 years after activation. The effect of ISA on speeding reduced significantly as time progressed. At one speed limit level (i.e., 45 km/hour), speed during the final measurement period was no different than during the pre-test. However, reductions in speed were significant at the other speed limit levels during the final measurement period, albeit a smaller effect than during the initial post-ISA period.

Additional ISA Studies. The effort of the SNRA was admirable and offshoot reports will surely continue from the field trial. It is likely that Sweden's endeavor also provided motivation for researchers in other countries. For example, in Belguim Vlassenroot et al. (2007) reported mixed results of an interactive ISA. On high speed roads, participants sped a smaller portion of the time, but this effect was not found for lower speed roads. However, the study had several flaws. In particular, the authors' intention of recording pre-ISA speed behavior was not met because of equipment failure.

Using a more rigorous experimental design, Regan et al. (2006) evaluated the effects of an ISA system on speed of a sample of Australian drivers. The system paired advisory information with an active accelerator pedal. The design used by Regan et al. was novel relative to other ISA studies because the researchers repeatedly introduced and removed the ISA system and observed the resulting effects. Specifically, participants began with a baseline period of 1,500 kilometers, and then drove 3 experimental phases. A phase comprised a 1,500 kilometer drive with ISA and a 1,500 kilometer drive without the system. The authors reported that the system reduced speed violations, defined as time spent more than 10 km/hour over the limit. The authors also reported that speed variance decreased during ISA phases. Interestingly, Regan et al. reported that there was no difference between travel times as a function of the ISA. A potential negative result reported by Regan et al. (2006) was that speeds increased significantly when the ISA system was removed, which suggests that ISA did not affect permanent change.

A major effort was recently completed in the United Kingdom (Personal communication, Carsten, March 2008; Carsten & Tate, 2005; Jamson et al. 2006.) Part of the UK's effort involved the examination of economic, legal, and macro system issues. If Carsten and Tate's (2005) estimate of a 37% reduction in fatal crashes were valid in the US, approximately 15,000 lives would be saved – annually. In addition to the UK, other countries have ongoing or recently completed but not published field tests. These countries include Canada (personal communication with Paul Boase, April 29, 2008.), China, France, and Belgium (Jamson et al. 2006). One ISA research endeavor with potential is to pair ISA technology with monetary incentives, e.g., insurance premium discounts, to determine the extent to which external motivation might reduce speeding.

Studies that Used Incentives. The goal of the current project was to test the effect of an advisory ISA similar to the system used by Warner and Aberg (2008) on driver speed and acceptance. In addition, the current study tested whether an external motivator, a cash bonus for observing the speed limit, by itself or paired with an ISA system affected speeding. There are insurance companies that provide discounts to drivers who document that they avoid situations that increase crash risk. From a behavioral perspective, this might be viewed as negative reinforcement. As speeding is one of these risk factors, ISA could be paired with the insurance policies. To date, it appears that two research efforts measured how incentives interacted with ISA. Hultkrantz and Linberg (2003) completed a project using vehicles from the Swedish field trial. The authors included 4 groups of drivers: 2 "bonus" groups (high versus low bonus amount) were crossed with 2 penalty groups (high versus low penalty). The "bonus" variable refers to the amount of money drivers could receive if they heeded speed limits. The high bonus group could earn approximately $100 per month; the low bonus group could earn $50 per month. The "penalty" variable referred to how much the money the drivers lost for each violation of the limit. Drivers were penalized based on the magnitude of violation; the penalty for speeds 20% over the speed limit was 10 times greater than violations that were 1 to 10% over the speed limit. Hultkrantz and Linberg (2003) also included 2 "control" groups that received high and low bonus amounts but were not penalized for speed violations. Drivers received a monthly report that documented how frequently they violated the speed limit and how much of a reward they would receive.

Hultkrantz and Lindberg (2003) focused on three ranges of speed violations 0 to 10% over the speed limit; 11 to 20% over the limit; and more than 21% over the limit. The authors reported a reduction in speed violations for all six participant groups during the first month; during this initial period there was a tendency for the drivers who were penalized for speeding to have fewer speed violations than the drivers who were not penalized, but the trend was not statistically significant. However, when the authors compared the violations of the "penalty" groups to the "no penalty" groups, a large difference was found, with the "penalty" drivers reducing their speed violations significantly more than the "no penalty" group. Hultkrantz and Lindberg (2003) also noted that participants who were assigned to the lower bonus group had greater reductions in violations than drivers who were assigned to higher bonus group. Few differences were noted between the drivers who were in the high penalty group relative to the low penalty group. These findings suggest that the potential to earn money is a viable external motivator for encouraging speed limit compliance, but also indicate that the contingency structure requires careful consideration.

A more recent project completed in Denmark also measured the effect of monetary incentive and an advisory ISA system on speeding behavior (Harms et al. 2007.) The authors described the advisory system as having visual and auditory displays, and the monetary incentive was the potential to receive a 30% discount on vehicle insurance premiums. The negative reinforcement schedule worked in a manner such that participants received an audible verbal warning when their speed was greater than 5 km/hour over the speed limit for six seconds. If the driver continued to speed the warning would repeat at 12 and 18 seconds. At 18 seconds, penalty points, which were defined as a reduction of the 30% insurance discount, would accrue. Harms et al. had four treatment groups: ISA only, ISA and penalty, penalty only, and neither ISA nor penalty points. The field study lasted for 6 months, with an initial 6 week baseline period. The authors divided the post-ISA period into 2 periods and showed that the participants in the three treatment groups effectively reduced their speeds, whereas the control participants did not change their speeding behavior during the study period. Harms et al. reported an interaction between the information group (ISA only), combination group (ISA + penalty points), and incentive group on the extent to which participants drove at speeds greater than 5kph. The two groups that had ISA reduced their speeds significantly more than the incentive and control groups during the first and second ISA periods. The authors reported that all groups but the control group increased the proportion of time spent driving at speeds that ranged from -5 to +5 km per hour within the speed limit.

In sum, Hultkrantz and Lindberg (2003) and Harms et al. (2007) demonstrated that ISA paired with the external motivation of money resulted in reduced speed violations. The first study used a form of positive reinforcement, with the magnitude of the reward contingent on the level of speed limit compliance, whereas Harms et al. used negative reinforcement, the reduction of insurance premiums. However, their studies leave several questions unanswered. For example, neither study monitored speeding violation after removing the ISA or the incentive. Some work suggests that no lasting behavioral change occurs after exposure to ISA (i.e., Regan et al. 2006), but Regan et al. did not use an incentive, which limits comparability with studies that did. Moreover, the samples using incentives were biased, particularly the Hultkrantz and Lindberg study, which used participants from the original Swedish field trial. Thus, the limitations of Biding and Lind (2002) apply here. Although Harms et al. used a sample of younger drivers, i.e., aged 18 to 28, their participants were significantly more agreeable toward automation than individuals who declined to participate.

The current study differed from the two monetary incentive studies with regard to the interface for individuals in the incentive conditions. Hultkrantz and Lindberg (2003) provided a monthly report to their participants that informed them about their bonus amounts and speeding behavior, and Harms et al's (2007) participants could view their insurance bonus "overnight" but did not indicate how this occurred. In the current study, the incentive amount was displayed on the dashboard when drivers started and turned off their vehicles.

Summary of Existing ISA Research.

In sum, intelligent speed adaptation is a relatively new technology, so there are several research questions yet to be answered. However, there have been a number of evaluations that allow some conclusions to be drawn about the potential positive and negative effects that may result with deployment of the system. As suggested by Carsten and Tate (2005) the research reviewed in this document suggests that the net effect of ISA seems positive, yet because of the limited history of ISA and some negative findings it would be premature to recommend wide scale adoption, particularly in the US where it is untested.

Benefits of ISA. The main benefit of ISA seems to be reduced propensity to speed, which should lead to a reduction in crashes. Nearly all work cited above indicates this positive effect of the system, regardless of the level of automation. Some authors found the effect to be consistent across roads with various speeds (e.g., Regan et al. 2006; Varhelyi & Makinen, 2001); whereas others found that certain speed limits were associated with attenuated effects (Warner & Aberg, 2008.) In addition to reducing the proportion of time that drivers violated the speed limit, some researchers reported reduced speed variance (Regan et al., 2006; Varhelyi et al., 2004), which is also suggested to lower crash risk (Shinar, 2007). A third objective measure shown to be positively affected by ISA was vehicle emissions (Varhelyi et al. 2004.)

These effects would combine to provide a significant economic benefit to countries that had wide scale deployment of ISA (Carsten & Tate, 2005.) The costs of crashes associated with speeding are estimated at 40 billion dollars per annum (NHTSA, 2007). If Carsten and Tates' estimates of ISA savings were accurate, ISA could lower this annual cost by 10 to 15 billion dollars. Finally, lowered vehicle emissions offer a significant societal benefit that may be more appropriately measured by a change in air quality. Cleaner air may in turn affect the prevalence of health issues such as respiratory function, although such a long term impact would be difficult to quantify.

Subjective results indicate ISA may also lower some aspects of mental workload, although these results were less conclusive than the objective results. Biding and Lind (2002) indicated that the level of automation affected various dimensions of workload ratings differently. For example, their interactive system was associated with lowered stress in high traffic situations; evidently removing speed monitoring from the drivers' task load reduced this component of mental workload.

A final subjective benefit of ISA is to the attitudes of the drivers who experience ISA. Participants in Europe, in general, had positive attitudes toward ISA. For example, Adell and Varhelyi (2008) reported that drivers felt that ISA made them safer drivers, and drivers also acknowledged that it reduced their chances of receiving tickets. Moreover, Carsten (2002) reviews work that suggests the attitude toward ISA continues to improve. Originally thought of as ludicrous for mechanical and privacy reasons, the idea of ISA being widely deployed is gaining more acceptance. However, as Carsten cautions, this favorable attitude may be in conflict with objectivity. In fact a bias to promoting ISA could lead to "automation abuse", i.e., the implementation of automation without fully considering potential outcomes (Parasuraman & Riley, 1997). Given the following summary of negative effects, it is clear that continued, objective evaluation of the effects of ISA is necessary to avoid such automation abuse.

Costs of ISA. In contrast to some findings that suggested ISA might lower stress levels as a result of lowering task load, there were consistent findings that suggested drivers experienced elevated levels of stress, frustration, and temporal demand (Biding & Lind, 2002; Comte, 2000; Varhelyi & Makinen, 2001.) These ratings were found to be similar for advisory, interactive, and mandatory ISA systems. Regarding the lowest level of automation, advisory ISA, the results were somewhat mixed. For example, Harms et al. (2007) reported that drivers preferred this level relative to interactive and mandatory ISA, whereas Biding and Lind and Brookhuis and De Waard (1999) indicate that the auditory displays were particularly annoying features of the advisory system. In addition to annoyance, long term use of advisory ISA may result with habituation to the warning and a return to pre-ISA speeding behaviors (Warner & Aberg, 2008).

Staunch proponents of mandatory ISA may argue that minimizing annoyance is of little concern because drivers would have no choice but to adapt to a government-mandated system. However, there are findings that suggest drivers who use mandatory or interactive ISA may change other safety related behaviors as a result of exposure to the system. These changes include shorter gap distances when turning, closer following distances, and poorer reallocation of the speed monitoring task (Comte, 2000; Hjalmdahl & Varhelyi, 2004). This failure of proper reallocation may be an example of mode error that resulted from overreliance on the system (Sarter & Woods, 1995). Comte also cautions that for the higher level of ISA, automation complacency may result in cognitive underload, which could slow reaction times. This last concern seems possible, but the claim was not supported in the ISA literature. In sum, the potential for overreliance, mode error, and induced complacency seem to suggest that advisory may be the optimal choice. However, results suggest that drivers may eventually habituate to the auditory warning or may deactivate it if they find the alert annoying.

In sum there are clear benefits to ISA yet there may be unintended consequences associated with all ISA levels that would reduce the safety benefits of the systems. The more severe behavioral adaptations, e.g., closer following distances, shorter gap acceptance, are associated with ISA systems that have a higher level of control. The minimization of these more severe behavioral adaptations is one basis for the use of an advisory system in the current project. In addition, this level of automation has the highest amount of driver acceptance (with the exception of annoyance level), which may result in less tampering. Ultimately, the proposed ISA system was selected based on the logic that all levels of ISA have shown reductions in speed, and the general population of drivers within the US should first be exposed to the most innocuous level of ISA automation and shown its benefits before testing the higher levels of automation. Careful design of the auditory interface may maximize speed reduction and driver acceptance of the system.

Features of the Tested ISA System: Automated Feedback & Monetary Incentive

Temporally linking feedback to a target behavior is frequently shown to shape behavior (Balcazar, Hopkins, & Suarez, 1986) and may increase the effects of ISA systems, particularly for drivers who are unintentionally speeding. Blincoe et al. (2006) surveyed drivers who were ticketed for speeding and found support for classifying the drivers into four groups based on participants' responses to questions about speeding. A significant proportion of two groups, 50% of "conformers" and 30% of "deterred drivers", indicated that inadequate signage was the main factor that caused their violation. These types of drivers may particularly benefit from and even appreciate immediate feedback when they violate the speed limit.

In contrast to drivers who unintentionally violate the speed limit, drivers who intend to speed may ignore or disable advisories. Such drivers may need a more compelling reason to refrain from speeding. The principles of instrumental conditioning established over a century ago, applied in conjunction with ISA, might result in improved driving behavior. Specifically, drivers who are exposed to extrinsic motivation may reduce their driving speed relative to drivers who only receive advisories. Thus, a second variable manipulated tested in this study was a monetary incentive; drivers who complied with the speed limit received a bonus. The bonus diminished progressively for drivers who chose to speed. Therefore, the proposed behavioral contingency was a delayed incentive combined with an immediate disincentive. This section of the literature review first reviews work related to the auditory interface, followed by a discussion of using tangible rewards to alter behavior.

Designing Appropriate Auditory Messages. The auditory display was designed to alert drivers when their speed exceeded the limit. The clear purpose in providing the alert was to have drivers slow down; however, the alert does not force drivers to slow down. In fact, drivers who are purposefully speeding may want to ignore the signal. Given this situation, a goal of the project was to create an advisory message that is clearly salient yet introduces minimal annoyance to the driver.

Marshall, Lee, and Austria (2007) provide a succinct summary of the relationships between annoyance, appropriateness, and perceived urgency of a sound. Alerts with a high level of perceived urgency are rated as annoying when the individual deems the alert to be inappropriate. Signals are judged to be appropriate when the level of perceived urgency of the warning matches the situational urgency, i.e., the true danger at the moment (Edworthy, Loxley, & Dennis, 1991). Marshall et al. completed a study in which participants rated several warnings in three contexts, i.e., warnings for a collision avoidance system, a navigation system, and an email system. The authors reported high positive correlations between ratings of appropriateness and perceived urgency when experimenters presented urgent signals in the collision avoidance context; weak correlations were reported between annoyance and urgency. In contrast, when Marshall et al. presented a less annoying warning with the low urgency situation, they found a strong relationship between annoyance and perceived appropriateness; in this situation, perceived urgency and appropriateness were uncorrelated. These findings suggest that in dire situations the user may benefit from what would be considered a noxious stimulus in less urgent contexts. Conversely, less urgent sounds should be paired with lower priority matters to improve the appropriateness of the advisory.

Edworthy et al. (1991) and Marshall et al. (2007) provide further insight regarding the relationship between urgency and annoyance and the parameters of the signal. As reviewed by Edworthy et al. designers typically follow four steps when creating the actual sound presented to the user. First, the designer must determine the appropriate decibel level of the sound, which can be a challenge in acoustically dynamic environments. The remaining three steps concern design of the pulse, the burst, and the time between bursts. When creating the pulse, e.g., a single beep or tone, the designer must specify its temporal and acoustical components. The duration of pulses tend to vary between 100-300 milliseconds (ms). In addition to duration the designer also determines the envelope, a term that describes how quickly the burst reaches peak amplitude and the characteristics of signal offsets. With regard to acoustical properties of the pulse, the designer must determine features such as speech versus non-speech and the fundamental frequency of the signal. The designer also determines the qualities of the burst, or a unitized group of pulses, which include specifying the pulses to include in one burst, the interval between pulses, and the harmonic properties of the burst. Finally, the designer determines the time period between each burst.

Research clearly indicates that manipulation of acoustical and temporal parameters affect the perceived urgency and annoyance of the sound. Researchers found the following conditions to increase perceived urgency: fast onset and offset of the signal, long pulse durations, short inter-pulse intervals, multiple pulse repetitions per burst, loud signals, high fundamental frequencies, irregular harmonics, large pitch ranges, and atonal pitch ranges (Edworthy et al. 1991; Marshall et al. 2007; Spain & Bliss, accepted; Tan & Lerner, 1995.) In fact, Edworthy et al. created a series of 16 different warnings and predicted with a high level of accuracy the order that participants would rank each signal with regard to perceived urgency. However, the Marshall et al. (2008) study discussed above indicates some parameters, e.g., burst offset, can be manipulated such that for a given level of perceived urgency, annoyance is minimized.

Increasing perceived urgency while limiting annoyance was a goal of the current study because speed warnings were given to an action that has a low situational urgency, particularly for those drivers who are intentionally speeding. Given the lower level of situational urgency, an objective for the warning design was to create a signal perceived as, at least initially, more urgent than annoying. However, a second design feature of the speed advisory was the gradation to differentiate egregious speeding from moderate speed limit violations. The proposed study will pilot test several potential warning sounds such as synthesized complex waveforms designed to be perceived as melodious.

Several additional factors associated with the presentation of the warning required pilot testing. For example, extensive pilot testing ensured that the system was functionally reliable, as the effect of trust on reliability is clear. If a warning is unreliable the user will have little reason for heeding the signal (Bliss & Fallon, 2006; Lee & See, 2004; Lee & Moray, 1991; Spain & Bliss, accepted). Another factor that required specification was the temporal tolerance of the signal; given that other drivers on the road will likely be speeding, it may be necessary to provide a period of time that allows drivers to adjust their speeds before the warning triggers. A final design consideration was the use of verbal versus non-verbal warnings; the current project considered only the latter. Although current technology allows the creation of realistic spoken warnings, the proposed study will use non-speech signals based on the recommendation of Lee and See (2004), who suggest that trust in automation may be compromised when using speech (but see Bliss & Kirkpatrick, 2000). In sum, the goal of the advisory ISA system was to alert drivers about their speed without annoying them to the extent that they tampered with the system. The alert informed those who are unaware of their speed, whereas an extrinsic motivator is to reduce intentional speeding.

Using extrinsic motivation to reduce speeding. One expectation for this study was a significant effect of the advisory ISA system on unintentional speeding. In contrast, a delayed incentive - immediate disincentive contingency was expected to reduce intentional speeding, particularly when coupled with the advisory system. Incidents of unintentional speeding may be situations in which the advisory signal provides useful information to the driver. However, drivers frequently choose to speed; as reviewed above, they perceive compliance with the speed limit as having little benefit. Thus, the current study includes an economic incentive, an extrinsic motivator, as a means of increasing the perceived benefit of speed limit compliance. As succinctly stated by Eisenberger and Cameron (1996, p. 1164), "any learnable category of performance, including original thinking, can be effectively strengthened by reward."

There is debate about the effect of extrinsic motivators such as money on behavior (Benabou & Tirole, 2003; Deci, 1975; Deci, Ryan, & Koestner, 1999; Eisenberger & Cameron, 1996; Kohn, 1993.) Some findings suggest extrinsic motivation may actually result in poorer performance than conditions in which no extrinsic motivation exists, and authors of this research argue that this negative effect is due to reductions in intrinsic task interest (see Deci, 1975). Participants in Deci's studies were or were not paid for working to solve puzzles. Experimenters using Deci's approach would observe how removal of reward affected participants' interaction with puzzle solving. Deci found that individuals who were in the reward condition stopped solving earlier and solved fewer puzzles than individuals who received no payment.

Researchers also report that when there is a positive effect of tangible rewards, the effect tends to decrease over long term exposure to the extrinsic motivation (Benabou & Tirole, 2003.) A key to the argument that extrinsic motivation decreases intrinsic task interest is the nature of the task itself. Researchers who argue strongly about these negative effects of tangible rewards (e.g., Kohn, 1993; Deci et al., 1999) frequently discuss the rewards' effects on tasks with clear intrinsic interest. It is with such tasks that the authors report a negative relationship between task interest and tangible reward.

The apparent lack of and sometimes negative effect of extrinsic motivation on tasks that have intrinsic interest has support, and many leaders in education research argue against their use because of this evidence. For example, Deci et al. (1999) completed an extensive meta-analysis that tested the effect of such motivation on tasks with inherent interest. The studies included in the analysis compared the effects of various types of reinforcement schedules, e.g., completion dependent, performance dependent, and positive feedback on intrinsic motivation. Deci et al. reported that extrinsic rewards, except for positive verbal feedback, consistently lowered intrinsic motivation. The authors conceded that concrete incentives were successful, but they referred to them as "controllers." Such incentives consistently changed behavior, but the individuals who received controllers also perceived the task as less interesting than individuals who received well-constructed verbal feedback or no feedback. Such controllers are assumed to undermine feelings of competence and self-determination, which are the central causal constructs associated with cognitive evaluation theory (see Deci, 1975.) These findings from psychological research fuel the debate about the effectiveness of bonuses in the workplace (see Kohn, 1993).

In contrast to Deci (1975) and Kohn (1993), Lazear (2000) indicates that pay based incentives significantly improve output. Lazear had the opportunity to evaluate a "natural experiment." Safelite, a windshield replacement service company, changed ownership in the 1990s. The new owners offered their employees the chance to switch salary payment structure from an hourly rate to a quantity based performance pay structure. Individuals who switched to the performance based system had the opportunity to earn more money and were guaranteed a minimum amount, which was close to their previous hourly wage. Workers were free to choose whether they wanted to continue being paid the hourly rate or switch to a new structure. Lazear was able to show that output increased by 44% relative to the output with hourly wages. The author emphasized that output continued to increase with the time on the program; this suggests that the results are unlikely due to the Hawthorne effect. Finally, Lazear (2000) emphasized that the experiment controlled for workers who sacrificed quality for quantity; workers had to pay for and install a new windshield before more work would be given.

Although the work of Lazear clearly supports the concept of performance pay, and Deci (1975) argues against it, other research indicates mixed results. Pokorny (2006) reports the results of a study that found a u-shaped function between incentive amount and performance on IQ tests. Participants who received no incentive performed significantly worse than individuals who received a small bonuses. However, the solution rate of the no-incentive group was similar to a group of participants who received high bonuses. In addition to incentive amount, Heyman and Ariely (2004) provided evidence to suggest the market relationship affects intrinsic task interest. The authors' work indicates that intrinsic motivation appears to be more crucial in social markets, where monetary rewards are not available. Social markets contrast with money markets. Heyman and Ariely results indicate that the potential cash incentive clearly affects individuals' willingness to engage in the hypothetical task of helping move furniture. Specifically, individuals offered a high reward were more willing to help than individuals offered a lesser reward. However, individuals who were assigned to the social markets were more willing to help than individuals assigned to the low reward group.

An added level to the debate about rewards is that the type of contingency is a significant determinant of effectiveness (Eisenberger & Cameron, 1996). Specifically, the authors reviewed three types of tangible rewards. Performance independent rewards are those given simply for engaging in an activity. The activity need not be completed much less completed well; the individual simply must engage in the task to receive the reward, e.g., shows up to move furniture. Completion dependent rewards are those given when individuals accomplish a predetermined task. Quality dependent rewards describe rewards dependent upon a predetermined standard. Proponents of cognitive evaluation theory such as Deci et al. (1999) argue that extrinsic rewards lower self determination and competence. Eisenberger and Cameron's (1996) review suggests that cognitive evaluation theory has difficulty with predictions about the effects of quality dependent rewards. These rewards should increase feelings of competence because the individual receives the bonus only if they perform well. Further, cognitive evaluation theory cannot accurately predict whether competence or self determination plays a larger role in the effect of rewards. A second argument presented by Eisenberger and Cameron suggests that Deci's paradigm is flawed. The common paradigm is to introduce a task with reward, and then measure engagement in the task after removing the reward. When individuals engage more in the task after removal of reward, researchers conclude that the reward lowered intrinsic motivation. However, it would be more appropriate to conclude in these situations that the *removal* of the reward affected behavior, not the reward itself. After presenting these arguments that counter cognitive evaluation theory, Eisenberger and Cameron presented the results of a meta-analysis.

When the authors controlled for the type of reinforcement, only expected, performance independent rewards adversely affected intrinsic task interest. Further, the authors suggested that learned helplessness could easily explain the results associated with such performance independent rewards. Unlike cognitive evaluation theory, this explanation faces no ambiguity predicting the effect of quality dependent rewards.

In sum, there appear to be mixed effects of incentives on behavior. In conditions where the task has little intrinsic motivation, incentives may be effective (Benabou & Tirole, 2003). However, in such unappealing situations described by Benabou and Tirole, the effectiveness of an incentive is frequently short lived. Researchers who use extrinsic motivators must also consider that behavioral contingencies such as punishment may be more effective than incentives when individuals know they are monitored. In addition, Eisenberger and Cameron (1996) reported that a quality dependent reward structure, which was the structure used in the proposed study, does not adversely affect behavior. Finally, the work of Lazear (2000) provides ecological validity to the notion that economic incentives can effectively increase desired performance.

Much of this section presented literature that focused on the effects of extrinsic reward on intrinsic task interest. However, the current study used an incentive to shape behavior for a task which is not intrinsically motivating. It is the converse of the target behavior, speeding, that has intrinsic appeal for many. In fact, a premise of the current project is that little intrinsic motivation exists with strict compliance to speed limits. The exception may be for individuals who perceive safety to be sufficiently threatened by speeding or for drivers who perceive the probability of a sanction to be substantially high. In other words, speed limit compliance is likely only intrinsically rewarding to individuals who do not speed. However, the literature (i.e., Freedman et al. 2007; Shinar et al. 1999; Shinar, 2007) suggests that these individuals would be statistical outliers.

Based on the assumptions that the target behavior in the current study is unappealing and that tangible incentives are successful motivators with such behaviors, adverse effects of monetary incentive on speeding were unexpected. Further, based on prospect theory (Kahneman et al. 1982), an incentive framed as a potential loss can affect decision making. The incentive structure was designed such that drivers assigned to the incentive condition began with a full bonus and lost portions of the incentive based on speeding. Thus, these drivers faced a loss, and based on prospect theory this outcome was expected to lead to decisions to minimize the loss. In addition to this relationship between losses and gains, a monetary incentive may close the gap between the perceived benefits associated with speeding versus not speeding.

In addition to emphasizing the potential loss of the cash bonus, the type of reward contingency was expected to affect compliance. According to Eisenberger and Cameron (1996), quality dependent rewards serve to guide behavior in the desired direction. The proposed incentive is such a reward; drivers receive the full award only if they adhere to the speed tolerance. In addition to the reward structure itself, some researchers might frame the subtraction of the bonus for speeding as a punishment. As indicated by Benabou and Tirole (2003), punishment is effective when the individual knows that their behavior is monitored, as will be the case in the proposed study. These same authors suggest that when the activity associated with reward is unappealing, i.e., reducing speed, monetary rewards are effective. In sum, decision making research suggests that the incentive will lead to reduced speeding as does the literature from behavior theory (Eisenberger & Cameron, 1996) and economics (Lazear, 2000).

Feedback Coupled with Monetary Incentive. One treatment group in the current study received exposure to the monetary incentive (MI) and the automated feedback (AF). Anecdotal evidence led to the expectations that these individuals would change their speeding behavior to a greater extent than either MI or AF groups alone. For example, the recent soaring of fuel prices drew attention to the Toyota Prius hybrid, which provides feedback about miles per gallon in real time. The Washington Post (Rosenwald, 2008) featured a story about Prius owners who compete to get the best MPG. These "hypermilers" are using the instantaneous feedback provided by the vehicle's display to help them save gas, the monetary incentive. This anecdotal evidence is supported by Balcazar et al. (1986) who analyzed over 100 studies that assessed the effects of feedback on employee performance. Consistent, robust improvements resulted from the pairing of tangible consequences and feedback. The authors argue that these particular feedback structures achieve success because the feedback becomes a conditioned reinforcer. This theoretical principle was key to the central hypothesis of this study. A summary table of the literature review precedes the proposed hypotheses.

TABLE 1: Literature Review Summary Table

Driving too fast for conditions is listed as causal factor for approximately 12,000 deaths per year[1].	1. NHTSA (2007)
Speeding is widespread [2]; drivers speed for many reasons (pragmatism, emotion, habit) [3]; drivers rate speeding as a relatively low safety risk[4]	2. Blincoe et al. (2006) 3. McKenna (2005) 4. Shinar et al. (1999)
Speed increases the probability[5] and severity of crashes. Impact forces increase exponentially as speed increases.[6]	5. Moore et al. (1995) 6. Shinar (2007)
Speeding places time pressure on information processing.[7] Decision making theorists would suggest that drivers use heuristics when choosing to speed and conclude that probable gains (saved time, increased enjoyment) outweigh probable costs (lost time, ticket, crash).[8]	7. Sternberg (1969) 8. Kahneman et al. (1982)
Reasons for Unintended speeding: human perceptual system adapts to constant velocity[9] or attentional overload or failure[10].	9. Schmidt & Tiffin (1969) 10. Blincoe et al. (2006)
ISA is a relatively new technology that shows promise as a speeding countermeasure. ISA not evaluated in US. ISA links GPS, speed limits, and speed of vehicle. User interface can provide information to driver about speed or limit speeding.[11]	11. Jamson et al. (2006)
Three levels of ISA automation - advisory, interactive, and mandatory.[12] Research has shown each level reduced frequency of speeding.[13, 14] Other benefits of ISA include fuel savings, reduced emissions, and lower workload associated with offloading speed monitoring task from driver to system. [15]	12. Carsten & Tate (2005) 13. Biding & Lind (2002) 14. Duynstee et al. (2001) 15. Biding & Lind (2002)
Potential costs of ISA include behavioral adaptations (decreased following distance, decreased gap acceptance) and increased mental workload associated with temporal demand and frustration.[16, 17]	16. Comte (2000) 17. Varhelyi & Makinen (2001)
One application of advisory ISA is to combine the advisory system with a behavioral contingency that uses extrinsic motivation. Two European studies showed these interventions to be effective. [18, 19]	18. Hultkrantz & Lindberg (2003) 19. Harms et al. (2007)
There is a debate about the effectiveness of extrinsic motivators such as money. Some researchers argue that such reinforcement is ineffective and that it lowers intrinsic motivation.[20] Other researcher indicates that quality dependent rewards effectively change behavior.[21] Linking feedback with extrinsic rewards consistently changes behavior. [22]	20. Deci et al. (1999) 21. Eisneberger & Cameron (1995) 22. Balcazar et al. (1986)

HYPOTHESES

Hypotheses Associated with Speed.

Hypothesis 1a. There was an interaction predicted between monetary incentive (MI) and automated feedback (AF). The combination of MI + AF was predicted to result in significantly lower speeds than the MI-only, AF-only conditions, and the baseline and control conditions (Balcazar et al., 1986; Eisenberger & Cameron, 1996; Harms et al., 2007; Hultkrantz & Linberg, 2003). The MI condition was predicted to result in significantly lower speeds than the control and baseline conditions (Lazear, 2002). Similarly, the AF treatment condition was predicted to result in lower speeds than the control and baseline conditions (Blincoe et al., 2006; Balcazar et al., 1986). The AF and MI treatment conditions occurred during Weeks 2 and 3 of experimental trials. The baseline conditions (no-AF and no-MI) occurred during Weeks 1 and 4. A control group of drivers drove their full trial without MI or AF.

Hypothesis 1b. Percentage of time speeding was predicted to be significantly lower for individuals who were assigned to the MI + AF treatment condition relative to the baseline period, the control group, and the three other MI/AF treatment conditions. The speed variance of the AF-only and MI-only groups was predicted to be significantly lower than the No-MI/No-AF conditions. Predictions follow from the work of Regan et al. (2005) and Varhelyi et al. (2004).

Hypothesis 1c. This hypothesis concerned the correlation between self report beliefs and behaviors about speeding before experiencing the incentive or the advisory and observed speed measures during the experimental trials. Individuals who on the self report measures indicated a proclivity for speeding were predicted to have higher speed measures than participants who had lower scores on these measures (Haglund & Aberg, 2000).

Hypotheses Associated with Subjective Mental Workload

Hypothesis 2a. This hypothesis pertained to testing perceived mental workload as measured by the NASA-TLX (Hart & Staveland, 1988.) Individuals assigned to the AF and MI treatment groups were predicted to have significantly higher ratings of perceived workload relative to control participants. The difference between the experimental and control group will be largely explained by the differences predicted in hypothesis 2b.

Hypothesis 2b. This hypothesis was for the testing of the "frustration" and "temporal demand" dimensions of the NASA-TLX. Based on previous ISA work (e.g., Biding & Lind, 2002; Comte, 2000; and Varhelyi & Makinen, 2002), individuals assigned to the AF-only condition were predicted to rate "frustration" and "temporal demand" significantly higher than individuals in the remaining experimental and control groups. Similarly, individuals in the AF+MI condition were expected to give significantly higher ratings than the MI-only condition and control participants. However, ratings provided by individuals in the AF+MI condition would be significantly lower for these two dimensions than the participants in the AF-only group.

Hypothesis 2c. This hypothesis was for testing the effect of ISA on the mental workload dimensions of effort and mental demand. Because individuals assigned to the MI-only condition were provided quality based extrinsic motivation to reduce speed, they were expected to be more vigilant with regard to their speed monitoring relative to individuals in the control group (Eisenberger & Cameron, 1996). Individuals who received AF were predicted to experience lower mental demand to the extent that these individuals offload the task of monitoring speed (Parasuraman & Riley, 1997). Given the extrinsic motivation to maintain speed and the increased prioritization to the task of speed monitoring, the MI-only group was predicted to have higher ratings of effort and mental demand.

Hypotheses Associated with ISA Acceptance.

Hypothesis 3a. Hypotheses 3a-3c were based on Biding and Lind (2002). Significant correlations were expected between driver acceptance of the AF system and initial attitudes toward automation in general. Individuals who provided favorable attitudes towards automation in general will have higher acceptance of the AF system relative to participants who indicated that they have negative views about automation.

Hypothesis 3b. Ratings of acceptance were expected to be significantly greater for individuals in the MI + AF conditions relative to individuals assigned to the MI-only or AF-only conditions.

Hypothesis 3c. A significant negative correlation was expected between the driver acceptance of ISA and the frustration dimension of the NASA-TLX. Individuals who indicate positive attitudes toward ISA would express less frustration via the TLX.

TABLE 2: Summary Table for Experimental Hypotheses

Measure	Prediction
Average speed	**1a.1.** Combined MI + AF would result in greatest reduction in speed.
	1a.2. MI would result in reduction in speed relative to controls.
	1a.3. AF would result in reduction in speed relative to controls.
Percentage of time speeding	**1b.1.** MI + AF would lead to greatest percentage of time not speeding.
	1b.2. MI would lead to greater reduction in speeding than controls.
	1b.3. AF would lead to greater reduction in speeding than controls.
Self-report & observed speed	**1c.1.** There would be a significant positive correlation between observed and self report speeding.
Mental Workload	**2a.1.** Mental workload will be higher for drivers in the AF, MI, or AF+MI conditions relative to baseline period and control groups.
	2b.1. Temporal demand and frustration would be highest for the AF.
	2b.2. Temporal demand and frustration would be higher for MI+AF than MI.
	2c.1. Mental demand and effort would be higher with MI.
	2c.2. Effort and mental demand would decrease with AF.
Trust and Acceptance	**3a.1.** There would a significant positive relationship between attitudes toward automation in general and acceptance of AF and MI.
	3b.1. Acceptance of MI would be greater in MI+AF than MI-only.
	3b.2. Acceptance of AF would be greater by MI+AF than AF only.
	3c.1. There would be a significant negative relationship between frustration and acceptance.

METHOD

Experimental Design

The basic research design was a split plot design with one between and one within subjects factor. Fifty drivers were randomly assigned to three independent groups and were measured at four one-week periods creating the 3 (Monetary Incentive) X 4 (Automated Feedback (AF) Week) mixed factorial design. Monetary Incentive (MI) was the between subjects variable, with 20 participants scheduled to get MI and 30 (20 who received AF plus 10 control drivers) who drove without receiving MI. The Automated Feedback (AF) system activated for one week, either Week 2 or Week 3. The 20 participants assigned to receive MI and the 20 participants assigned to the no-MI conditions experienced the AF system. The 10 participants in the control group did not receive AF, but they did provide data at the same four periods as the 40 participants who received AF. Weeks 1 and 4 served as baseline and reversal periods for the 40 experimental participants, respectively. Table 2 shows how AF and MI were crossed during the AF period. The AF condition was counterbalanced within each MI group; half of the MI and half of the no-MI group received the advisory during Week 2 and the other half of each group experienced it during Week 3.

TABLE 3: Experimental Design

	Week 1	**Week 2 AF On or Off***	**Week 3 AF On or Off***	**Week 4**
Incentive – yes Between Subjects (n=20)	Baseline	Advisory On or Off Incentive Yes	Advisory On or Off Incentive Yes	Reversal
Incentive – no Between Subjects (n=20)	Baseline	Advisory On or Off Incentive No	Advisory On or Off Incentive No	Reversal
Control (n=10)	Baseline	Baseline	Baseline	Baseline

* Within the MI and no-MI groups, the advisory was counterbalanced between Weeks 2 and 3.

During Week 1, the instrumented vehicles monitored and recorded measures used to derive many of the dependent variables described below. During Week 2 and 3 the individuals in the MI group had the opportunity to earn a cash bonus and received AF during one of these weeks. In contrast, those in the no-MI group did not have the cash incentive but were exposed to AF during either Week 2 or 3. During the Week 4 return to baseline period the AF and MI systems were deactivated, but dependent measure recording continued.

In addition to the primary analyses associated with the 3 X 4 design, there were opportunities to code several variables and conduct correlative analyses of relationships that were of secondary importance. For example, correlations were used to explore relationships between observed speeding, self-reported speeding, and sensation seeking.

Dependent Variables

Dependent Variables Recorded by the Data Monitoring Device. The primary dependent variables were associated with speed. The streets within the geographic study region were grouped by speed limit. For each speed limit category, speed was recorded a minimum of once every six seconds or when monitored vehicle status changed. The criteria that would trigger data points included exceeding the speed limit or crossing speed thresholds associated with the two speed cushions, i.e., more than 4 mph over the limit and more than 9 mph over the limit. From this raw data record, the analysis program computed weekly average speeds, miles driven per week, and the percentages of time spent traveling at or below the speed limit (Speed Bin 0), 1-4 mph (Speed Bin 1), 5-8 mph (Speed Bin 2), and 9 mph or more (Speed Bin 3) over the speed limit for each speed limit zone..

Subjective Dependent Variables. Participants provided subjective data related to several constructs. These data included self-report demographic items, and self-report attitudes about driving over the speed limit and the ability and frequency of doing so without being ticketed. Participants also responded to questions about sensation seeking, self-report attitudes about trust and acceptance of automation in general and with respect to the AF and MI systems,, and self-report ratings of perceived workload. The acceptance and workload data elements were repeatedly collected during each experimental session.

Participants provided the demographic information and information about attitudes toward speeding during Week 1. Trust and acceptance was measured by a self-report, eight-item scale. The scale was adapted from a previously validated instrument (Bustamante, Fallon, Bliss, Bailey, & Anderson, 2005; Fallon, Bustamante, Ely, & Bliss, 2005). Participants completed iterations of this scale at the end of each week they experienced MI or AF. The ratings, which were on a scale from 1 to 10, indicated the extent to which participants felt that the MI or AF systems were reliable, predictable, trustworthy, acceptable, pleasing, annoying, accurate, and agreeable. Fallon et al. reported that the scale has high internal consistency reliability (Cronbach alpha = .93), and the scale was sensitive to conditions known to affect trust in automation, e.g., task load and reliability. Participants also provided ratings of perceived mental workload; at the end of each week of the study, participants completed the NASA-Task Load Index (TLX), created by Hart and Staveland (1988). At the end of the study, participants also provided ratings about perceived safety benefits of and willingness to keep the system. To view the self-report questions, please see Appendix B.

Participants

The participants were a convenience sample of 50 drivers (26 males and 24 females) who live and work within the Kalamazoo, Michigan metro area. Drivers ranged in age from 23 to 39. Table 3 presents the number of males and females and average age for the incentive, no-incentive, and control groups. Participants had to possess a valid driver license and must have had a minimum of five years of driving experience. Drivers convicted of impaired or reckless driving or who had their license suspended were prevented from participating. For liability reasons, a third party verified potential participants' driver abstracts (Michigan's Department of Motor Vehicles records of driver history of licensure, violations, and crashes) and ensured they met these driving record requirements. To obtain participants who would provide adequate driving exposure, the initial recruitment effort also required that participants reported driving a minimum of 20 miles per day 5 times per week.

TABLE 4: Number of Males and Females and Average Age by Experimental Group

Group	Males	Females	Average Age (SD)
Control	5	5	27.7 (4.22)
Incentive	10	10	27.8 (3.43)
No-Incentive	11	9	28.0 (4.90)

Given the several eligibility requirements, the research team used a multi-stage recruitment process for the project. Potential participants learned of the experiment by class visits from the research assistant, e-mail from the Graduate Student Advisory Committee (GSAC) or from recruitment posters that were posted around the campus of Western Michigan University. The posters and presentations presented the participation criteria, including the need to provide driving records. Potential participants signed an initial informed consent document and provided self report information regarding driving exposure and their driver license numbers for the Driver Record Abstract check (Appendix C). If participants passed the abstract check and indicated that they met the exposure requirements, they were contacted to gauge interest in beginning the actual experiment. Individuals who expressed interest in continuing signed a second informed consent document (Appendix C). This multiple informed consent procedure ensured that potential participants clearly understood the study. Participants were asked to sign a non-disclosure statement at the end of week 1 and reiterated their non-disclosure contract at the end of week 4 to prevent participants from speaking to potential future participants and subsequently affecting their behavior.

All drivers received compensation for their participation in the field study. The test vehicles received a full tank of gas upon Day 1 of the experimental session, and participants received $60 for completing the full 4 week trial, and $10 for each phone appointment (to complete the NASA-TLX and Trust and Acceptance scales) met during the session. Payments were made upon completion of the study. Participation was voluntary, and the participants were assured that their performance was confidential. Institutional review boards of Western Michigan University, Old Dominion University, and Westat, Inc. approved the project.

Materials

Vehicles. Project staff instrumented eight vehicles for use during the field study. NHTSA provided a 2002 Oldsmobile Intrigue, a 2001 Saturn L 200, a 1998 Chevrolet Malibu, a 2000 Ford Taurus, a 2005 Cadillac STS, a 1999 Toyota Camry, a 2003 Toyota Corolla, and a 2004 Toyota Sienna. The vehicles were four-door sedans, except for the Sienna, which was a mini-van. The Corolla had a manual transmission, and the remaining vehicles had automatic transmissions. The Saturn, Camry, and Corolla were four-cylinder vehicles; the Intrigue, Malibu, Taurus and Sienna had six cylinders; the

Cadillac had an eight-cylinder engine. During the third cohort, the Saturn was totaled when two vehicles, unassociated with the experiment, collided. The collision propelled one of the vehicles into the Saturn. The participant assigned to the Saturn, who just began his final week in the study, was not injured and wanted to finish the experiment. Thus, he finished his fourth week of data collection when the Malibu became available. Other than this driver, participants kept the vehicle to which they were assigned at the onset of their trial. Several participants traveled out of the area for holidays, conferences, and family emergencies; these individuals resumed their respective weeks of driving upon their return. Vehicle assignment was partially counterbalance between the control, MI, and no-MI groups to control for the confound of vehicle type. The instrumentation in the Toyota Corolla began malfunctioning after four participants completed the study with the vehicle. The project budget prevented troubleshooting and replacing components, so the vehicle was removed from the vehicle fleet.

Speed Map. To create the map a research assistant first obtained blueprints of the street networks for the Kalamazoo and Portage areas from the municipal governments and a separate data base that contained the speed limits of the streets in the road network. The assistant then color coded the streets on the blueprint by speed limit. Finally, three research assistants traveled roads on which speed limits changed. The team then noted the distance between a transition point and the nearest intersection, and then transposed this information to the color-coded map so that the transition point in the database was accurate within 50 feet of the speed limit sign. The areas outside of the speed mapped zone were coded to have a speed limit of "0." This designation let the project's software engineer deactivate the advisory and incentive displays when the vehicles were outside the mapped zone. The research assistant then provided the color coded municipal map to Persentech, Inc., the company that integrated the speed limit information into an existing Automate™ GPS device. Appendix A contains a map of Michigan and a more detailed map of the speed mapped area. Figure 1 is an image of the GPS device. As shown in the figure, the devices were mounted in the rear window of the vehicles, except for the Toyota Sienna, where the installers placed the device on the front windshield above the display box. The angle of the Sienna's rear windshield degraded the GPS signal and prevented the mounting of the device in the rear. The project's software engineer then designed the microprocessor to receive GPS and speed limit information from the GPS device and vehicle speed information from the anti-lock brake sensors or vehicle speed sensors. Based on this input the microprocessor recorded driving data and activated the incentive and feedback systems.

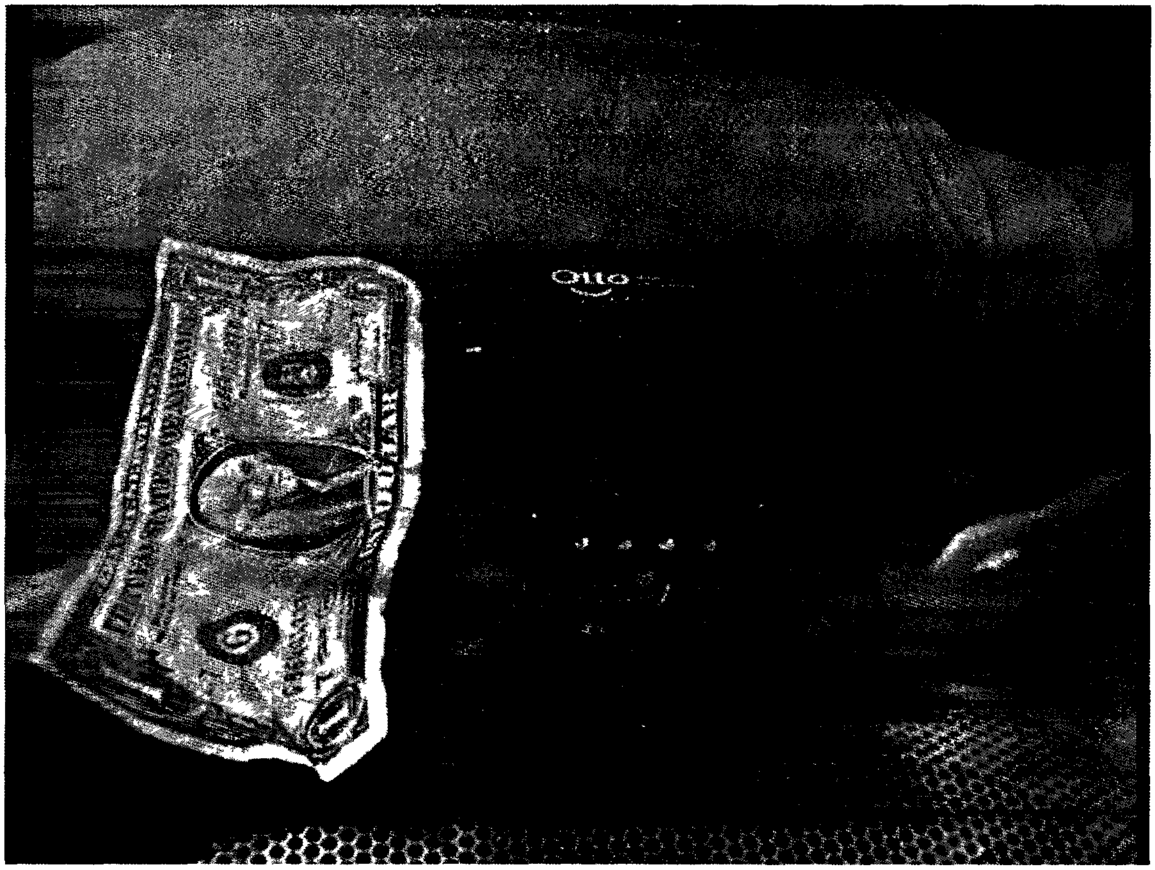

Figure 1. GPS system used for project (dollar bill included for size scale).

Monetary Incentive (MI) System. As discussed in the Introduction section, the MI condition was structured as a bonus system with a delayed incentive and an immediate disincentive. Individuals who were in the MI condition began Weeks 2 and 3 with $25.00. In a manner similar to Harms et al. (2007), the bonus declined by 3 cents every 6-second period that the driver was 5-8 mph over the limit. The penalty increased to 6 cents if the driver was 9 mph or more over the limit during any segment of the six second period when they were at least 5 mph over the limit. In other words, if the driver drove 5-8 mph over the limit but slowed to 4 mph over the limit or slower before 6 seconds elapsed then they would not lose any of the incentive. A visual display, analogous to a meter in a taxi cab, provided updated bonus amounts. This display activated for five seconds after the driver turned the ignition on or off. The visual display box consisted of five, red seven-segment LEDs that were approximately .4" H x .2" W.

Advisory Display. The display box that presented the updates about the incentive also displayed the visual speed alert and housed the speaker that annunciated the auditory component of the speed feedback. The automated feedback (AF) provided two tones and one visual signal to drivers assigned to the conditions associated with AF. Each auditory signal consisted of a 400 Hz pure tone. Based on recommendations provided by Sorkin (1987) and Jones and Broadbent (1987), the strength of the auditory signal should be between 6 and 15 dB above the masked threshold, defined as the point at which a target auditory stimulus can be heard 50% of the time in the presence of other ambient noise (e.g., engine noise or stereo system.) The designer amplified the tone to approximately 70dB. The research assistant ensured that the alert was audible from the driver's seat in the presence of the ambient noise of popular music playing at a level deemed to be "loud." This testing indicated that the initial design was not loud enough in the presence of loud music. Drilling holes in the display boxes amplified the alert sufficiently so that the signal was audible in the presence of significant ambient noise.

The temporal pattern of the auditory alert varied as a function of the magnitude of speed violation, i.e., one alert for violations from 5 to 8 mph (Alert A) over the limit and one alert for 9 mph or more (Alert B) over the speed limit. Each alert lasted for three seconds. Alert A consisted of 4 bursts with 2 pulses per burst (beep-beep----beep-beep----beep-beep----beep-beep); Alert B consisted of 4 bursts with 3 pulses per burst (beep-beep-beep---beep-beep-beep---beep-beep-beep---beep-beep-beep). The design of these alerts stemmed from the intent to increase urgency and minimize annoyance. (Edworthy et al., 1991; Marshall et al., 2007; Spain & Bliss, 2008). Biding and Lind (2002) reported that drivers who experienced the auditory feedback suggested a pulse rate that cued them to more excessive speed violations would be preferable to a binary alert. A final effort to reduce annoyance was the termination of the auditory alert after three consecutive presentations without a change in speed, with the exception of 70 mph roads. Specifically, if drivers drove at 79 mph or faster, then Alert B would continue to sound. The project team decided upon this configuration because 70 mph roads provided the only situations in which drivers could drive for minutes at a time without stopping. Experimenters wanted to avoid having drivers maintain speeds above 79 mph, ignore the three warnings and then continuing to speed above 79 mph to avoid hearing the alert trigger again. Figure 2 depicts several potential speed scenarios and how the auditory alert system would react to each scenario; Figure 3 is an image of the display box for the AF and MI, in this instance the LEDs display the bonus amount.

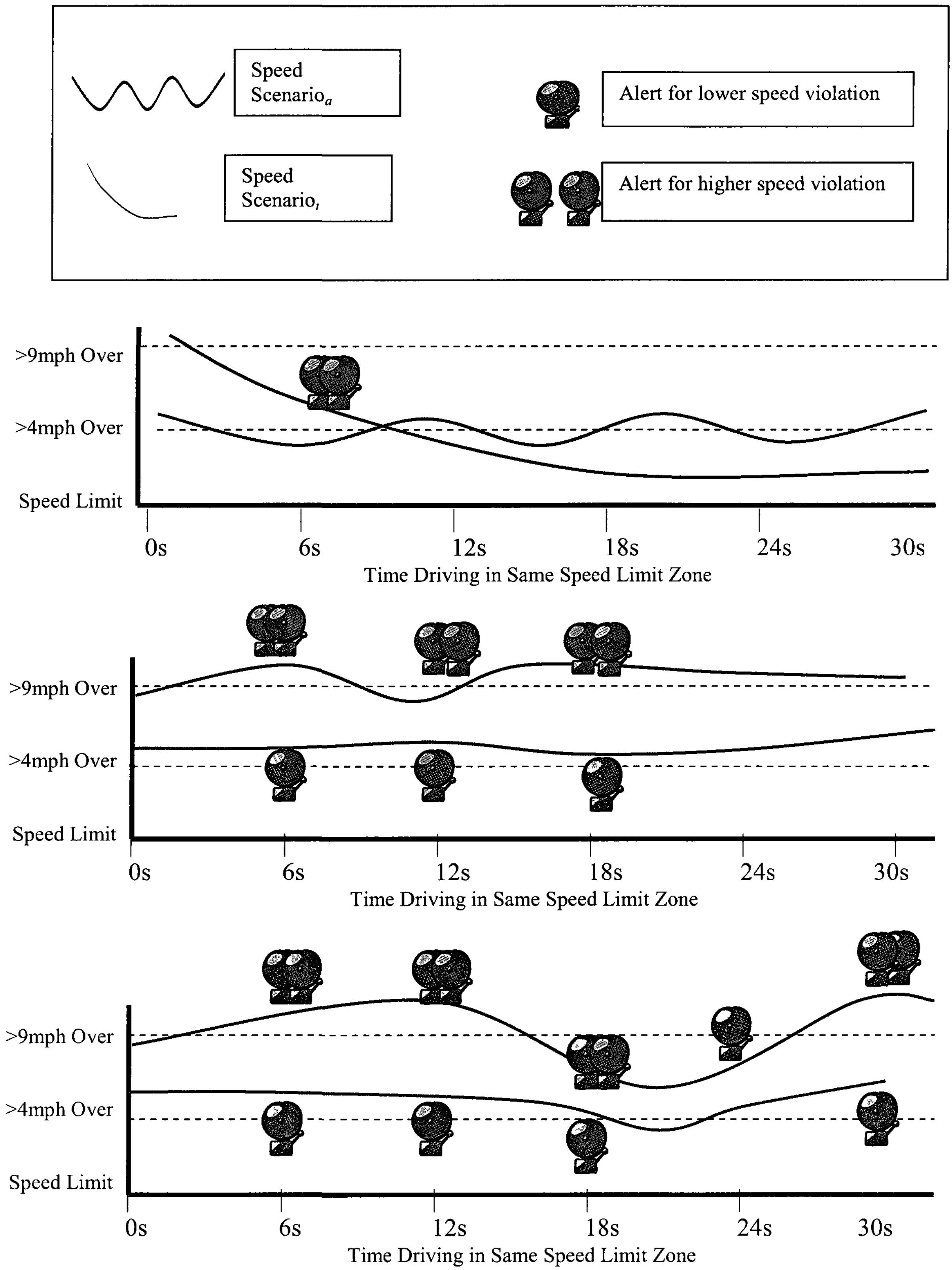

Figure 2. Potential speed scenarios.

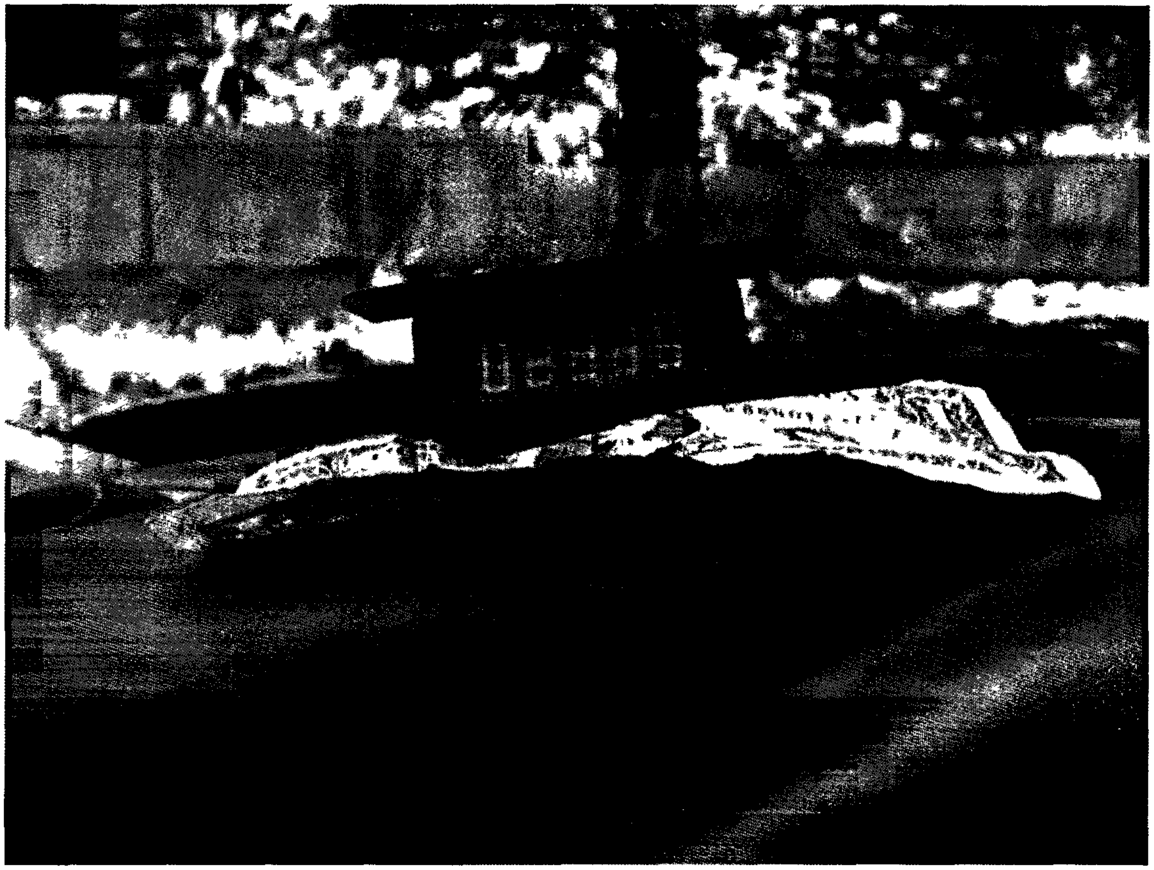

Figure 3. AF and MI display showing a bonus amount ($23.35).

In contrast to the auditory signal, the visual alert continued to display at six second intervals as long as the driver was over either speed violation threshold. The alert was displayed on the same interface as the monetary incentive. The display flashed the speed limit that the driver violated at the same time that the auditory alert sounded. In sum, the auditory and visual advisory, although a separate system than the monetary incentive system, was designed to be conceptually similar to the incentive system, so that participants who received both MI and AF would feel that the two systems were related.

Data Recording System. The engineering team designed the data logger, specified the information recorded by the data logger, and created an interface between the data logger and the experimenter. The data logger was programmed using Microchip Pic Assembler and received inputs from the experimental vehicles and the GPS system. Based on participant assignment, the logger provided output to the MI and AF displays. The data logger sampled at a 2 Hz rate for status changes in 62 monitored data elements, including speed limit and speed of vehicle. If there were no changes in the data elements, as when the speed limit was not changing and the driver was driving below the limit, then the data logger recorded all data elements once every six seconds. However, the data logger recorded all data elements if there were a change in system status. The device initially stored information on the EEPROM (data logger memory chip). For example, the data logger recorded vehicle speed, speed limit, time stamp, activation of Alert A or B, and vehicle speed being over or under speed threshold 1 (>4 mph over) or 2 (>9 mph over).

Input from the GPS system to the data logger and output to the MI and AF display were transmitted through custom made serial cables. Vehicle inputs fed into a custom wire harness connected to the data logger. The wiring harness design varied as a function of the input for vehicle speed, with four vehicles obtaining vehicle speed from their vehicle speed sensors, three vehicles from their anti-lock brake sensors, and one vehicle from the GPS system. Data was stored on the EEPROM and output through a cellular modem, which was connected to the data logger by an RS232 interface.

The project engineer used Visual Basic (VB) to design an interface for access to the data logger via a PC that connected to cellular modem (see Appendix A). The VB interface allowed the research assistant to activate the experimental conditions at the beginning of each week, to monitor the AF and MI system during pilot testing and throughout the study, to download the raw data, and to reduce the raw data to a summary file used for analysis. Each download of raw data resulted in access to an Excel file. Similarly, the data reduction program produced a summary data file from which data could be transferred to SPSS for statistical analysis. Figure 2 contains an image of the data logger box with input and output as well as the wireless modem.

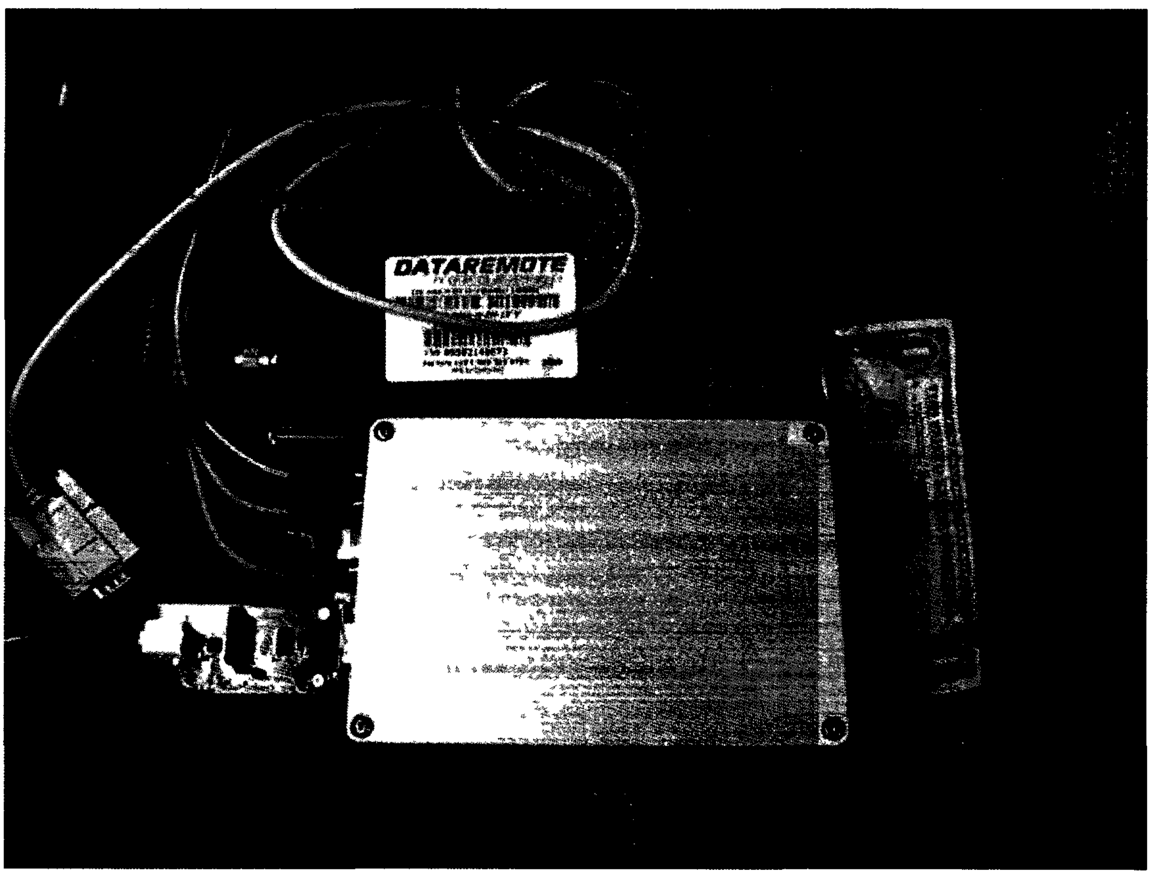

Figure 4. Data logger and cellular modem.

Procedure

System Development. The NHTSA project team began developing the speed map and the data logger in September of 2008. Bench testing of the data logger components began in January of 2009. Road tests for functional reliability of the system began in March of 2009 and ended in July of 2009. During this period several improvements and corrections were made to the ISA system. For example, some of the roads within the mapped area were coded incorrectly by the GPS system, which resulted in faulty input to the data logger. The faulty input, in turn, created false advisory alerts or faulty reductions to the MI. However, at the end of the functional reliability testing period, each system in each vehicle was working in a highly reliable manner. This reliability was verified by completing many road tests during which a member of the research team drove a vehicle while another member used the VB application to access the data logger. The interface allowed the researchers to view, in real time, the crucial data elements such as vehicle speed and speed limit, experimental condition, and incentive amount. For these test drives, the project member would select Alerts A and B to activate at low speed limit violations (e.g., >1 and >3 mph, respectively). This procedure permitted testing of the AF for valid, reliable functioning without egregious speed limit violations. During this testing, research team members noted slight discrepancies between the speedometer needle and the speed input to the data logger (+/- 1-2mph). This occurrence was also noted in previous research (see Biding & Lind, 2002). The current research team addressed this issue by calibrating the data logger settings for each vehicle to reflect the reading on the speedometer. This decision allowed the experimenter to provide consistent instructions to participants in the MI and AF conditions. After the first ISA system was tested and determined to be functioning reliably, the project engineer began building the systems for the remaining vehicles.

When these systems were installed, the remaining vehicles were tested for functional reliability using the same procedure just described.

Pilot Testing Behavioral Effects. While waiting for system installation in the remaining vehicles, the researchers assigned the initial instrumented vehicle to naïve drivers to pilot test the system for behavioral effects. This pilot testing occurred during July and August of 2009. Three drivers participated in the pilot test. The drivers operated the vehicle for approximately two weeks each. The first week provided baseline measures of driving. In the second week, the drivers drove with the AF activated and had the opportunity to earn the MI as planned in the experiment. The drivers received the instructions for the second week after driving the baseline period. The raw data generated during this pilot test was used to validate the summary data produced by the data reduction program (e.g., miles driven per day by speed limit zone, percentage of time spent speeding 1-4 mph over the limit by speed limit zone). The correlations between manual computations of measures in the raw data and those produced by the summary data were nearly perfect (r's > .99). The combined effect of the AF and MI therefore appeared promising.

Field Study – Initial Recruitment and Week 1. Potential participants contacted the experimenters to begin the initial screening process. After receiving prospective participants' informed consent, the research assistant collected self-report driving exposure data and driver license numbers. The experimenter explained that the study period ranged from one to four weeks and after establishing eligibility, he would contact these individuals to schedule delivery of the test vehicles. When participants received the vehicle at the beginning of Week 1, the experimenter explained the nature of the study in further detail without alluding to the exact nature of the project. The experimenter informed drivers that the study was testing an emerging system that could benefit traffic safety and that the vehicles had systems that recorded distance traveled, speed, seatbelt use, GPS, and time of day.

After this explanation of the study, participants provided the second informed consent and answered self report questions mentioned previously (Appendix B). The experimenter provided participants an overview of the vehicle to which they were assigned and explained the various features, e.g., location of the wipers, gas tank, headlamps, and other controls and displays. The experimenter instructed participants that during the month-long trial they should drive as they would during normal, everyday driving. Participants signed an agreement not to allow anyone else to drive the vehicle or to drive the vehicle more than 50 miles from Kalamazoo (see Appendix C). The first week began after the participant had an opportunity to ask the experimenter questions about the study. In summary, participants were aware that a number of safety related driving behaviors were recorded but were not specifically told that the target behavior in the study was speeding.

Weeks 2 and 3. After Week 1, participants who met the exposure criteria (distance and speed limit violations) continued to Week 2. The distance criterion was to drive approximately 100 miles during Week 1. The speeding criterion was based on the $25.00 bonus that participants in the incentive condition could receive. Specifically, the data logger was programmed to record the bonus amount regardless of a participant's assigned condition. The team decided that participants had to drive in such a manner that they would have lost approximately 35% of the bonus amount ($8.00) during the baseline week had they been in the incentive condition. The criteria allowed the researchers to validate self-report measures with Week 1 baseline data. The experimenter retrieved vehicles from participants who did not meet the criteria and issued them $20 compensation.

The experimenter met with participants who satisfied Week 1 criteria to provide further instructions and to have participants answer questions about sensation seeking and automation use and complete the NASA-TLX for Week 1. To complete the TLX, the researcher asked participants to consider mental workload demand associated with the overall driving task (steering, navigating, maintaining speed, avoiding hazards) when providing rankings. The research assistant also made appointments with participants to complete, by telephone, the NASA-TLX and Trust and Acceptance scales at the end of Weeks 2 and 3. After completing the Week 1 TLX and the sensation seeking and automation use self-report instruments, the research assistant continued with instructions about the following weeks of the study.

The remaining instructions included explanations of the AF and MI systems, depending on group assignment. Individuals in the MI condition had the opportunity to earn the full bonus, or $25 per week during Weeks 2 and 3. The incentive system was explained to these participants as described above. The researcher explained the 6-second time cushion that was built into the system, so participants knew that they would not lose bonus points the moment that they exceeded the 5 mph or 9 mph thresholds. The researcher told the MI participants that the display would show the bonus amount at the beginning and end of each drive.

The 40 participants in the MI and no-MI groups drove for one week, either Week 2 or 3, with the automated feedback system in active mode. The researcher used stratified random assignment for this condition to ensure that 10 participants in each MI condition experienced active AF during Week 2, and the remaining 10 per group drove with AF active during Week 3. The researcher activated the system and provided instructions at the beginning of the appropriate week. Specifically, the researcher told participants what would trigger the auditory and visual alerts and that there were two separate alerts, with one alerting them to driving 5-8 mph over the limit and one alerting them to driving 9 mph over the limit. The researcher also explained the time threshold for triggering the alerts, so participants knew that the alerts would not activate until they were driving over threshold A or B for six seconds. For the 20 MI participants in Weeks 2 and 3 and all participants during the AF condition, the researcher explained the area in which speed limits were mapped and where the system would become inactive. The researcher took this measure so participants did not think that either system was faulty.

At the end of Weeks 2 and 3, the participants in the MI condition provided trust and acceptance ratings on the MI system. The 40 participants completed the same trust and acceptance scale after completing the AF condition. The full sample of 50 participants completed the NASA-TLX at the end of Weeks 2 and 3. Participants rated their perceived mental workload associated with general driving rather than rating workload specific to speed maintenance. The decision to frame the NASA-TLX in this manner was to keep the control participants naïve to the purpose of the study so as not to affect their driving speed.

Week 4. During the final measurement period, Week 4, participants drove their assigned vehicles configured in the same manner as Week 1. The AF and MI systems were deactivated, but the data loggers in the vehicles recorded the same measures as in the first three weeks of the trials. At the end of Week 4, participants provided subjective workload ratings via the NASA-TLX and then completed a debriefing during which the researcher asked questions to gather qualitative data about participants' experience with the incentive and feedback systems. The researcher ended the month-long trials by informing participants that they would receive a full debriefing about the purpose and outcome of the study after the experiment was complete, reiterating their non-disclosure form agreeing not to discuss the study with others, and then paying the participants the money owed them for completing the experiment.

RESULTS

Data Inspection and Cleaning

For the first cohort of participants, the experimenter inspected the summary files for data accuracy by randomly selecting summary data elements (e.g., average speed in 25 mph zones for day 1) and computing the same elements by hand from the raw data. Another data inspection method was to inspect instances that seemed implausible; for example, a participant having spent driving four hours in 30 mph zones on a single day. This data inspection process led to the discovery of some anomalous occurrences. A list of these occurrences and the resulting action of the project team are provided in Appendix D. Some data elements in the summary files had to be re-ordered prior to import into SPSS, and some of the 'watchdog' data elements, not needed for analyses, were not imported. Additionally, the experimenter had to compute the miles driven per week for each speed limit zone, as these data were not in the summary files. This was computed from the number of seconds spent in each zone per week and average speed per week in each zone. The measures of average weekly speeds by zone and percentages of time in driving at or below the speed limit, 1 to 4 mph over the speed limit, 5 to 8 mph over the speed limit, and 9 or more mph over the speed limit were weighted by the time spent each day in each zone. This resulted in the adjustment of the measures for drivers who varied in how much they drove from day to day. For example, if a driver drove on a 55 mph road for 100 seconds on day 1 and 200 seconds on day 2, then the measures for that week of driving would reflect that the driver spent twice as much time in the zone on day 2 relative to day 1. After data inspection and cleaning, the data were imported into SPSS for descriptive and inferential statistical analysis.

Descriptive Analyses

Tables 5 and 6 provide descriptive statistics for the self report demographic and attitudinal data elements recorded during the onset of participant trials. The demographic data include age, years licensed, and education level. Additional self report data included beliefs and behaviors about sensation seeking, driving style, and general use and acceptance of automation.

TABLE 5: Descriptive Statistics for Demographic Variables by Experimental Group

Variable	N	Mean	Standard Deviation
Years with License			
Control	10	10.40	3.37
Incentive	20	10.90	4.08
No-Incentive	20	11.15	3.79
Self-report miles per week			
Control	10	128.50	81.04
Incentive	20	122.25	70.48
No-Incentive	20	163.25	128.40
Education Level (1 = HS/GED; 5 = some graduate; 8=post masters)			
Control	10	5.40	1.17
Incentive	20	5.55	1.32
No-Incentive	20	5.25	1.29

TABLE 6: Self-report Items about Sensation Seeking, Automation and Driving Behaviors

Variable	N	Mean	Standard Deviation
I would like to explore strange places (1 = not like me, 5 = very much like me)			
Control	10	3 90	1 37
Incentive	20	3 80	1 11
No-Incentive	20	3 70	1 17
I like to do frightening things (1 = not like me, 5 = very much like me)			
Control	10	2 40	1 07
Incentive	20	2 55	1 32
No-Incentive	20	2 90	1 48
I like new & exciting experiences even if I have to break the rules (1 = not like me, 5 = very much like me)			
Control	10	2 30	1 16
Incentive	20	2 60	1 05
No-Incentive	20	2 70	1 30
I prefer friends who are exciting and unpredictable (1 = not like me, 5 = very much like me)			
Control	10	2 70	1 25
Incentive	20	2 80	95
No-Incentive	20	3 10	1 07
In general, I like completing tasks manually (1 = not like me, 5 = very much like me)			
Control	10	3 70	1 16
Incentive	20	3 50	83
No-Incentive	20	3 95	83
In general, I am suspicious of new technologies (0 = not at all, 5 = very much like me)			
Control	10	2 70	1 06
Incentive	20	1 70	92
No-Incentive	20	1 90	1 12
Car Passing (1 = cars pass me more often than I pass them, 2 = I pass as many cars as pass me, 3= I pass cars more often that they pass me)			
Control	10	2 40	52
Incentive	20	2 15	59
No Incentive	20	2 05	39
On a 55 mph or greater road, how many miles over the limit can you drive before the police gives you a ticket?			
Control	10	7 30	2 41
Incentive	20	7 20	2 78
No-Incentive	20	6 35	2 41

TABLE 6 Continued

Variable	N	Mean	Standard Deviation
On a 40 mph or greater road, how many miles over the limit can you drive before the police gives you a ticket?			
Control	10	4.90	1.20
Incentive	20	5.75	3.78
No-Incentive	20	5.50	2.93
On a 35 mph or slower road, how many miles over the limit can you drive before the police gives you a ticket?			
Control	10	4.80	2.25
Incentive	20	4.25	3.16
No-Incentive	20	4.35	2.18
How often do you wear your seatbelt? (1 = never, 5 = always)			
Control	10	4.80	.42
Incentive	20	4.80	.52
No-Incentive	20	4.75	.64
How often do you talk on cell when driving? (1 = all trips, 5 = never)			
Control	10	3.50	1.08
Incentive	20	3.55	1.10
No-Incentive	20	3.45	.94

Random assignment to the control, No-MI, and MI conditions controlled for any potential effect that individual differences among these variables might have on the dependent variables that were the central focus of the study. The dependent variables (4 speed ranges X 9 speed limit zones X 4 weeks; 7 mean speeds by zone X 4 weeks; and 6 NASA-TLX dimensions X 4 weeks) were inspected for outliers using the following approach recommended by Tabachnik and Fidell (2001): z-scores were generated for each DV; outliers were defined as having an absolute z-score greater than 3.3; outlying observed scores were changed to one unit greater than the next largest score. This process resulted with the identification and changing of 44 observed values.

Percentage of Time Speeding by and across Speed Limit Zone

Statistical Approach. A series of 3 (Monetary Incentive – between subjects) x 4 (AF activation week – repeated measures) mixed factorial ANOVAs tested for the effects of Monetary Incentive (MI) and Automated Feedback (AF). There were eight series of analyses, with four ANOVAs in each series for a total of 32 ANOVAs. The 8 series represent separate analyses for seven speed limit zones, i.e., 25 mph, 30 mph, 35 mph, 40mph, 45 mph, 55 mph, and 70 mph; as well as one series to analyze the percentage of time speeding across all speed limit zones. The 4 ANOVAs in each series were to analyze the percentage of time driving in the following speed ranges: Bin 0 (percentage of time driving ≤ the speed limit), Bin 1 (percentage of time driving 1 to 4 mph over the limit), Bin 2 (percentage of time driving 5 to 8 mph over the limit), and Bin 3 (percentage of time driving 9 or more over the speed limit). AF activation period was counterbalanced during Weeks 2 and 3 for the No-MI and MI groups. For ease of interpretation, the following analyses present the AF activation period as having occurred during Week 2. In addition to screening and adjusting outlying scores, the approach to satisfying the statistical assumptions of ANOVA was based on recommendations by Tabachnik and Fidell (2002) to ensure appropriate use of the mixed ANOVAs. Normality was assumed when error degrees of freedom is greater than 20. Thus, the only analyses in which normality was violated were those for 55 mph roads (discussed in detail below). For each ANOVA, Levene's tests were computed to check for homogeneity of variance.

Tabachnik & Fidell state that an accepted approach to addressing instances of heterogeneity of variance is to reduce the alpha criterion to a more stringent level, such as $p <. 025$. In the current project the alpha criterion was set at $p < .01$ for all inferential analyses. This reduced criterion was to satisfy instances when the Levene's test indicated heterogeneity of variance and to establish a more conservative threshold due to the large number of analyses. If the assumption of sphericity was violated, then the Greenhouse-Geisser statistic was reported. The use of Greenhouse-Geisser will be evident if the within group degrees of freedom have decimal points. Trend analyses were used as follow-up tests for significant effects. For analyses with significant interactions and main effects, only interactions are interpreted (Tabachnik & Fidell, 2001).

Percentage of time driving at or below the Speed Limit. Statistical assumptions were examined prior to interpreting each 3 X 4 ANOVA. The ANOVA indicated a significant main effect for AF Week, $F(3, 141) = 7.85$, $p < .001$, partial $\eta^2 = .14$. The main effect for Incentive Group was not significant, $F(2,47) = 4.91$, $p < .05$, partial $\eta^2 = .17$. The interaction between AF Period and Incentive Group was also significant, $F(6, 141) = 8.45$, $p < .001$, partial $\eta^2 = .27$, observed power = 1.00. Trend analyses indicated a significant quadratic trend for the interaction, $F(2,47) = 16.71$, $p < .001$, partial $\eta^2 =.42$, observed power = 1.00. Drivers in the MI group significantly increased the percentage of time spent driving at or below all speed limits during Weeks 2 (M = 83.05%) and 3 (M = 81.85%) relative to Weeks 1 (M = 68.90%) and 4 (M = 70.95%) and to the control group and no-MI group at each week of driving. In contrast, the amount of time spent driving at or below the speed limit did not vary reliably within or between the control and no-MI groups across the four measurement periods (see Figure 5).

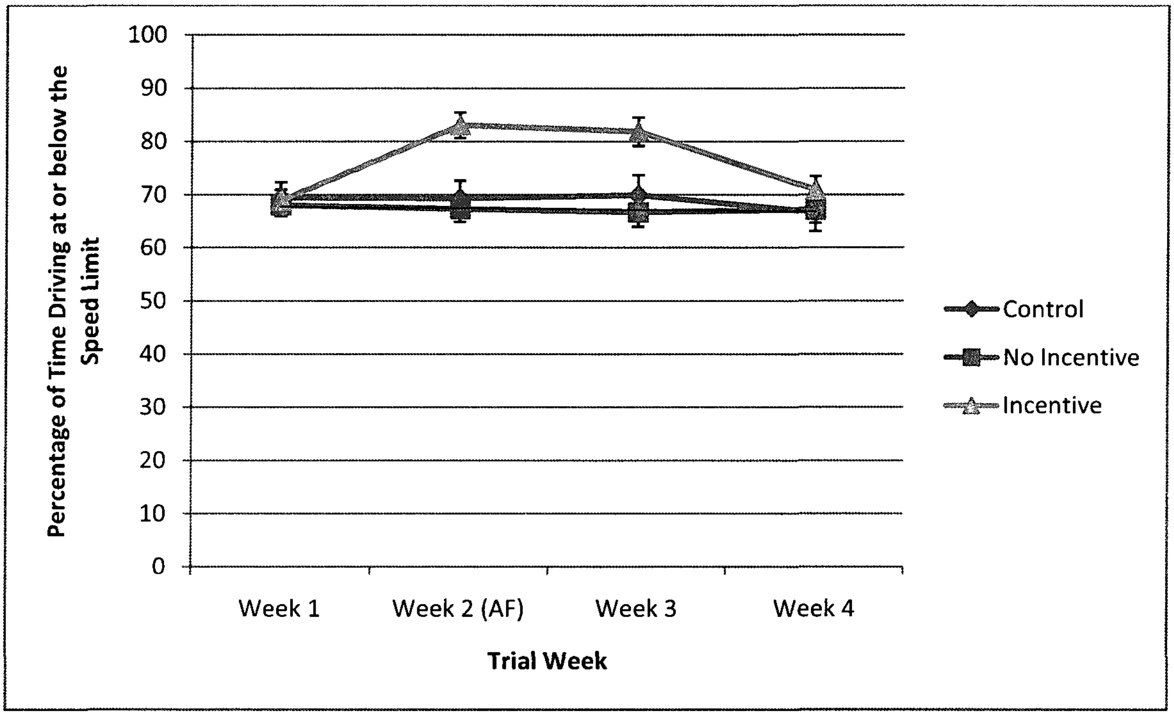

Figure 5. Percentage of time driving at or below the speed limit as a function of monetary incentive and advisory feedback. Error bars indicate the standard errors of the means.

Percentage of time driving 1 to 4 mph over the limit. The 3 X 4 ANOVA revealed no significant main effects for AF Period, $F(1.70, 73.02) = 1.05$, *n.s.* and Experimental Group, $F(2,43) = 1.23$, *n.s.* The omnibus F-test of the interaction between AF Period and Experimental Group was not significant, $F(3.40, 73.02) = .51$, *n.s.*

Percentage of time driving 5 to 8 mph Over the Speed Limit. The F-tests revealed a significant main effect for AF Week, $F(3, 141) = 13.78$, $p < .001$, partial $\eta^2 = .23$ and Incentive Group, $F(2,47) = 11.83$, $p < .001$, partial $\eta^2 = .34$, respectively. The interaction between AF Period and Incentive Group was also significant, $F(6, 141) = 13.15$, $p < .001$, partial $\eta^2 = .36$. Trend analyses indicated a significant quadratic trend for the interaction, $F(2,47) = 35.64$, $p < .001$, partial $\eta^2 = .60$. During Week 2 (Feedback On), drivers in the MI group spent a lower percentage of time driving in Bin 2 (M = 2.05%) relative to Week 1 (M = 9.75%), Week 3 (M = 3.65%), and Week 4 (M = 8.55%). The MI group's score for Week 3 was significantly lower than Weeks 1 and 4. The MI group's percentage scores for Weeks 2 and 3 were significantly lower than the control and no-MI groups' scores across each of the four measurement periods. Finally, the time spent driving 5 to 8 mph over the speed limits did not vary reliably within or between the control and no-MI groups across the four measurement periods (see Figure 6).

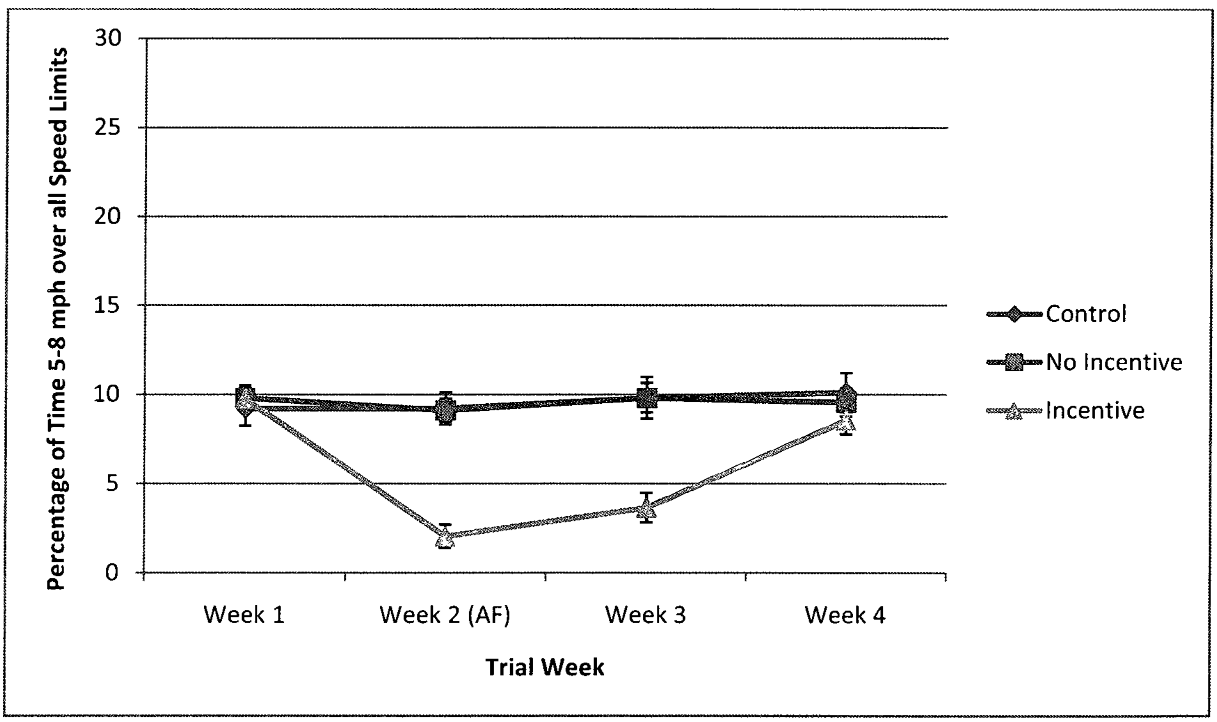

Figure 6. Percentage of time driving 5 to 8 mph over all speed limits as a function of monetary incentive and advisory feedback.

Percentage of time driving 9 or more mph over all speed limits. The ANOVA revealed significant main effects for AF Week, $F(3, 141) = 11.21$, $p < .001$, partial $\eta^2 = .19$ and Incentive Group, $F(2,47) = 5.88$, $p < .01$, partial $\eta^2 = .20$, respectively. The interaction between AF Period and Incentive Group was also significant, $F(6, 141) = 5.03$, $p < .001$, partial $\eta^2 = .18$. Trend analyses indicated a significant quadratic trend for the interaction, $F(2,47) = 7.17$, $p < .01$, partial $\eta^2 = .23$. Drivers in the MI group spent significantly less time driving 9 mph or more over the limit during Week 2 (M = .35%) and Week 3 (M = .60%) relative to Week 1 (6.45%) and Week 4 (4.75%). The MI group's scores for Weeks 2 and 3 were significantly lower than the control and no-MI groups' scores across each of the four measurement periods. The no-MI group spent a lower percentage of time driving 9 or more mph over the speed limit during Week 2 when the AF was active ($M = 5.05$) relative to Week 1 ($M = 7.15$), Week 3 ($M = 8.60$), and Week 4 ($M = 8.95$). The no-MI group spent more time driving 9 or more mph over the limit during Week 3 than the control ($M = 5.80$), but did not differ from the control group at other measurement periods. The control group's scores for Bin 3 did not vary across the four weeks of driving (see Figure 7).

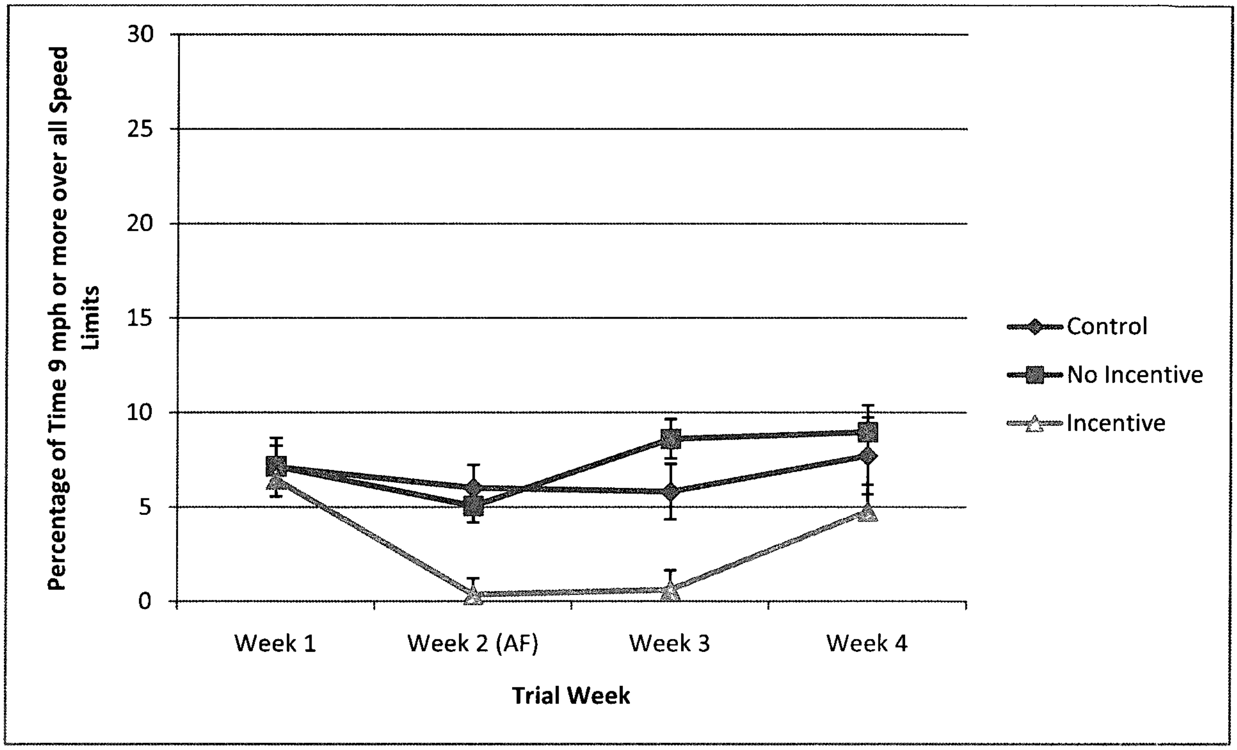

Figure 7. Percent of time driving 9 or more mph over all speed limits as a function of monetary incentive and advisory feedback.

Percentage of time driving at or below 25 mph speed limits. The main effects for Week and Incentive Group were not significant, $F(2.48, 116.72) = 3.47$, *n.s.* and $F(2, 47) = 4.54$, *n.s.* The interaction between Week and Incentive was significant, $F(4.97, 116.72) = 7.86$, $p < .001$, partial $\eta^2 = .25$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 47) = 14.50$, $p < .001$, partial $\eta^2 = .38$. Drivers in the MI group significantly increased the percentage of time driving at or below 25 mph speed limits during Week 2 ($M = 87.65\%$) and Week 3 ($M = 87.25\%$) relative to Week 1($M = 78\%$) and Week 4 ($M = 79.70\%$). The MI group's values for Weeks 2 and 3 were significantly greater than the no-MI group's and the control group's percentages at all four weeks. The MI group's percentage of time at or below the speed limit on 25 mph roads during

Week 4 was also greater than the no-MI group's percentages during Week 2 (*M* = 72.80%), Week 3 (*M* = 74.05%), and Week 4 (*M* = 74.2%). The no-MI group's percentage of time driving below 25 mph limits during Week 2 was also significantly lower than the MI group's and the control group's (*M* = 78.40%) percentages during Week 1. Finally, the percentage of time driving at or below 25 mph speed limit roads did not vary significantly within the month of driving for the control group (Range = 76.9 – 78.4%) or the no-MI group (Range = 72.8 – 75.85%) (See Figure 8).

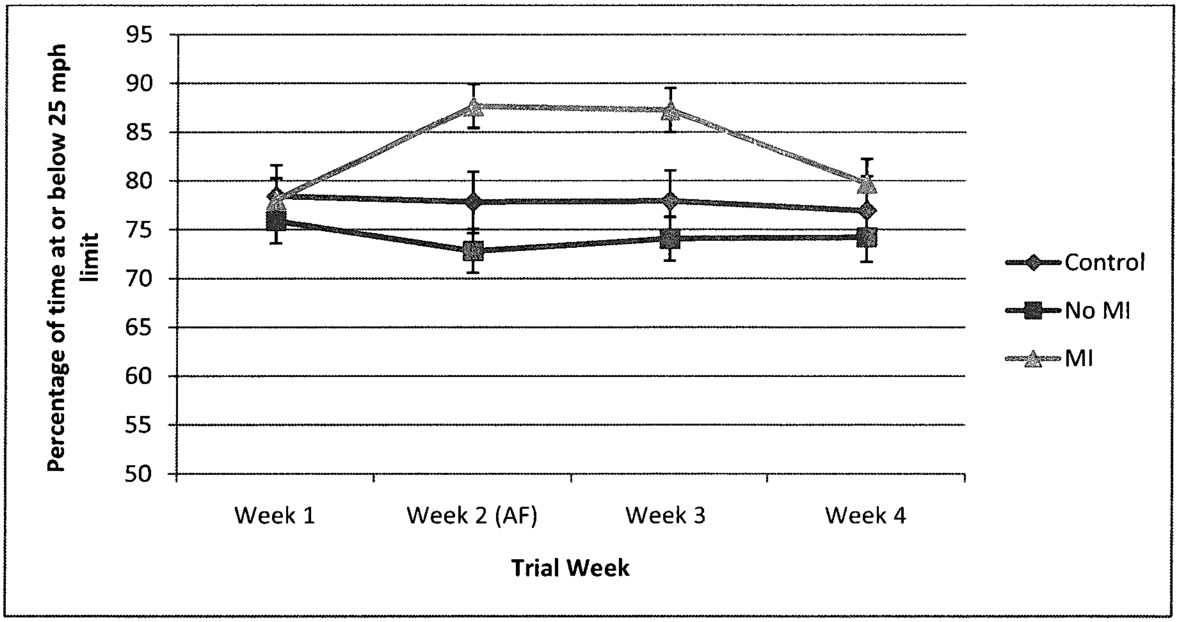

Figure 8. Percent of time driving at or below 25 mph speed limits as a function of monetary incentive and advisory feedback.

Percentage of time driving 1 to 4 mph above 25 mph speed limits. Neither the main effect of Week nor Incentive Group or the interaction between the two were significant , *F*(2.47, 116.25) = .36, *n.s.*The *F*(2, 47) = .80, *n.s.*; *F*(4.95, 116.25) = 1.12, *n.s.*, respectively.

Percentage of time driving 5 to 8 mph above 25 mph speed limits. The main effects for Week and Incentive Group were not significant, $F(3, 141) = 1.88$, *n.s.* and $F(2, 47) = 4.93$, *n.s.,* respectively. The interaction between Week and Incentive Group was significant $F(6, 141) = 8.02$, $p < .001$, partial $\eta^2 = .25$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 47) = 25.56$, $p < .001$, partial $\eta^2 = .51$. The MI group's percentage of time spent driving 5 to 8 mph over 25 mph roads was significantly lower during Weeks 2 ($M = 2.15\%$) and 3 ($M = 2.80\%$) than Weeks 1 ($M = 5.90\%$) and 4 ($M = 5.55\%$) and relative to the control (Range = 5.50% - 6.90%) and no-MI groups' percentages (Range = 5.80% - 7.25%) for all weeks. The no-MI group's percentage during Week 2 when the AF was active ($M = 7.25\%$) was significantly higher than Week 1 ($M = 5.80\%$) and the control group's average percentage during Week 1 ($M = 5.80\%$). Finally, the no-MI group's percentage of time driving 5 to 8 mph over 25 mph limits during Weeks 2 ($M = 7.25\%$) and 3 ($M = 6.95\%$) was significantly higher than the MI group's percentage during Week 4 ($M = 5.55\%$). Control group scores did not differ significantly across the four weeks (see Figure 9).

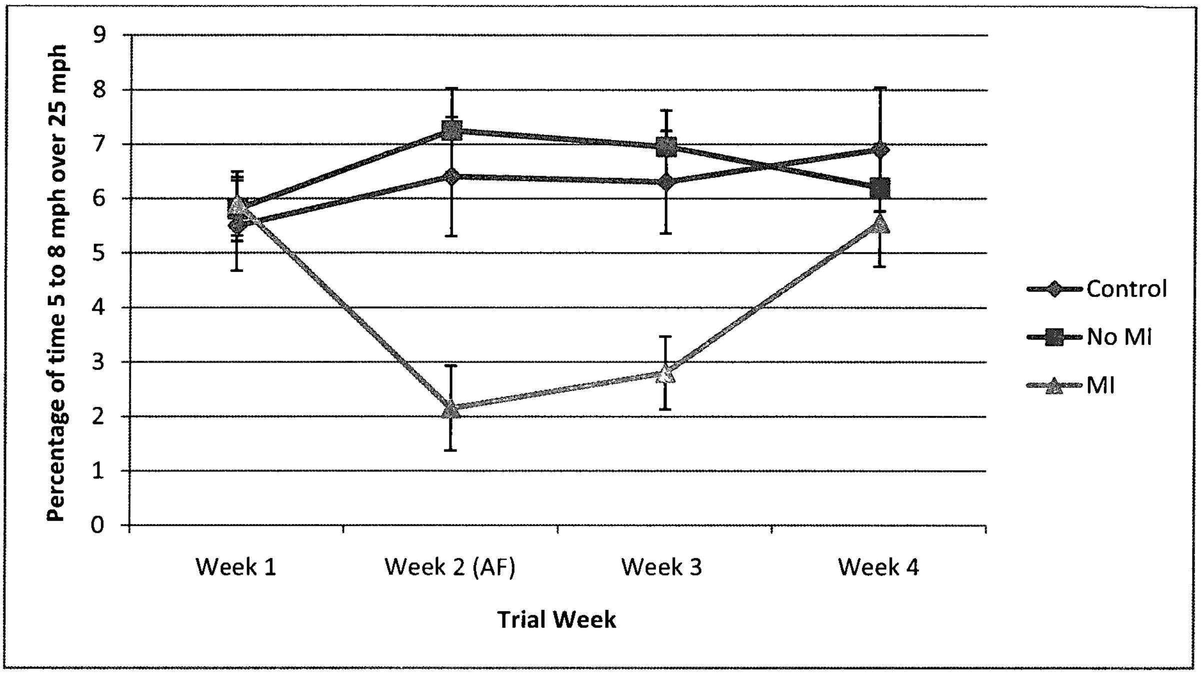

Figure 9. The effect of Monetary Incentive (MI) and Automated Feedback on the percentage of time driving 5 to 8 mph over 25 mph limits.

Percentage of time driving 9 or more mph above 25 mph speed limits. The main effects for Week and Incentive Group were not significant, $F(1.84, 86.29) = 1.52$, *n.s.* and $F(2, 47) = 2.53$, *n.s.*, respectively. Due to the violation of sphericity and the reduced alpha criterion, the interaction between Week and Incentive Group was not significant $F(3.67, 86.29) = 3.27$, *n.s.*.

Percentage of time driving at or below 30 mph speed limits. The main effects for Week and Incentive Group were not significant, $F(2.29, 78) = .22$, *n.s.* and $F(2, 34) = 1.19$, *n.s.*, respectively. The interaction between Week and Incentive Group was significant, $F(4.59, 78) = 4.11$, $p<.01$, partial $\eta^2 = .20$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 34) = 6.87$, $p<.01$, partial $\eta^2 = .29$. The MI group significantly increased the percentage of time driving at or below the speed limit during Weeks 2 (*M* = 65.27%), 3 (*M* = 65.80%), and 4 (*M* = 62.20%), relative to Week 1 (*M* = 54.20%). The MI group's percentages for Weeks 2-4 were significantly greater than the control group's percentages for the same 3 weeks (Range 52.13 to 52.50%). The no-MI group spent significantly less time driving at or below the limit during Week 2 (*M* = 56.79%) than the MI did during Week 2 and 3. During Week 1 the no-MI group spent significantly more time at or below the speed limit (*M* = 61.07%) than the control group at Weeks 2, 3, and 4; and the MI group during Week 1. Neither the control group nor the no-MI group significantly increased or reduced their respective amounts of time driving at or below the speed limit on 30 mph roads from week to week (See Figure 10).

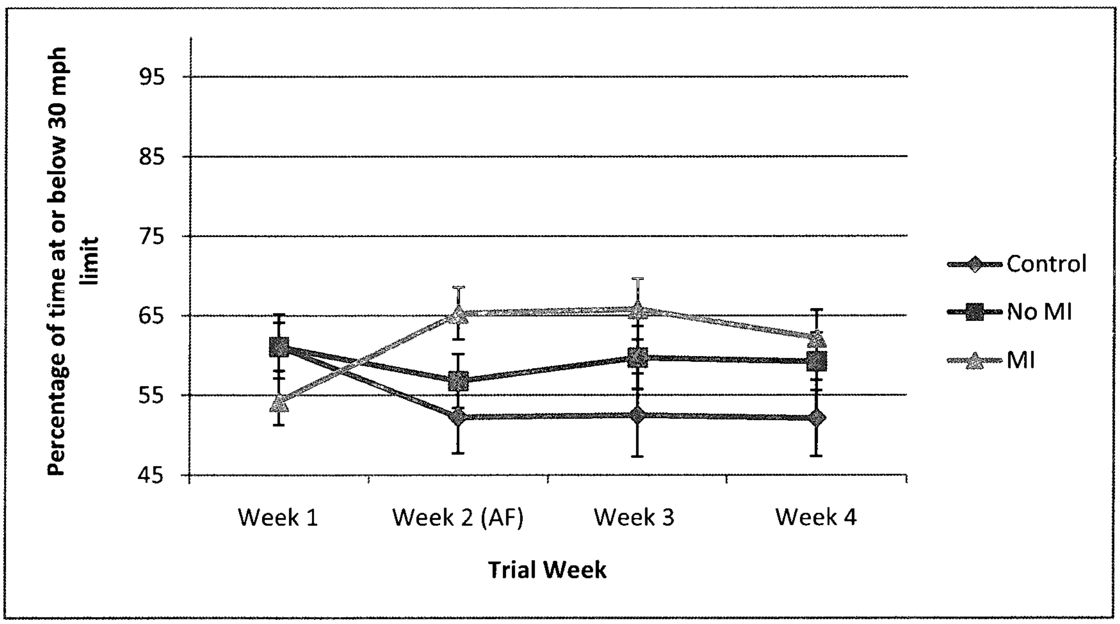

Figure 10. The effect of monetary incentive and automated feedback on the percentage of time driving at or below a 30 mph limit.

Percentage of time driving 1 to 4 mph over 30 mph speed limits. The main effect for Incentive Group was not significant, $F(2, 34) = .99$, *n.s.* The interaction between Week and Incentive Group was not significant, $F(6, 102) = 1.79$, *n.s.* The main effect of Week was significant, $F(3, 102) = 6.19$, $p<.01$, partial $\eta^2 = .15$. The Bonferroni post-hoc test indicated that averaging across the three incentive groups, drivers spent significantly less time driving 1 to 4 mph over 30 mph roads during Weeks 1 (M = 19.24%) and 4 (M = 19.23%) than Week 2 when the AF was active (M = 24.84%).

Percentage of time driving 5 to 8 mph over 30 mph speed limits. The main effect of Week was not significant, $F(3, 102) = 1.78$, *n.s.* The main effect for Incentive Group was significant, $F(2, 34) = 4.47$, $p<.01$, partial $\eta^2 = .21$, as was the interaction between Week and incentive Group, $F(6, 102) = 5.00$, $p<.001$, partial $\eta^2 = .23$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 34) = 10.08$, $p<.01$, partial $\eta^2 = .37$. Drivers in the MI group spent significantly less time driving 5 to 8 mph over 30 mph limits during Week 2 (M = 6.07%) and Week 3 (M = 7.33%) relative to Week 1 (M = 16.40%) and Week 4 (M = 11.53%). The amount of time drivers in the MI group spent in this speed range during Week 4 remained significantly lower than Week 1. The amount of time that the MI group spent driving 5 to 8 mph over 30 mph roads during Weeks 2 and 3 was significantly lower than the control group (Range 13.00-16.00%) and no-MI group (Range 11.57-13.36%) at any of the four weeks. The MI (M = 16.40%) group spent significantly more time driving 5 to 8 mph over 30 mph roads during Week 1 than the no-MI group did during Weeks 1 (M = 11.86%) , 2 (M = 13.21%), and 3 (M = 13.36%) . The no-MI group spent significantly less time driving 5 to 8 mph over 30 mph limits during Week 1 and Week 2 than the control group did during Weeks 2 (*M* = 15.88%), 3 (*M* = 16%), and 4 (*M* = 16%) (see Figure 11).

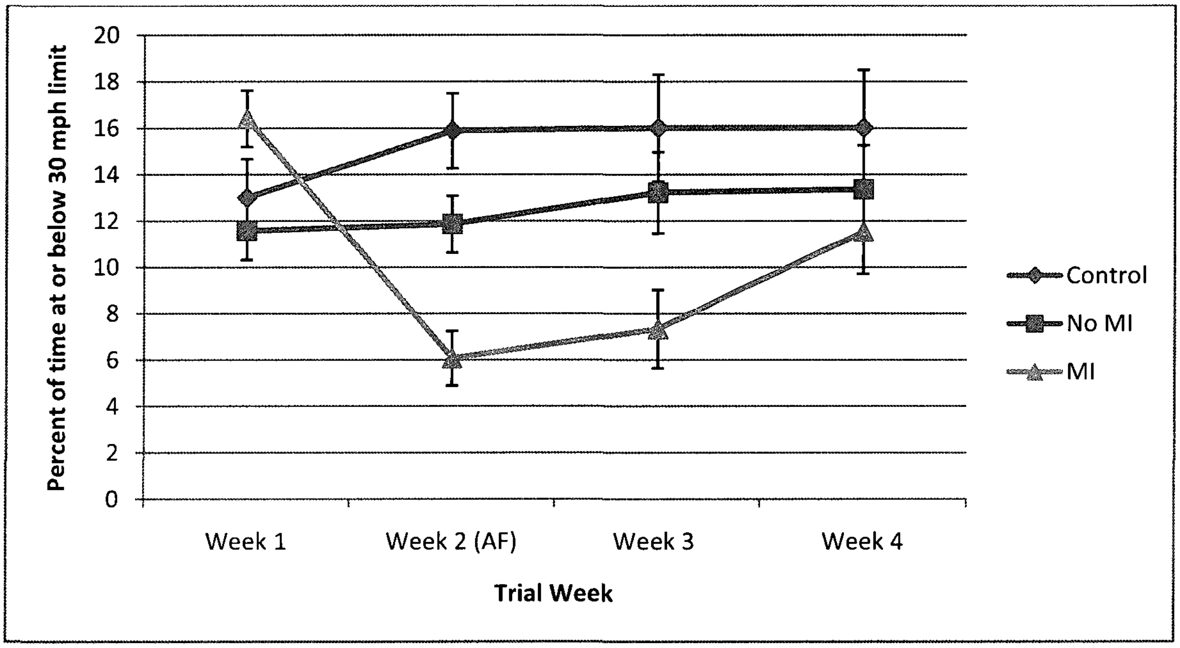

Figure 11. The effect of monetary incentive and automated feedback on the percentage of time driving 5 to 8 mph over a 30 mph limit.

Percent of time driving 9 or more mph over 30 mph speed limits. The main effects for Week and Incentive Group were not significant, $F(3, 102) = 3.47$, *n.s.* and $F(2, 34) = 2.87$, *n.s.*, respectively. The interaction between Week and Incentive Group was significant, $F(6, 102) = 5.97$, $p < .001$, partial $\eta^2 = .26$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 34) = 10.50$, $p < .001$, partial $\eta^2 = .38$. The MI group spent significantly less time driving 9 mph or more over 30 mph speed limits during Week 2 (*M* = 1.00%) and Week 3 (*M* = 1.13%) than they did during Week 1 (*M* = 10.60%) and Week 4 (*M* = 6.13%), and Week 4 was significantly lower than Week 1.

The Week 2 and Week 3 average percentages of the MI group were significantly lower than Weeks 1-4 for the control group (Range 6.13 to 12.25%) and no-MI groups (Range 6.43 to 8.57%). In contrast, the control group increased the amount of time driving 9 mph or more over 30 mph roads such that Week 4 (M = 12.25%) was significantly greater than Week 1 (M = 6.13%). The percentage of time that the no-MI group spent driving 9 mph or more over the limit did not vary across the four weeks of driving. However, the no-MI group spent significantly less time in this speed range during Week 1 (M = 7.07%) and Week 2 (M = 6.43%) than the MI group during Week 1 (M = 10.60%) and the control group during Week 4 (M = 12.25%). Finally, during Week 4 the no-MI group spent significantly less time in this speed range (M = 8.07) than the control group (M = 12.25%). See Figure 12.

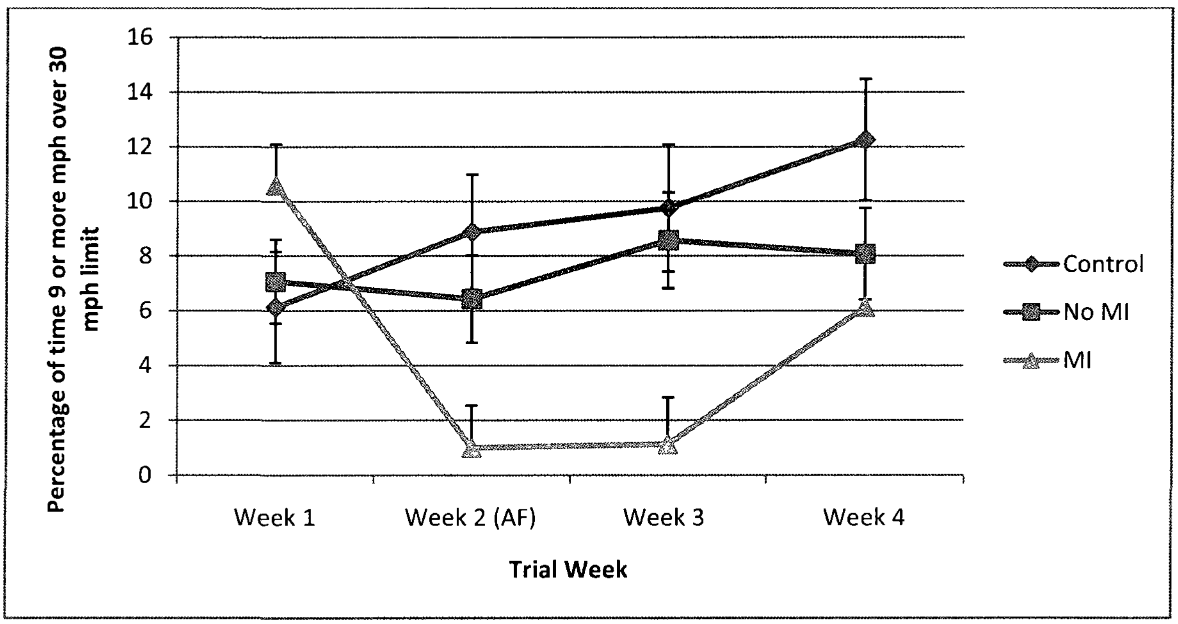

Figure 12. The effect of monetary incentive and automated feedback on the percentage of time driving 9 or more mph over a 30 mph limit.

Percent of time driving at or below 35 mph speed limits. . The main effects of Week and Incentive Group were significant, $F(3, 138) = 8.22$, $p < .001$, partial $\eta^2 = .15$ and $F(2, 46) = 12.47$, $p < .001$, partial $\eta^2 = .35$; respectively. The interaction between Week and Incentive Group was significant, $F(6, 138) = 10.91$, $p < .001$, partial $\eta^2 = .32$,. Trend analysis indicated a significant quadratic trend, $F(2,46) = 23.91$, $p < .001$, partial $\eta^2 = .51$. The MI group spent significantly more time driving at or below 35 mph roads during Week 2 (M = 80.65%) and Week 3 (M = 82.65%) than Week 1 (M = 64.90%) and Week 4 (M = 70.5%). The mean percentages of the MI group for Weeks 2 and 3 were significantly higher than all measurement periods for the control group (Range 61.2% to 64.8%) and no-MI group (Range 58.21% to 61.84%). During Week 4, the MI group spent more time (M = 70.5%) at or below the speed limit than Week 1, and this Week 4 percentage was significantly greater than all four Weeks of the no-MI group and Weeks 1, 2, and 4 of the control group. The percentage of time that drivers in the no-MI group spent at or below 35 mph limits during Week 2 (M = 58.21%) and 4 (M = 59.68) was also less than the time drivers in the MI group spent at or below 35 mph limits during Week 1 (M = 64.90%). Neither the control group nor the no-MI group varied between or within groups across the four weeks (See Figure 13).

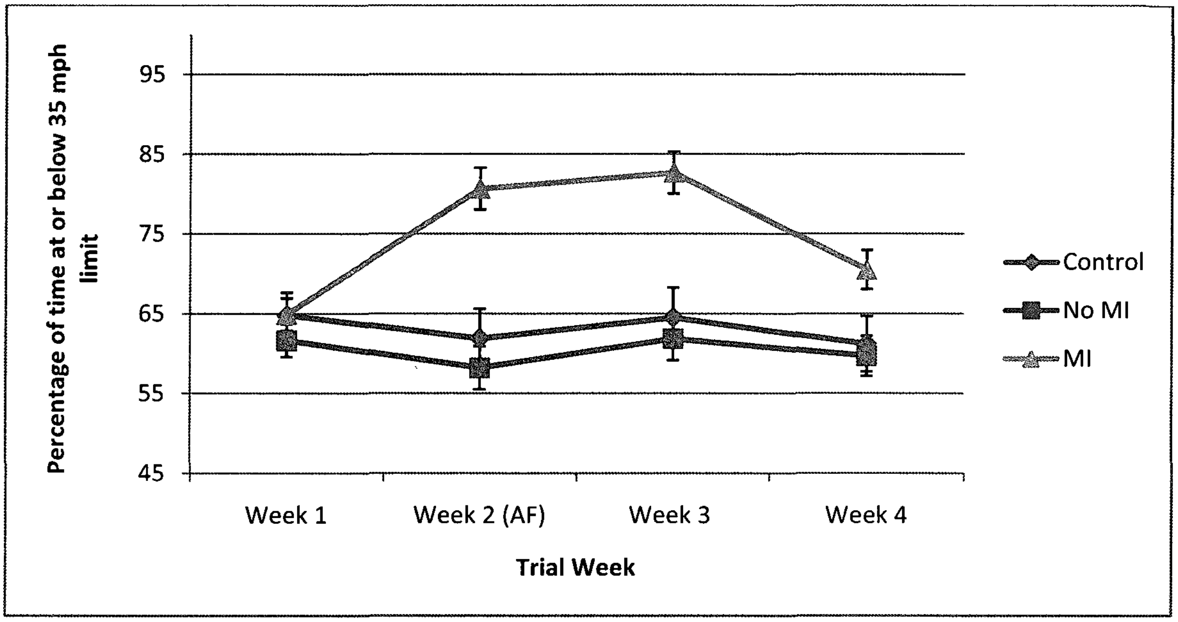

Figure 13. The effect of monetary incentive and automated feedback on the percentage of time driving at or below a 35 mph limit.

Percent of time driving 1 to 4 mph over 35 mph speed limits. The main effects of Week and Incentive Group were not significant, $F(2.06, 94.71) = 2.99$, *n.s.*; $F(2, 46) = 1.85$, *n.s.*; respectively. The interaction between Week and Incentive Group was significant, $F(4.12, 94.71) = 3.97$, $p < .01$, partial $\eta^2 = .15$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 46) = 5.37$, $p < .01$, partial $\eta^2 = .19$. Drivers in the no-MI group significantly increased the amount of time driving 1 to 4 mph over the limit during Week 2 ($M = 22.74\%$) relative to Week 1 ($M = 18.42\%$), Week 3 ($M = 17.95\%$), and Week 4 ($M = 17.21\%$). The no-MI group's percentage during Week 2 was significantly greater than all four weeks of MI group (Range 13.55 to 19.60%) and Week 1 of the control group ($M = 19.30\%$). In contrast, drivers in the MI group spent significantly less time driving 1 to 4 mph over the limit during Week 2 ($M = 16.15\%$) and Week 3 ($M = 13.55\%$) than they did during Week 1 ($M = 19.60\%$). During Week 3, drivers in the MI group spent less time driving 1 to 4 mph over the limit (*M* = 13.55%) than Week 4 (*M* = 18.30%) and less time than the control group (Range 19.3% to 21.1%) and no-MI group at all four weeks. Drivers in the MI group also spent less time in the 1 to 4 mph over the limit speed range during Week 2 than the control group did during Week 4 (*M* = 21.10%). The amount of time that drivers in the control group drove 1 to 4 mph over 35 mph limits did not vary significantly across the four weeks (Figure 14).

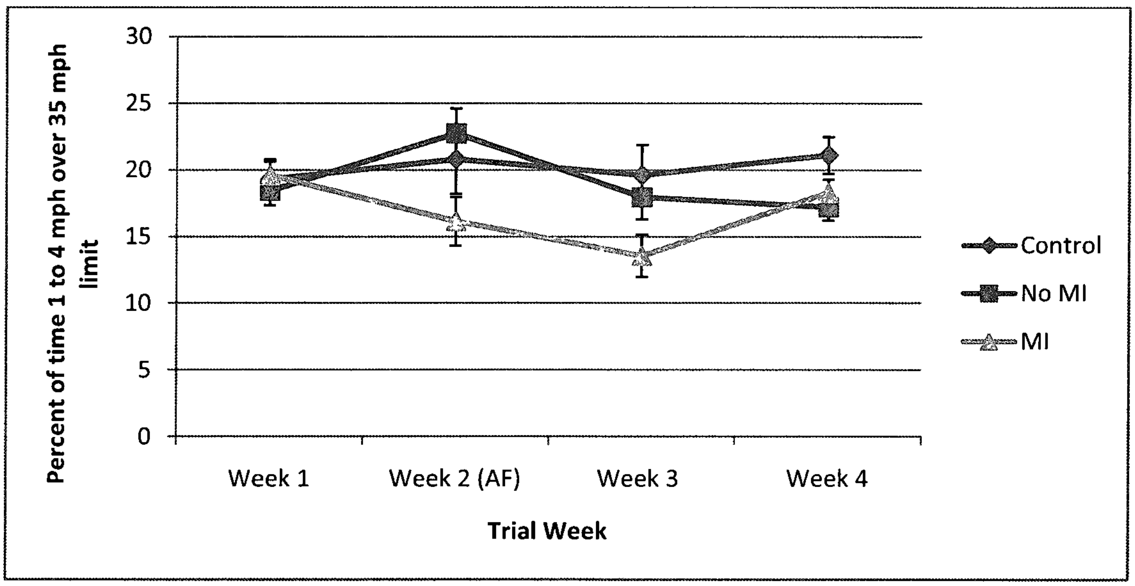

Figure 14. The effect of monetary incentive and automated feedback on the percentage of time driving 1 to 4 mph over 35 mph roads.

Percent of time driving 5 to 8 mph over 35 mph roads. The main effects of Week and Incentive group were significant, $F(3, 138) = 6.37$, $p < .001$, partial $\eta^2 = .12$; and $F(2, 46) = 15.20$, $p < .001$, partial $\eta^2 = .40$, respectively. The interaction between Week and Incentive Group was significant, $F(6, 138) = 7.60$, $p < .001$, partial $\eta^2 = .25$. Trend analysis indicated that there was a significant quadratic trend for the interaction $F(2, 46) = 21.26$,

$p < .001$, partial $\eta^2 = .49$. Drivers in the MI group spent significantly less time speeding 5 to 8 mph over 35 mph limits during Week 2 (*M* = 1.71%) and Week 3 (*M* = 2.07%) than Week 1 (*M* = 9.38%) and Week 4 (*M* = 7.36%). Throughout the month of driving, drivers in the control group (Range 10.0% to 12.9%) and no-MI group (Range 10.25% to 11.84%) spent significantly more time driving 5 to 8 mph over the limit than the MI group during Weeks 2 and 3. Drivers in the MI group spent significantly less time driving 5 to 8 mph over the limit during Week 4 (*M* = 8.65%) than the no-MI group did at each measurement period and the control group during Weeks 2, 3, and 4. Drivers in the no-MI group spent significantly more time driving 5 to 8 during Week 1 (*M* = 12.74%) and Week 4 (*M* = 12.84%) than the control group during Week 1 (*M* = 10.00%) and MI group during Week 1 (*M* = 10.25%). Drivers in the no-MI group did not significantly change the percentage of time spent driving in this speed range from week to week across the month of driving. Drivers in the control increased the amount of time driving 5 to 8 over the limit during Week 2 (*M* = 12.90%) relative to Week 1 (*M* = 10.00%). See Figure 15.

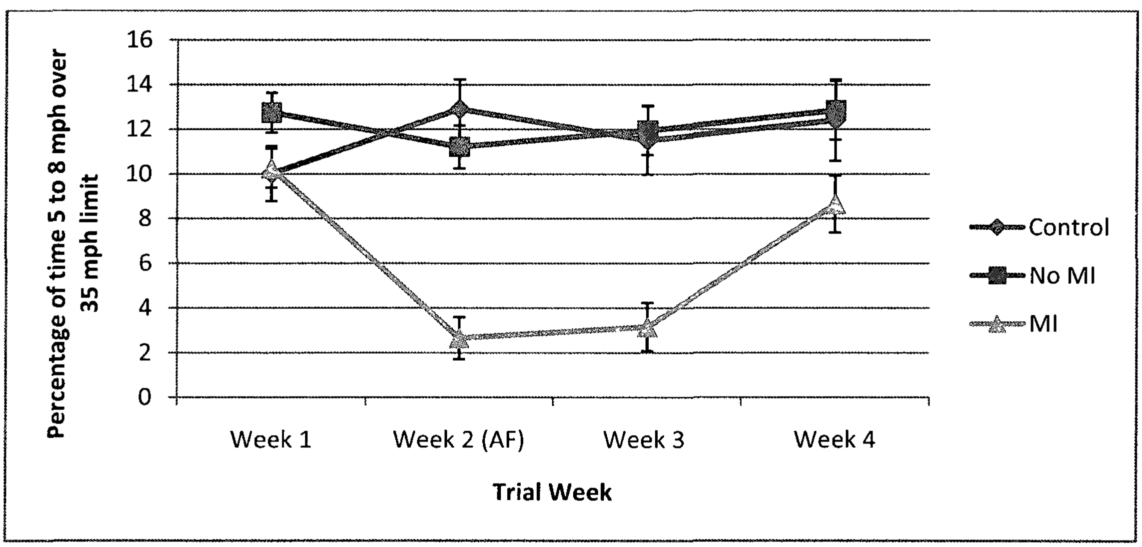

Figure 15. The effect of monetary incentive and automated feedback on the percentage of time driving 5 to 8 mph over 35 mph roads.

Percent of time driving 9 or more mph over 35 mph roads. The main effect of Week and Incentive Group were significant, $F(3, 138) = 5.44$, $p < .01$, partial $\eta^2 = .11$; and $F(2, 46) = 7.17$, $p < .01$, partial $\eta^2 = .24$, respectively. The interaction between Week and Incentive Group was significant, $F(6, 138) = 2.99$, $p < .01$, partial $\eta^2 = .12$. Trend analysis indicated a significant linear trend for the interaction, $F(2, 46) = 5.83$, $p < .01$, partial $\eta^2 = .20$. Drivers in the MI group significantly decreased the percentage of time driving 9 or more over 35mph speed limits during Weeks 2 (M = .55%) and 3 (M = .65%) relative to Weeks 1 (M = 5.25%) and 4 (M = 2.55%) and relative to all 4 Weeks of driving completed by drivers in the control (Mean Range 4.4% to 5.3%) and no-MI group (Mean Range 5.89% to 9.21%). Drivers in the MI group spent significantly less time driving 9 or more over the limit during Week 4 than Week 1. In contrast, drivers in the control group did not significantly vary the percentage of time spent driving 9 or more mph over the limit during their month of driving. Drivers in the no-MI group spent significantly less time driving 9 or more over the limit during Week 2 (M = 5.89%) relative to Week 4 (M = 9.21%). Finally, drivers in the no-MI group spent significantly more time speeding 9 or more mph over the limit during Week 3 (M = 7.68%) and 4 (M = 9.21%) than the MI group did during Week 1 (M = 5.25%) and Week 4 (M = 2.55%) (see Figure 16).

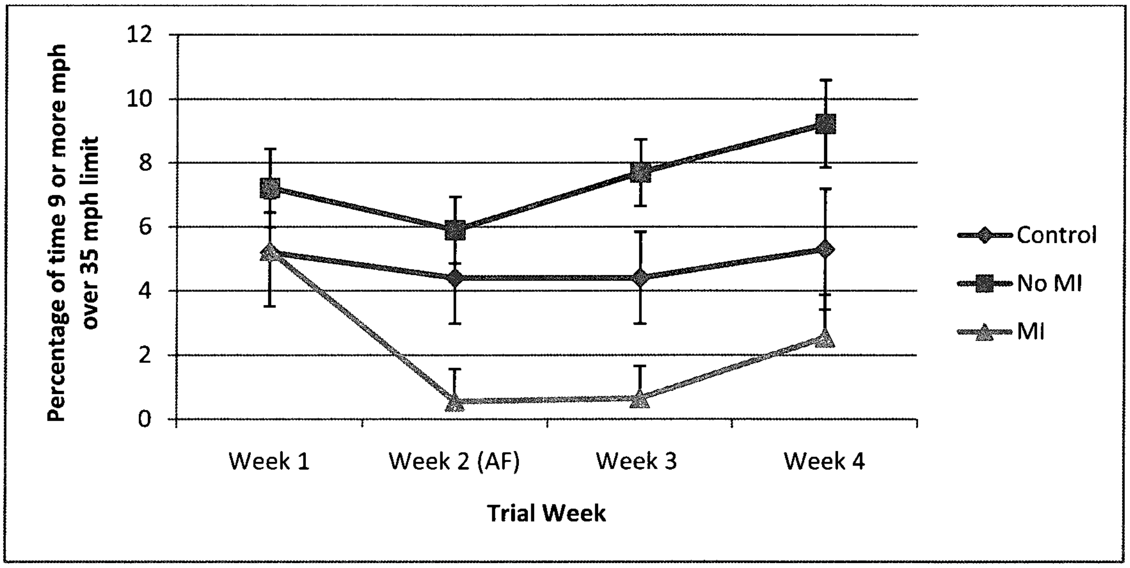

Figure 16. The effect of monetary incentive and automated feedback on the percentage of time driving 9 or more mph over 35 mph roads.

Percent of time driving at or below 40 mph roads. The main effect of Week was significant, $F(3, 129) = 5.71$, $p < .01$, partial $\eta^2 = .12$. The main effect for Incentive Group was not significant, $F(2, 43) = 2.78$, *n.s.* The interaction between Week and Incentive Group was significant, $F(6, 129) = 3.24$, $p < .01$, partial $\eta^2 = .13$. Trend analysis indicated that there was a significant quadratic trend for the interaction, $F(2, 43) = 8.56$, $p < .01$, partial $\eta^2 = .29$. Drivers in the MI group significantly increased the percentage of time driving at or below the speed limit during Week 2 (M = 83.72%) and Week 3 (M = 84.78%) relative to Week 1 (M = 69.06%) and Week 4 (M = 74.78%). The amount of time that the MI participants spent driving in this speed range during Weeks 2 and 3 was significantly higher than any week driven by the control group (Mean Range 69.00% to 75.7%) and the no-MI group (Mean Range 69.06% to 70.56%). The within group variability for the control or no-MI group was not statistically significant (see Figure 17).

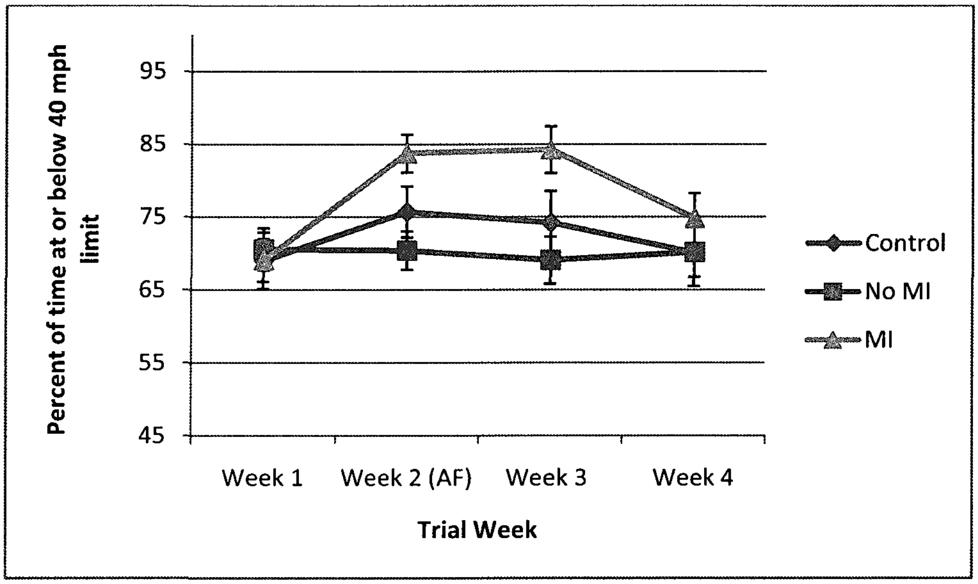

Figure 17. The effect of monetary incentive and automated feedback on the percentage of time driving at or below 40 mph roads.

Percentage of time driving 1 to 4 mph over 40 mph roads. The main effects of Week and Incentive Group and the interaction between Week and Incentive Group were not significant, $F(3, 129) = 2.17$, *n.s.*; $F(2, 43) = .44$, *n.s.*; and, $F(6, 129) = 2.01$, *n.s.*; respectively.

Percentage of time driving 5 to 8 mph over 40 mph roads. The main effect of Week was significant, $F(3, 129) = 5.48$, $p < .01$, partial $\eta^2 = .11$. The effect of Incentive Group was not significant, $F(2, 43) = 4.54$, *n.s.* . The interaction between Week and Incentive Group was significant, $F(6, 129) = 4.66$, $p < .001$, partial $\eta^2 = .18$. Trend analysis indicated a significant quadratic trend for the interaction, $F(2, 43) = 13.73$, $p < .001$, partial $\eta^2 = .39$. Drivers in the MI group significantly reduced the mean percentage of time spent driving 5 to 8 mph over 40 mph roads during Week 2 (M = 1.94%) and Week 3 (M = 2.94%) relative to Week 1 (M = 9.50%) and Week 4 (M = 7.61%). The mean percentage of time that MI participants spent driving 5 to 8 mph over 40 mph roads during Weeks 2 and 3 was significantly lower than any week driven by the control group (Mean Range 7.5% to 10.0%) and the no-MI group (Mean Range 7.61% to 10.22%). Drivers in the no-MI group spent significantly less time driving 5 to 8 mph over 40 mph roads during Week 2 (*M* = 7.61%) than during Week 3 (*M* = 10.22%). The mean percentage of time control group drivers spent driving 5 to 8 mph over 40 mph roads did not vary significantly during the four weeks of driving. Drivers in the control group did not differ significantly from drivers in the no-MI group with respect to the time driving 5 to 8 mph over 40 mph roads during the four weeks of driving (see Figure 18).

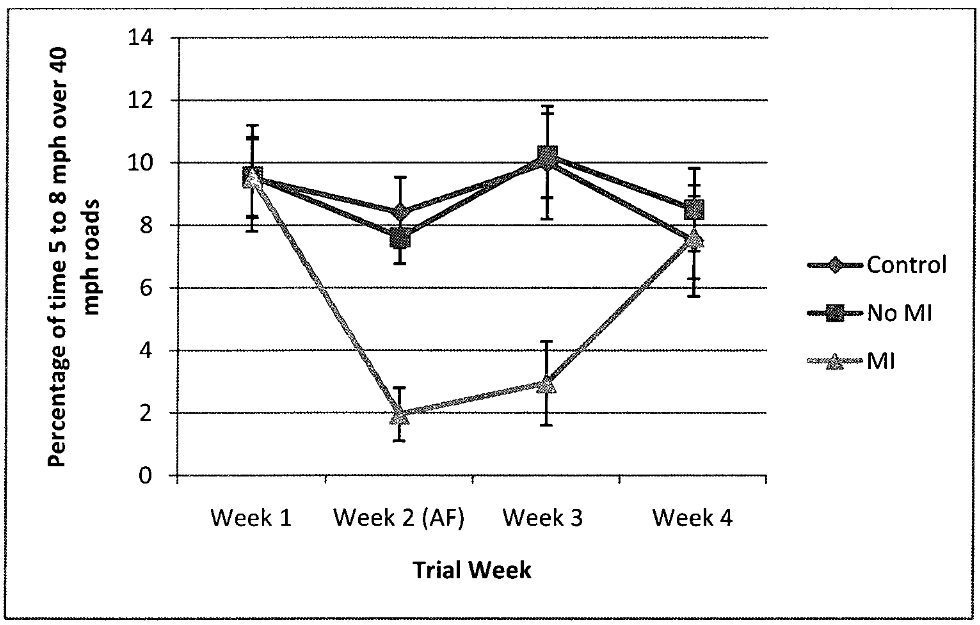

Figure 18. The effect of monetary incentive and automated feedback on the percentage of time driving 5 to 8 mph over 40 mph roads.

Percent of time driving 9 or more mph over 40 mph roads. . The main effect of Week was significant, $F(2.38, 102.38) = 5.12$, $p < .01$, partial $\eta^2 = .11$. The Bonferroni post-hoc test indicates that all drivers spent a significantly higher percentage of time driving 9 or more mph during Week 1 (*M* = 4.57%) than Week 2 (*M* = 2.09%) or Week 3 (*M* = 4.57%). The main effect of Incentive Group and the interaction between Week and Incentive Group were not significant, $F(2, 43) = 4.62$, *n.s.*. and $F(2, 43) = 2.69$, *n.s.*, respectively.

*Percentage of time driving at or below 45 mph roads.*The main effects of Week and Incentive Group were not significant, $F(2.42, 101.55) = 3.78$, *n.s.* The interaction between Week and Incentive Group was not significant, $F(4.84, 101.55) =.96$, *n.s.*

Percentage of time driving 1 to 4 mph over 45 mph roads. The main effects of Week and Incentive Group were not significant, $F(2.29, 96.04) = 2.47$, *n.s.* and $F(2, 42) =3.01$, *n.s.*, respectively. The interaction between Week and Incentive Group was not significant, $F(4.84, 101.55) =.96$, *n.s.*

Percentage of time driving 5 to 8 mph over 45 mph roads. The effect of Week was significant, $F(2.47, 103.76) = 6.25$, $p < .01$, partial $\eta^2 = .13$, observed power = .93. Drivers significantly decreased the amount of time they drove 5 to 8 mph over 45 mph roads during Week 2 (*M* = 1.15%) relative to Week 1 (*M* = 2.61%) and Week 3(*M* = 2.28%). Additionally, drivers spent significantly less time driving 5 to 8 mph over the limit during Week 4 (*M* = 1.63%) relative to Week 1 (*M* = 2.61%).

Percentage of time driving 9 or more mph over 45 mph roads. . The main effects of Week and Incentive Group were not significant, $F(2.10, 88.20) = 1.89$, *n.s.* and $F(2, 42) = 1.98$, *n.s.*, respectively. The interaction between Week and Incentive Group was not significant, $F(4.84, 101.55) = 1.51$, *n.s.*

Percentage of time driving at or below 55 mph roads. The analysis of speeding in 55 mph zones is based on a limited number of participants having driven on roads with this speed limit. Eleven (3 control participants, 4 MI participants, and 4 no-MI participants) of the 50 participants drove on 55 mph roads during each week of driving. Thus there were > 20 degrees of freedom for the within-group error term, but only 8 for the between group error term, so the assumption of normality for each ANOVA associated with 55 mph roads was violated for the between subjects comparisons. With regard to the ANOVA to test for differences for the percentage of time driving at or below the speed limit, the assumption of sphericity was satisfied, but homogeneity of variance was violated. The main effect of Week and Incentive Group were not significant, $F(3, 24) = .75$, *n.s.*; and $F(2, 8) = 4.70$, *n.s.*, respectively. The interaction between Week and Incentive Group was significant, $F(6, 24) = 4.81$, $p < .01$, partial $\eta^2 = .55$. Trend analysis indicated a significant cubic trend for the interaction, $F(2, 8) = 6.25$, $p < .01$, partial $\eta^2 = .54$, observed power = .61. Drivers in the MI group significantly increased the percentage of time that they drove at or below the 55 mph speed limit during Week 2 (M = 91.00%) and Week 3 (M = 88.75%) relative to Week 1 (M = 68.25%). In contrast, the control group significantly decreased the percentage of time driving at or below 55 mph speed limits during Week 2 (M = 58.67%) and Week 3 (M = 61.67%) relative to Week 1 (M = 84.33%). The percentage of time driving at or below 55 mph limits did not vary significantly during the month for drivers in the no-MI group (Range 44.50% to 59.75%). Comparisons of the MI group with the no-MI group and control group indicated that drivers in the MI group spent significantly more time driving at or below the limit during Weeks 2 (*M* = 91.00%), 3 (*M* = 88.75%), and 4 (*M* = 83.00%) than the no-MI group did at all four weeks and the control group at Weeks 2 (*M* = 58.67%), 3 (*M* = 61.67%), and 4 (*M* = 63.67%) (see Figure 19).

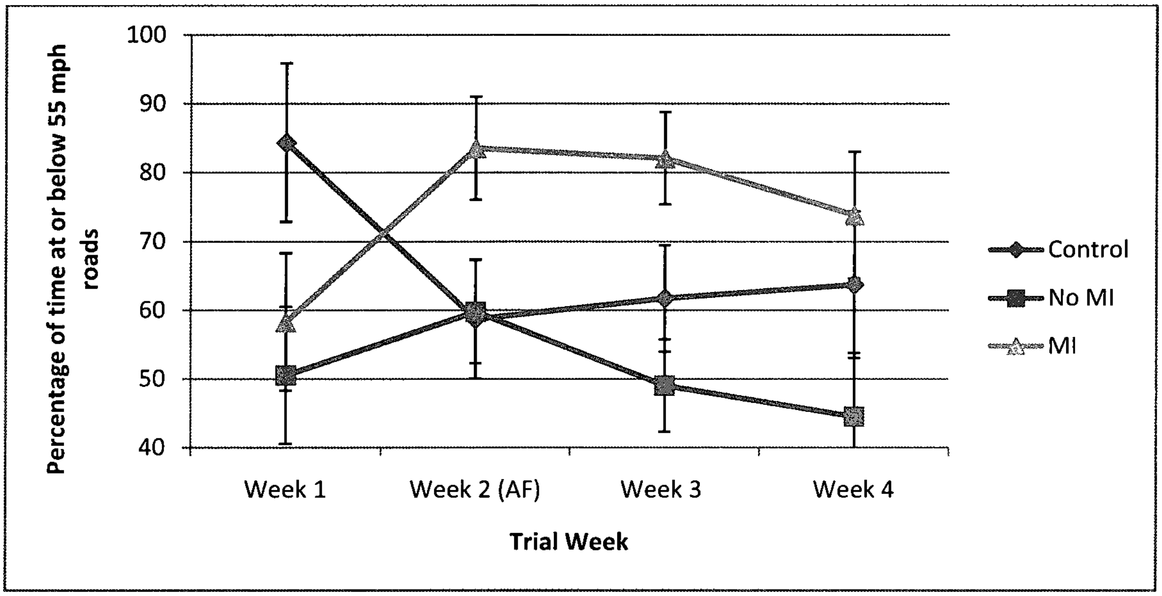

Figure 19. The effect of monetary incentive and automated feedback on the percentage of time driving at or below the 55 mph speed limit.

Percentage of time driving 1 to 4 mph over 55 mph roads. The main effect of Week and Incentive Group and the interaction between the two were not significant, $F(3, 24) = .62$, *n.s.*; $F(2, 8) = 1.64$, *n.s.*; and $F(3.38, 13.52) = 1.86$, *n.s*, respectively.

Percentage of time driving 5 to 8 mph over 55 mph roads. The main effects of Week and Incentive Group and the interaction between the two main effects were not significant, $F(1.69, 13.52) = .62$, *n.s.*; $F(2, 8) = 1.64$, *n.s.*; and $F(6, 24) = 1.93$, *n.s.* respectively.

Percentage of time driving 9 or more mph over 55 mph roads. The main effects of Week and Incentive Group were not significant, $F(3, 24) = 1.07$, *n.s.* and $F(2, 8) = 2.99$, *n.s.*, respectively. The interaction between Week and Incentive group was not significant, $F(6, 24) = 1.60$, *n.s.*

Percent of time driving at or below 70 mph roads. The main effect of Week was significnant, $F(3, 72) = 6.84$, $p < .001$, partial $\eta^2 = .22$. Drivers spent significantly more time driving at or below the speed limit during Week 3 ($M = 65.06\%$) than Week 1 ($M = 51.23\%$) and Week 4 ($M = 50.31\%$). There was no significant difference between the mean percentage of time drivers drove at or below 70 mph roads during Week 2 ($M = 64.66\%$) and the other 3 weeks of driving. The main effect of Incentive Group and the interaction between Incentive Group and Week was not significant, $F(2, 25) = 2.85$, *n.s.* and $F(6, 72) = 1.62$, *n.s*, respectively.

Percentage of time driving 1 to 4 mph over 70 mph roads. The main effects of Week, Incentive Group, and the interaction between the two terms were not significant, $F(2.23, 53.47) = 1.19$, *n.s.*; $F(2, 24) = .14$, *n.s*; and $F(4.46, 53.47) = .56$, *n.s.*, respectively.

Percentage of time driving 5 to 8 mph over 70 mph roads. The main effect of Week was significant, $F(3, 72) = 8.55$, $p < .001$, partial $\eta^2 = .26$. Drivers spent significantly less time driving 5 to 8 mph over 70 mph limits during Week 2 ($M = 8.19\%$) than Weeks 1 ($M = 16.13\%$) and 4 ($M = 16.64\%$), and drivers spent significantly less time driving 5 to 8 mph over 70 mph in Week 3 ($M = 11.29\%$) than Week 4. The effects of Incentive Group and the interaction between Week and Incentive Group were not significant $F(2, 24) = 3.86$, *n.s.;* and $F(6, 72) = 2.45$, *n.s.*, respectively.

Percentage of time driving 9 or more mph over 70 mph roads. The main effect of Week was significant, $F(3, 72) = 6.84$, $p < .001$, partial $\eta^2 = .22$. Drivers spent significantly less time driving 9 or more mph over 70 mph limits during Week 2 (M = 7.70%) relative to Week 1 (M = 16.03%). The main effect of Incentive Group and the interaction between Week and Incentive Group were not significant, $F(2, 24) = 2.44$, *n.s.*; and $F(6, 72) = 1.13$, *n.s.*, respectively. Table 7 presents a summary of the percentages of time spent driving within the four speed ranges in the above results. These percentages are grouped by Incentive Group, Week of driving, and speed limit zone. The last column indicates the results of the omnibus statistical tests.

TABLE 7: Mean Percentage of Time Driving within Speed Ranges by Week and MI group

Speed Range		Week 1	Week 2(AF)	Week 3	Week 4	Sig. Effects*
At or below limit						
All Limits Combined						
	Control	69.4%	69.3%	69.9%	66.7%	Week
	No-MI	68.0%	67.3%	66.7%	67.2%	W x MI
	MI	68.9%	83.05%	81.85%	70.97%	
25 mph limits						
	Control	78.4%	77.8%	77.9%	76.9%	W x MI
	No-MI	75.85%	72.8%	74.05%	74.2%	
	MI	78.0%	87.65%	87.25%	79.7%	
30 mph limits						
	Control	61.13%	52.25%	52.5%	52.13%	W x MI
	No-MI	61.07%	56.79%	59.71%	59.21%	
	MI	54.2%	65.27%	65.8%	62.2%	
35 mph limits						
	Control	64.80%	61.90%	64.50%	61.20%	Week
	No-MI	61.63%	58.21%	61.84%	59.68%	MI
	MI	64.90%	80.65%	82.65%	70.50%	W x MI
40 mph limits						
	Control	69.00%	75.70%	74.20%	70.10%	Wk
	No-MI	70.56%	70.39%	69.06%	70.17%	W x MI
	MI	69.06%	83.72%	84.22%	74.78%	
45 mph limits						
	Control	85.00%	91.00%	88.00%	88.67%	*n.s.*
	No-MI	89.78%	90.78%	89.39%	90.61%	
	MI	92.00%	96.78%	96.28%	94.33%	
55 mph limits						
	Control	84.33%	58.67%	61.67%	63.67%	W x MI
	No-MI	50.50%	59.75%	49.00%	44.50%	
	MI	68.25%	91.00%	88.75%	83.00%	
70 mph limits						
	Control	41.67%	57.00%	54.67%	38.00%	WK
	No-MI	58.27%	59.18%	58.91%	50.81%	
	MI	53.70%	77.80%	81.60%	62.10%	
1-4 mph over limit						
All Limits Combined						
	Control	14.3%	14.5%	14.5%	15.5%	*n.s.*
	No-MI	14.8%	18.55%	14.1%	13.9%	
	MI	14.25%	14.55%	13.9%	15.75%	
25 mph limits						
	Control	9.1%	9.4%	9.0%	9.3%	*n.s.*

TABLE 7 Continued

Speed Range		Week 1	Week 2(AF)	Week 3	Week 4	Sig. Effects*
	No-MI	10.05%	12.2%	10.75%	9.7%	
	MI	9.55%	8.9%	9.05%	9.8%	
30 mph limits						
	Control	19.75%	23.00%	21.75%	19.63%	Week
	No-MI	19.71%	23.86%	17.28%	17.93%	
	MI	18.26%	27.67%	25.73%	20.13%	
35 mph limits						
	Control	19.30%	20.80%	19.60%	21.10%	W x MI
	No-MI	18.42%	22.73%	17.21%	12.74%	
	MI	19.60%	16.15%	13.55%	18.30%	
40 mph limits						
	Control	17.90%	13.70%	14.00%	18.70%	*n.s.*
	No-MI	15.39%	17.67%	16.33%	15.44%	
	MI	15.83%	14.17%	12.44%	15.78%	
45 mph limits						
	Control	9.78%	6.22%	7.44%	8.22%	*n.s.*
	No-MI	7.39%	7.33%	7.17%	6.28%	
	MI	6.06%	3.06%	3.61%	4.44%	
55 mph limits						
	Control	10.33%	25.00%	17.67%	13.67%	*n.s.*
	No-MI	23.00%	23.25%	16.00%	18.75%	
	MI	16.25%	7.5%	8.5%	16.25%	
70 mph limits						
	Control	16.67%	14.33%	15.00%	22.17%	*n.s.*
	No-MI	14.91%	22.64%	14.00%	17.09%	
	MI	18.30%	21.40%	15.00%	19.50%	
5-8 mph over limit						
All Limits Combined						
	Control	9.2%	9.2%	9.8%	10.1%	Week
	No-MI	9.8%	9.1%	9.8%	9.55%	MI
	MI	9.75%	2.05%	3.65%	8.55%	W x MI
25 mph limits						
	Control	5.5%	6.4%	6.30%	6.90%	W x MI
	No-MI	5.8%	7.25%	6.95%	6.20%	
	MI	5.9%	2.15%	2.80%	5.55%	
30 mph limits						
	Control	13.00%	15.87%	16.00%	16.00%	MI
	No-MI	11.57%	11.86%	13.21%	13.36%	W x MI
	MI	16.40%	6.07%	7.33%	11.53%	
35 mph limits						
	Control	10.00%	12.90%	11.50%	12.40%	Week
	No-MI	12.74%	11.21%	12.95%	12.84%	MI
	MI	10.25%	2.65%	3.15%	8.65%	W x MI

TABLE 7 Continued

Speed Range	Week 1	Week 2(AF)	Week 3	Week 4	Sig. Effects*
5-8 mph over limit					
40 mph limits					
Control	9.50%	8.40%	10.00%	7.50%	Week
No-MI	9.56%	7.61%	10.22%	8.50%	W x MI
MI	9.50%	1.94%	2.94%	7.61%	
45 mph limits					
Control	4.22%	1.67%	3.67%	2.40%	Week
No-MI	2.22%	1.61%	3.06%	1.61%	
MI	1.39%	.17%	.11%	.83%	
55 mph limits					
Control	4.00%	13.00%	15.33%	17.33%	*n.s.*
No-MI	17.00%	10.25%	23.00%	16.75%	
MI	8.25%	1.50%	2.25%	3.25%	
70 mph limits					
Control	18.33%	12.67%	17.50%	20.50%	Week
No-MI	13.45%	11.09%	13.36%	17.91%	
MI	16.60%	.80%	3.00%	11.50%	
9 mph or more over limit					
All Limits Combined					
Control	7.1%	6.0%	5.8%	7.7%	Week
No-MI	7.15%	5.05%	8.6%	8.95%	MI
MI	6.45%	.35%	.60%	4.75%	W x MI
25 mph limits					
Control	6.2%	6.40%	6.80%	6.90%	*n.s.*
No-MI	8.3%	8.40%	10.45%	9.25%	
MI	6.55%	1.30%	.90%	4.95%	
30 mph limits					
Control	6.13%	8.88%	9.75%	12.25%	W x MI
No-MI	7.07%	6.43%	8.57%	8.07%	
MI	10.60%	1.00%	1.13%	6.13%	
35 mph limits					
Control	5.20%	4.40%	4.40%	5.30%	Week
No-MI	7.21%	5.89%	7.68%	9.21%	MI
MI	5.25%	.55%	.65%	2.55%	W x MI
40 mph limits					
Control	3.60%	2.20%	1.80%	2.20%	Week
No-MI	4.50%	3.89%	4.39%	5.56%	
MI	5.61%	.17%	.39%	1.83%	
45 mph limits					
Control	1.00%	.67%	.89%	.67%	*n.s.*
No-MI	.33%	.22%	.67%	1.39%	
MI	.28%	.00%	.00%	.39%	

TABLE 7 Continued

Speed Range		Week 1	Week 2(AF)	Week 3	Week 4	Sig. Effects*
9 mph or more over limit						
55 mph limits						
	Control	1.33%	3.33%	5.33%	7.33%	*n.s.*
	No-MI	9.50%	6.75%	12.00%	13.75%	
	MI	7.25%	.00%	.50%	.00%	
70 mph limits						
	Control	23.33%	16.00%	12.83%	19.33%	Week
	No-MI	13.36%	7.09%	13.72%	13.18%	
	MI	11.40%	.00%	.40%	6.90%	

*Significant effects for the 3 X 4 ANOVAs: Week = significant main effect for AF week, MI = significant main effect for Monetary Incentive Group, W x MI = significant interaction between AF week and MI, *n.s.* = the main effects and interaction were not statistically significant.

Analysis of Variance for Mean Speeds by Speed Limit Zone

Statistical approach and assumptions. The same approach used for the analysis of the percentage of time speeding was used to compare differences between the control, no-MI, and MI groups within the four weeks of driving. The computation of average speed used for the analysis excluded speed of zero. This resulted in seven 3 X 4 mixed ANOVAs, with one for each speed limit zone with sufficient degrees of freedom, i.e., 25 mph, 30 mph, 35 mph, 40 mph, 45 mph, 55 mph, and 70 mph. Outlying scores, defined as raw score values with z-scores greater than absolute 3.3, were changed so the new value was one unit greater than the next greatest score. The assumptions of normality, homogeneity of variance, and sphericity were evaluated using the same methods as the analyses for percentage of time speeding.

Mean speed on 25 mph roads. The main effects of Incentive Group and Week were not significant, $F(2,47) = 3.86$, *n.s.* and $F(3,141) = 2.26$, *n.s.*, respectively. The interaction between Week and Experimental Group was significant $F(6,141) = 4.53$, $p<.001$, partial $\eta^2 = .16$. Trend analysis indicated a significant quadratic trend for this interaction, $F(2,47) = 19.29$, $p<.001$, partial $\eta^2 = .28$. Drivers in the MI group significantly reduced their mean speed during Weeks 2 and 3 (M = 14.80 mph) relative to Weeks 1 (M = 16.60 mph) and 4 (M = 16.40 mph). The MI group's mean speed during Weeks 2 and 3 was lower than the mean speeds of the control group and no-MI group at each measurement period. The mean speed of the no-MI group during Week 4 (M = 18.2 mph) was also significantly higher than the MI group's mean speed at Week 1 (M = 16.6 mph) and Week 4 (M = 16.4 mph). Mean speed of the control and no-MI groups did not differ significantly from week to week (see Figure 20).

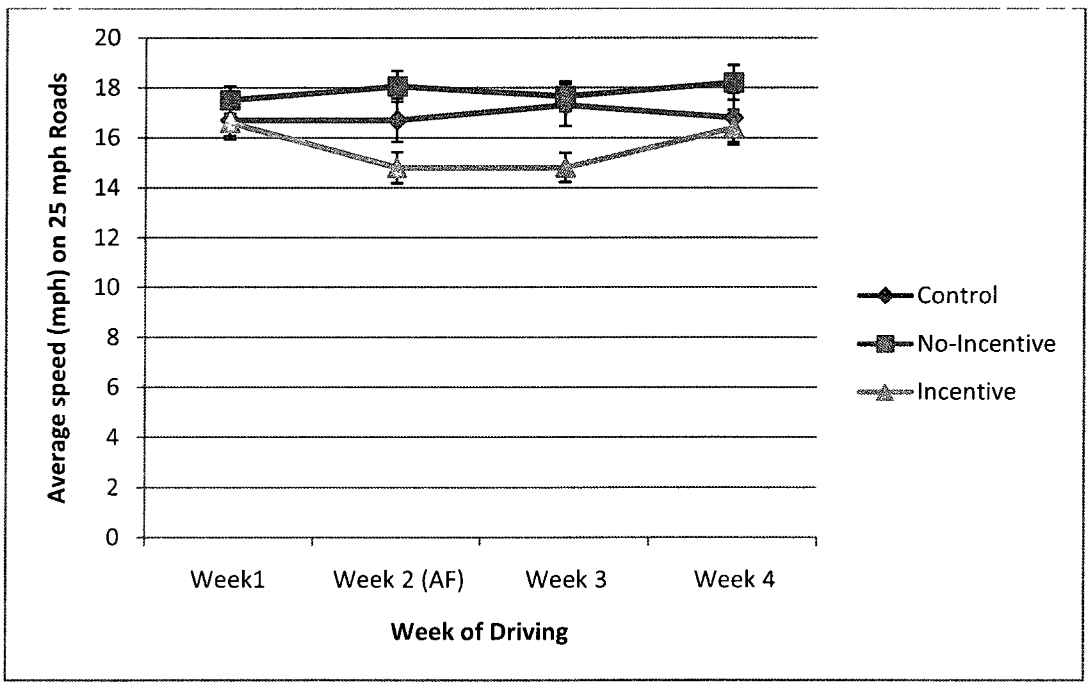

Figure 20. Average speed on 25 mph roads as a function of monetary incentive and advisory feedback.

Mean speed on 30 mph roads. The main effects of Week and Experimental Group were not significant, $F(3,102) = 2.26$, *n.s.*; $F(2,34) = 2.26$, *n.s.*, respectively. The interaction between Week and Experimental Group was significant, $F(6,102) = 4.11$, $p<.01$, partial $\eta^2 = .20$. Trend analysis indicated a significant quadratic trend for this interaction, $F(2, 34) = 4.06$, $p<.05$, partial $\eta^2 = .19$. During Week 1, the MI group drove significantly faster (M = 26.33 mph) than the no-MI group (M = 24.64 mph), but the difference between the mean speed of the control group (M = 24.86 mph) and the other two groups was not statistically significant. The control group's mean speed increased significantly during Weeks 2 (M = 27.0 mph), 3 (M = 27.0 mph), and 4 (M = 27.63 mph) relative to Week 1 (M = 24.86 mph). In contrast, drivers in the MI condition had a significantly lower mean speed during Weeks 2 (M = 24.53 mph) and 3 (M = 24.86 mph) than Week 1 (M = 26.33 mph). The MI group's mean speed during Weeks 2, 3, and 4 was significantly lower than the control group's average speed during the same weeks. In contrast, drivers in the no-MI group significantly increased their mean speed during Week 2 (M = 26.00 mph) relative to Week 1. The no-MI group's mean speed during Week 1 was significantly lower than the control group's mean speed during Weeks 2, 3, and 4. The no-MI group's mean speed during Week 2 was significantly lower than the control group's mean speed during Week 4 and the MI group during Week 1. The no-MI group's mean speed during Week 3 (M = 25.36 mph) was significantly lower than the control group's mean speed during Weeks 2 and 4. Finally, the no-MI group's mean speed during Week 4 (M = 26.07 mph) was significantly faster than the MI group's mean speed during Week 2 (See Figure 21).

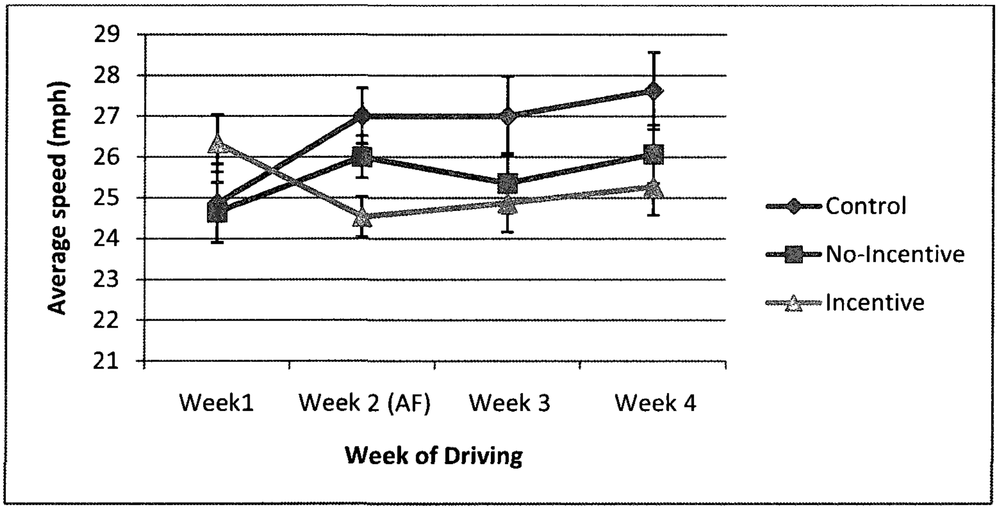

Figure 21. Average speed on 30 mph roads as a function of monetary incentive and advisory feedback.

Mean Speed on 35 mph roads. The main effect of Week was not significant, $F(3, 141) = 3.95$, *n.s.* The main effect of Incentive Group was significant: $F(2, 47) = 10.25$, $p<.001$, partial $\eta^2 =.30$, respectively. The interaction between Week and Incentive Group was significant, $F(6, 141) = 5.68$, $p<.001$, partial $\eta^2 =.20$. Trend analysis indicated a significant cubic trend for the interaction, $F(2, 47) = 10.25$, $p<.001$, partial $\eta^2 =.30$. Drivers in the MI group significantly reduced their average speed during Week 2 (M = 26.05 mph) and Week 3 (M = 26.15 mph) relative to Week 1 (M = 28.45 mph) and Week 4 (M = 27.30 mph). For the MI group, average speed during Week 4 was significantly lower than Week 1. The MI group's average speed during Weeks 2 and 3 was significantly lower than the average speed of the control group (Range 28.45 to 29.30 mph) and no-MI group (Range 28.95 to 30.15) during each week of driving. The mean speed of the no-MI group during Week 4 (M = 30.15 mph) was also significantly greater than the no-MI group's mean speed during Week 3 (M = 28.95 mph) and the control group's mean speed during Week 1 (*M* = 28.20 mph) and Week 3 (*M* = 28.70 mph). The mean speed of the control group did not vary significantly during the month of driving (See Figure 22).

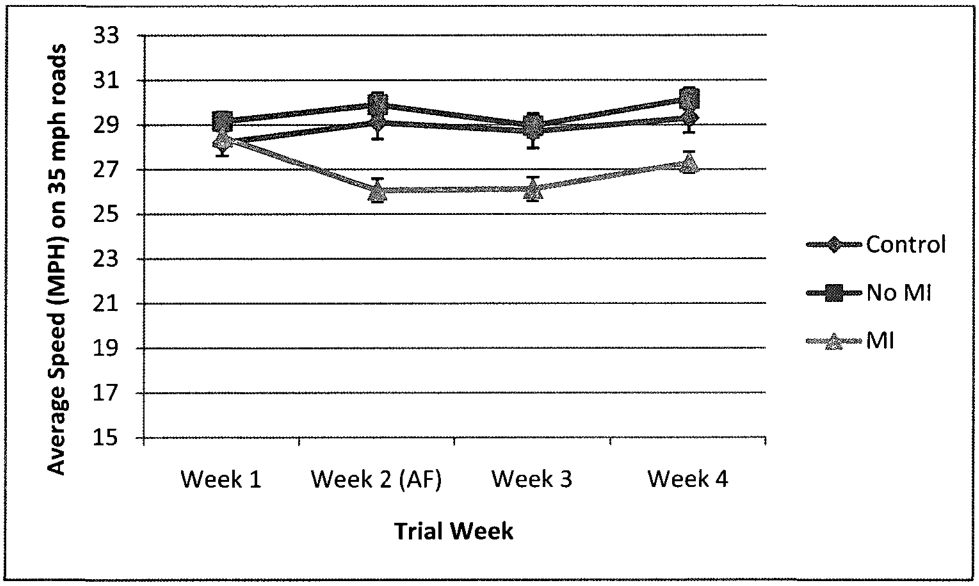

Figure 22. Average speed in 35 mph zones as a function of monetary incentive and automated feedback.

Mean Speed on 40 mph roads.. The main effects of Week and Incentive Group were not significant, $F(3, 129) = 3.61$, *n.s.* and . $F(2, 43) = 1.17$, *n.s.,* respectively. The interaction between Week and Incentive Group was not significant, $F(6, 129) = 1.63$, *n.s.*

Mean Speed on 45 mph roads. The main effects of Week and Incentive Group were not significant, $F(3, 126) = 1.34$, *n.s.*; $F(2, 42) = 1.69$, *n.s.*, respectively. The interaction between Week and Incentive Group was not significant, $F(6, 126) = 1.63$, *n.s.* Mean speed on 45 mph roads did not differ significantly within or between groups during the 4 weeks of driving.

Mean Speed on 55 mph roads. Given the reduced number of participants who drove on 55 mph roads during each week of driving, there were greater than 20 degrees of freedom for the within-subjects comparison of Week and the interaction between Week and Incentive Group, but only 8 degrees of freedom for the between-subjects comparison. Thus, the assumption of normality was violated. Sphericity and homogeneity of variance were satisfied. The main effects for Week and Incentive Group were not significant, $F(3, 24) = 1.32$, *n.s.* and $F(2, 8) = 2.00$, *n.s.*, respectively. The interaction between Week and Incentive Group was not significant, $F(6, 24) = 2.71$, *n.s.*

Mean speed on 70 mph roads. The main effects of Week and Incentive Group and the interaction between the two terms were not significant, $F(3, 72) = 3.66$, *n.s.*,$F(2, 24) = 1.79$, *n.s.*, and $F(6, 72) = .89$, *n.s*, respectively.

Miles driven per week

A 3 (Incentive Group) X 4 (Week) mixed ANOVA assessed if miles driven by each Incentive Group varied from week to week. The test of sphericity was not violated, but the Levene's test for homogeneity of variance was significant. The effect of Week was significant, $F(3, 141) = 6.16$, $p < .01$, partial $\eta^2 = .12$, observed power = .96. The Bonferroni post-hoc test indicated that drivers drove significantly more miles during Week 1 ($M = 167.91$) than Week 2 ($M = 141.90$), Week 3 ($M = 141.92$), and Week 4 ($M = 132.37$) (See Figure 26). The interaction between Incentive Group and Week was not significant, $F(6, 141) = 1.83$, *n.s.* The effect of Incentive group was not significant, $F(2, 47) = 1.17$, *n.s.* (see Figure 23).

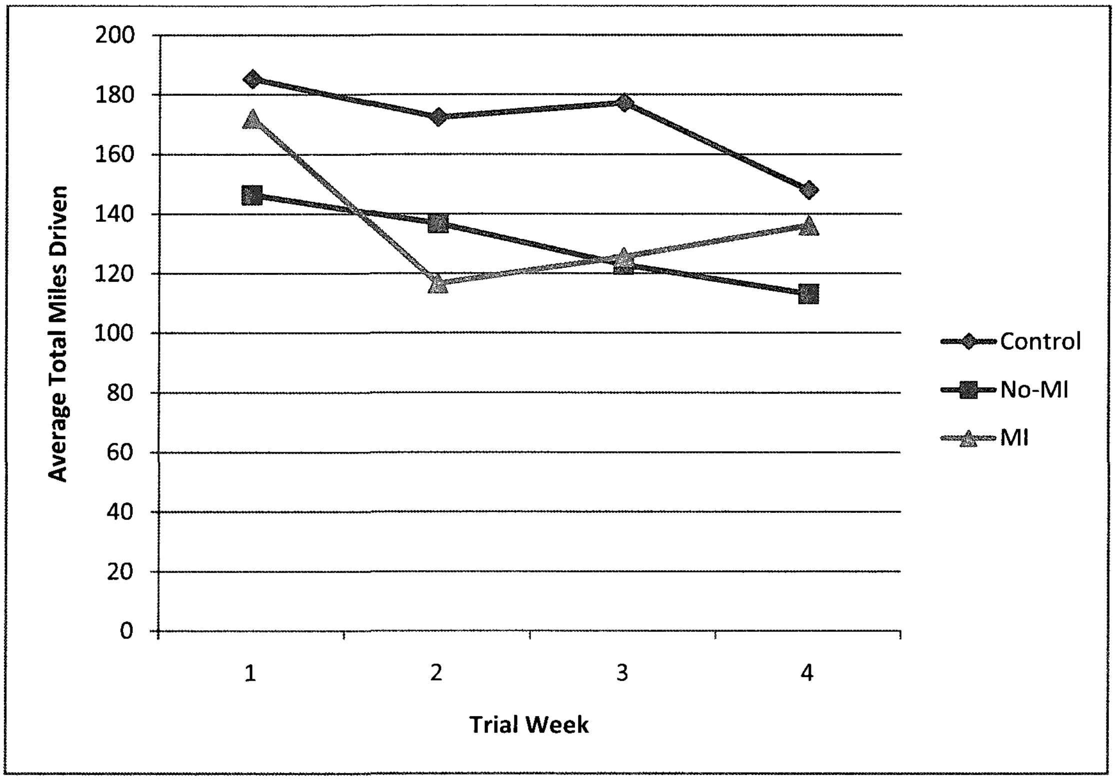

Figure 23. Average total miles driven per week by incentive group.

Perceived Mental Workload

Statistical approach and assumptions. The six dimensions of the NASA-TLX, mental demand, physical demand, temporal demand, performance, effort, and frustration, were analyzed with a series of 3 (Incentive Group) X 4 (Week) mixed ANOVAs. The automated feedback system was coded as active during Week 2 and inactive for weeks 1, 3, and 4. The incentive was available for the MI group during Weeks 2 and 3. The statistical assumptions of normality, absence of outliers, homogeneity of variance, and sphericity were satisfied, with the exception of 2 instances. Specifically, the Levene's test for homogeneity of variance for Week 3 ratings of temporal demand was significant. However, Tabachnik and Fidell (2001) state that if the *F*-max test is less than 10 then ANOVA is robust to this violation. The *F*-max value in this instance was 1.06. The second assumption violated was sphericity for the DV of physical demand. Therefore, the Greenhouse-Geisser statistic is reported for this dimension. In the following text, tests with significant interactions are reported and interpreted. Main effects are interpreted when the interaction between Incentive Group and Week was not statistically significant. Trend analyses were used as follow-up tests for significant effects.

Mental Demand. The 3 X 4 ANOVA indicated a significant main effect for Week, $F(3, 141) = 8.98$, $p < .001$, partial $\eta^2 = .16$. The effect of Incentive Group was not significant, $F(2, 47) = 3.37$, *n.s.* The interaction between Week and Incentive Group was significant, $F(6,141) = 3.68$, $p < .01$, partial $\eta^2 = .14$. The results of the trend analysis indicated a significant quadratic trend for the interaction, $F(2,43) = 8.21$, $p < .01$. The MI group's ratings of mental demand were significantly higher during Weeks 2 ($M = 6.00$) and 3 ($M = 6.25$) relative to Weeks 1 ($M = 4.75$) and 4 ($M = 3.80$). Additionally, the MI group's ratings for Weeks 2 and 3 were significantly higher than the control and no-MI groups' ratings at all four weeks. The trend analyses also indicated that the no-MI group's perceived mental demand during Week 2 ($M = 4.15$) was significantly higher than the ratings for Weeks 3 ($M = 3.30$) and 4 ($M = 2.95$). In contrast, the perceived mental demand of the control group decreased across the four weeks such that the group's Week 4 rating ($M = 3.30$) was significantly lower than Week 1 ($M = 5.10$). (See Figure 24).

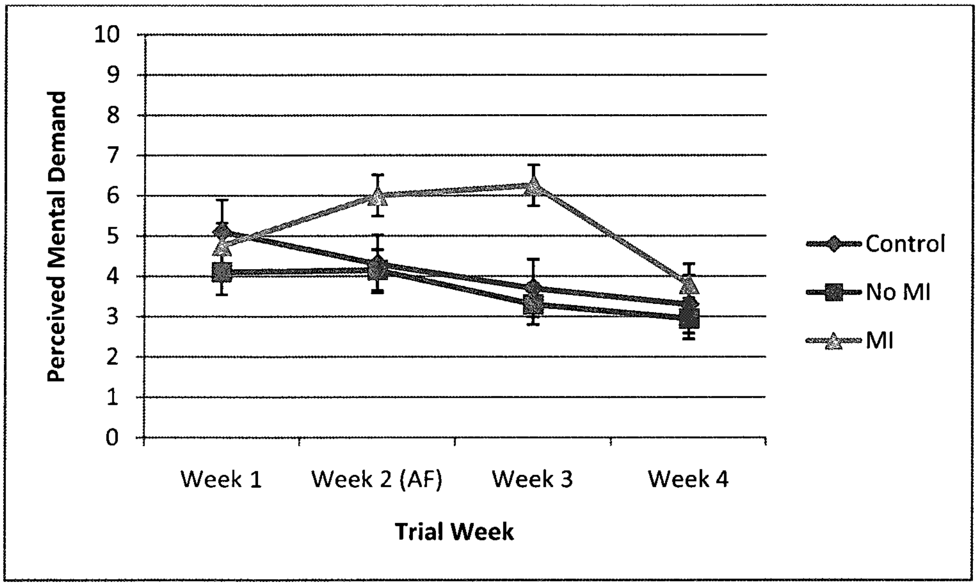

Figure 24. Perceived mental demand as a function of monetary incentive and automated feedback.

Physical demand. The ANOVA for the ratings of physical demand indicated the main effects for Week and Incentive Group were not statistically significant. The interaction between Week and Incentive Group was not significant.

Temporal demand. The ANOVA for the ratings of temporal demand indicated that the main effect for Week was statistically significant, $F(3,141) = 4.29$, $p < .01$, partial $\eta^2 = .08$. The main effect for Incentive Group was not statistically significant. The interaction between Week and Incentive Group was significant, $F(6,141) = 5.94$, $p < .001$, partial $\eta^2 = .20$. The results of the trend analysis indicated a significant quadratic trend for the interaction, $F(2,47) = 15.83$, $p < .001$, partial $\eta^2 = .40$. The MI group's ratings of temporal demand were significantly higher during Weeks 2 ($M = 4.50$) and 3 ($M = 4.75$) relative to Weeks 1 ($M = 2.45$) and 4 ($M = 2.65$). Further inspection of the estimated marginal means indicated that the MI group's ratings of temporal demand for

Weeks 2 and 3 were significantly higher than the no-MI groups' ratings during these two weeks (*M* = 3.20 *M* = 2.90 for Weeks 2 and 3, respectively). The control group's ratings of temporal demand for Weeks 3 and 4 (*M* = 3.30 for each week) was significantly lower than the MI group's Week 2 and Week 3 ratings. The controls within-group ratings did not vary reliably across the four weeks of driving nor did they vary significantly from the no-MI groups ratings (see Figure 25).

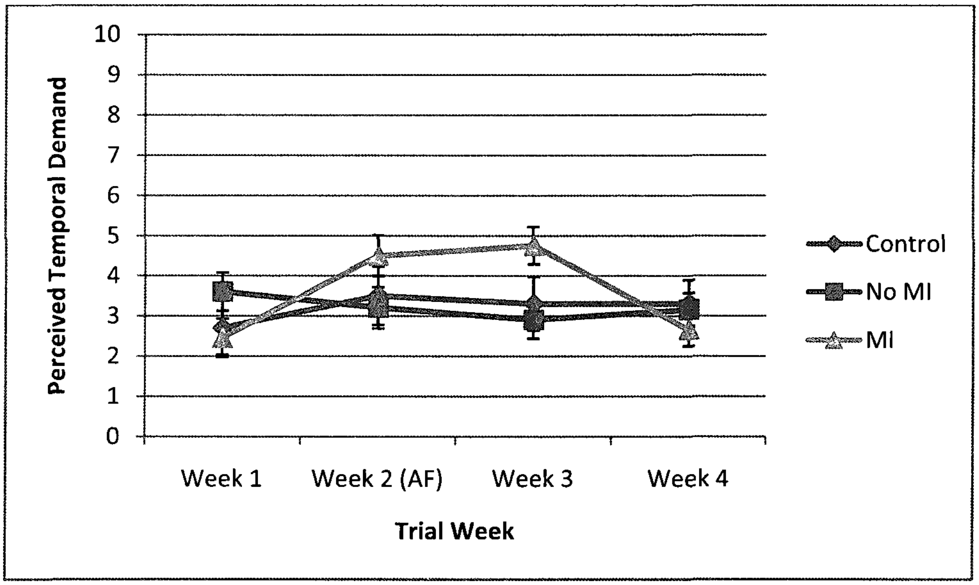

Figure 25. Perceived temporal demand as a function of monetary incentive and automated feedback.

Performance. The main effects for Week and Incentive Group were not significant, $F(3, 141) = 3.88$, *n.s.* and $F(2,47) = 1.26$, *n.s.*, respectively. The interaction between Week and Incentive Group was not significant, $F(6,141) = 2.38$, *n.s.*

Effort. The 3 by 4 ANOVA indicated significant main effects for Week and Incentive Group, $F(3, 141) = 8.43$, $p < .001$, partial $\eta^2 = .15$, observed power = .99 and

$F(2, 47) = 5.30$, $p < .01$, partial $\eta^2 = .18$, observed power = .81, respectively. The interaction between Week and Incentive Group was also significant, $F(6,141) = 5.11$, $p < .001$, partial $\eta^2 = .18$, observed power = .99. The results of the trend analysis indicated a significant quadratic trend for the interaction, $F(2,43) = 10.61$, $p < .001$. Examination of the group means at each measurement period indicated that the MI group's ratings of effort were significantly higher during Week 2 ($M = 5.60$) and 3 ($M = 6.10$) relative to Weeks 1 ($M = 3.65$) and 4 ($M = 3.30$). Additionally, the MI group's ratings of perceived effort for Weeks 2 and 3 were significantly higher than the control and no-MI groups' ratings at all four weeks (Range = 2.60 to 3.60). The trend analyses also indicated that the no-MI group's perceived effort during Week 2 ($M = 3.60$) was significantly higher than ratings for Week 1 ($M = 2.60$) but not Weeks 3 ($M = 3.30$) or 4 ($M = 3.30$). The control group's ratings of perceived effort did not vary across the month (see Figure 26).

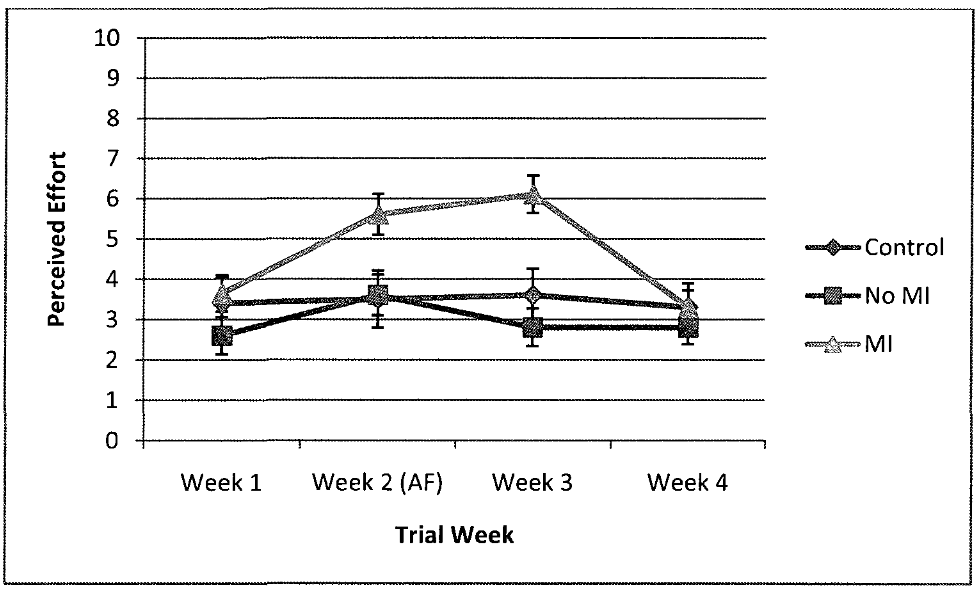

Figure 26. Perceived effort as a function of monetary incentive and automated feedback.

Frustration. The 3 X 4 ANOVA indicated a significant main effect for Week, $F(3, 141) = 20.43$, $p < .001$, partial $\eta^2 = .30$. The main effect for Incentive Group was not significant, $F(2, 47) = 3.82$, *n.s.* The interaction between Week and Incentive Group was significant, $F(6,141) = 4.75$, $p < .001$, partial $\eta^2 = .17$. The results of the trend analysis indicated a significant quadratic trend for the interaction, $F(2,43) = 9.64$, $p < .01$. Inspection of the group means at each measurement period indicated that the MI group's ratings of frustration were significantly higher during Week 2 ($M = 6.05$) and 3 ($M = 5.35$) relative to Weeks 1 ($M = 2.90$) and 4 ($M = 2.35$). Additionally, the MI group's ratings for Weeks 2 and 3 were significantly higher than the control groups' ratings at all four weeks (Range = 2.90 to 3.90); the MI group's Week 2 rating was significantly higher than the no-MI group's Week 2 ($M = 4.90$) rating. The no-MI group's rating of frustration during Week 2 was higher relative to Week 1 ($M = 2.05$), 3 ($M = 2.80$), and 4 ($M = 2.35$) (see Figure 27). Table 8 is a summary of the 6 ANOVAs associated with mental workload.

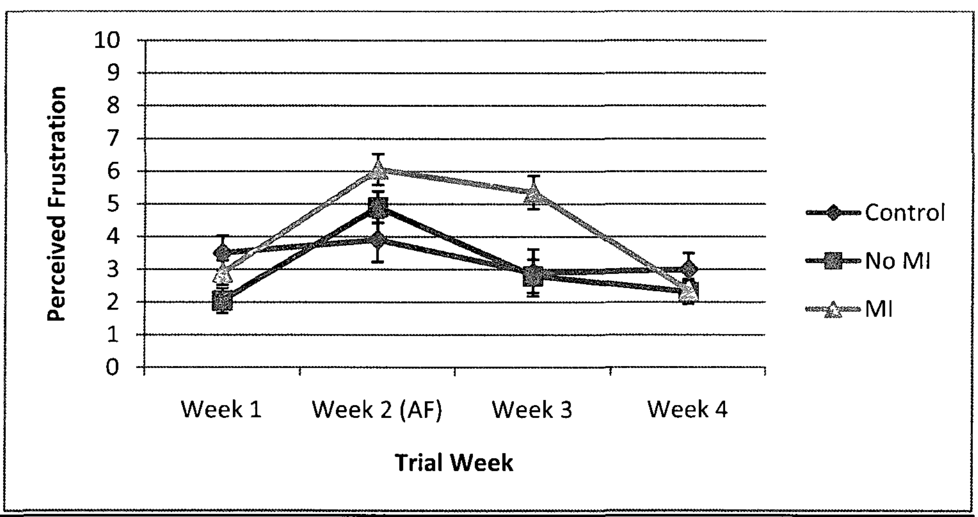

Figure 27. Perceived frustration as a function of MI and AF.

TABLE 8: Analysis of Variance for the Six Dimensions of the NASA-TLX.

Source	*df*	*F*	*partial* η^2	*p*
Dimension 1: Mental Demand				
Between Subjects				
Group (G)	2	3 34*	13	04
Error	47	(15 20)		
Within Subjects				
Week (W)	3	8 99***	16	00
G X W	6	3 68**	14	00
Error	141	(2 18)		
Dimension 2: Physical Demand				
Between Subjects				
Group (G)	2	1 31	05	28
Error	47	(15 20)		
Within Subjects				
Week (W)	3	2 62	05	05
G X W	6	2 34*	09	04
Error	141	(2 18)		
Dimension 3: Temporal Demand				
Between Subjects				
Group (G)	2	29	01	75
Error	47	(15 20)		
Within Subjects				
Week (W)	3	4 29***	16	00
G X W	6	5 94***	20	00
Error	141	(2 18)		

*$p <$ 05 ** $p <$ 01 *** $p <$ 001 Values in parentheses are mean square errors The Between Subjects variable "Group" represents the control, incentive, and no incentive/feedback only groups The Within Subjects variable "Week" represents the four consecutive weeks of driving, with feedback coded as occurring in Week 2 or 3 Only tests with p values < 01 were interpreted as statistically significant

TABLE 8 Continued

Source		df	F	partial η^2	p
Dimension 4: Performance					
	Between Subjects				
	Group (G)	2	1 26	05	29
	Error	47	(15 20)		
	Within Subjects				
	Week (W)	3	3 88*	08	01
	G X W	6	2 38*	09	03
	Error	141	(2 18)		
Dimension 5: Effort					
	Between Subjects				
	Group (G)	2	5 30**	18	01
	Error	47	(15 20)		
	Within Subjects				
	Week (W)	3	8 43***	15	00
	G X W	6	5 11***	18	00
	Error	141	(2 18)		
Dimension 6: Frustration					
	Between Subjects				
	Group (G)	2	3 82*	14	03
	Error	47	(15 20)		
	Within Subjects				
	Week (W)	3	20 43***	30	00
	G X W	6	4 75***	17	00
	Error	141	(2 18)		

*p < 05 ** p < 01 *** p < 001 Values ın parentheses are mean square errors

Trust and Acceptance of Automated Feedback.

Participants in the MI and no-MI group completed the eight item Trust and Acceptance scale at the end of the week that they drove wıth AF. The partıcipants rated each item on a scale from 1 to 10 with one ındicating complete dısagreement and 10 ındicating complete agreement. Independent samples t-tests were conducted on each ıtem of the scale to test for dıfferences ın perceıved trust and acceptance of the AF system as a function of incentive group. Mıscommunicatıon between the experimenter and research assistant about the administration of the scale resulted in five missing data sets for the MI group. Specifically, during the AF week, the MI participants were to complete the trust and acceptance scale twice. The first iteration was to provide ratings about the feedback system, and the second iteration was to provide ratings about the monetary incentive system. However, the first five MI participants completed the scale only once, and the research assistant did not specify which system these participants were rating. Therefore it is unclear whether these five individuals were rating the AF system, the MI system, or a combination of the two systems. Thus, the five data sets were removed from the analysis prior to completing the t-tests.

Of the eight analyses, only the test for the statement, "the speed warning system was trustworthy" was marginally statistically significant, $t(33) = 2.44$, $p < .05$. Drivers in the MI group rated the system as being less trustworthy ($M = 6.80$) than drivers in the no-MI group ($M = 8.40$). The remaining seven analyses were not statistically significant (see Table 5). Seven of the eight items (perceived reliability, predictability, trust, acceptability, annoyance, accuracy, and agreeability) received mean ratings above six for both groups. Both groups' ratings for perceived pleasantness were less than five.

TABLE 9: Mean Ratings and *t*-coefficients for Trust and Acceptance of the AF system.

Item	N	Mean (Std Dev)	t	df
The speed warning system was:				
Reliable				
No-MI	20	7.95 (2.33)	1.48	33
MI	15	6.87 (1.88)		
Predictable				
No-MI	20	8.50 (1.57)	1.49	33
MI	15	7.67 (1.72)		
Trustworthy				
No-MI	20	8.40 (1.76)	2.44*	33
MI	15	6.80 (2.11)		
Acceptable				
No-MI	20	6.95 (2.62)	-.66	33
MI	15	7.47 (1.77)		
Pleasing				
No-MI	20	3.40 (1.90)	-1.38	33
MI	15	4.33 (2.09)		
Annoying				
No-MI	20	7.40 (2.46)	.77	33
MI	15	6.53 (2.66)		
Accurate				
No-MI	20	7.65 (2.37)	1.42	33
MI	15	6.53 (2.20)		
Agreeable				
No-MI	20	6.50 (2.56)	.54	33
MI	15	6.07 (1.98)		

* $p < .05$

Trust and Acceptance of Monetary Incentive System.

Participants who were in the MI group completed the trust and acceptance scale at the end of each week that they drove with the opportunity to earn the cash incentive. A paired sample *t*-test assessed whether ratings of the incentive system differed as a function of activation of the AF system. As with the trust and acceptance ratings, the miscommunication between the experimenter and research led to five missing data sets for the analysis. None of the *t*-tests were statistically different (see Table 6).

TABLE 10: Mean Ratings and *t*-coefficients for Trust and Acceptance of the MI system.

Item	N	Mean (Std Dev)	t	df
The incentive system was:				
Reliable				
MI only	15	8.40 (1.99)	-.35	14
MI+AF	15	8.60 (1.59)		
Predictable				
MI only	15	7.27 (2.22)	-1.68	14
MI+AF	15	8.20 (1.52)		
Trustworthy				
MI only	15	8.07 (2.43)	-.61	14
MI+AF	15	8.40 (1.30)		
Acceptable				
MI only	15	9.20 (1.21)	1.38	14
MI+AF	15	8.60 (1.55)		
Pleasing				
MI only	15	8.00 (1.77)	-1.21	14
MI+AF	15	8.67 (1.29)		
Annoying				
MI only	15	4.40 (2.32)	1.61	14
MI+AF	15	3.27 (2.12)		
Accurate				
MI only	15	8.13 (2.00)	.89	14
MI+AF	15	7.60 (1.99)		
Agreeable				
MI only	15	8.66 (1.40)	.72	14
MI+AF	15	8.33 (1.23)		

Debriefing Survey Results

At the end of the four week trial each participant completed an eight item questionnaire designed to gather feedback from the participants about the AF and MI conditions that they experienced. Participants rated on a scale from 1 to 10, the extent to which they agreed with statements about the systems' overall usefulness, safety benefits, and their hypothetical willingness to keep the systems given various conditions. Participants in the no-MI condition rated their experience with the AF system. Participants in the MI condition rated the combined experience of the MI and AF systems. Thus, descriptive analyses were completed separately for the MI and no-MI conditions (see Tables 7a and 7b). One item, "I would keep the system if I had to pay for it," had an open ended follow-on question, which was, "How much would you pay?" Only two of the 20 no-MI participants indicated that they would pay for such a system, in contrast to eight of the 20 MI participants.

TABLE 11: Descriptive Analysis of Responses to Debriefing Survey, no-MI participants.

Item*	N	Mean	Std. Dev.
"I found the system useful."	20	6.05	1.57
"The system improves traffic safety."	20	6.45	2.34
"The system makes me a better driver."	20	4.85	2.81
"I would keep the system if it were free."	20	4.05	3.56
"I would pay to keep the system."	2	2.20	2.21
"How much would you pay?"	2	$5.00	---
"The system would be helpful for novice drivers."	19	7.68	2.11
"I would keep system if offered an insurance discount."	18	6.72	3.08

* All items except "How much would you pay to keep the system" were answered on a scale of 1 to 10, with 1 indicating full disagreement and 10 indicating full agreement.

TABLE 12: Descriptive Analysis of Responses to Debriefing Survey, MI Participants.

Item	N	Mean	Std. Dev.
"I found the system useful."	20	6.95	2.11
"The system improves traffic safety."	20	6.85	2.60
"The system makes me a better driver."	20	6.25	2.84
"I would keep the system if it were free."	20	5.25	2.91
"I would pay to keep the system."	20	2.05	1.65
"How much would you pay?"	8	$54.38	$33.96
"The system would be helpful for novice drivers."	19	8.11	1.94
"I would keep system if offered an insurance discount."	18	8.61	1.58

Responses to open-ended questions at debriefing meeting

The final portion of the debriefing meeting consisted of the research assistant asking participants a series of questions to gather information about their approval of the MI or AF systems and suggestions for improvement of them. Several participants indicated that the auditory component of the AF system was unpleasant. However, there were some individuals who indicated that the auditory component was acceptable and should have been louder. Participants reported that the incentive system was acceptable and was largely responsible for their reductions in speeding. Suggestions for improvement largely focused on the AF system, although there were some recommendations associated with the incentive system (see Table 8). The complete responses as transcribed by the research assistant, are in Appendix B.

TABLE 13: Sample Responses to Open-ended Debriefing Quesitons.

Question	Sample Responses
What features of the system did you like?	"Information of speed limits " "It was effective the visual and auditory component that acted as a flag " "The incentive based part of the system, but I also liked that the tone wasn't overwhelming " "that it was very accurate and reliable " "Uhm I mean know when to slow down when I was speeding " "Useful going downhill with speed change" "some roads had no signs, I liked knowing the limit " "Getting paid to do normal behaviors – made me more cognizant of how fast I was going " "It beeped and gave me enough time as a buffer " "None "
What features of the system did you dislike?	"It was not built into the vehicle " "Auditory component was punishing " "Sometimes (the beep) would make me feel a little stressed out " "That once I was over it would immediately take money, it would be nice if I could slow down if there was a time delay " "The inability to turn the system off " "The audio tone – there was some situations that I would rather speed and take the risk but couldn't because of the irritation of the noise " "Some-times the numbers were inaccurate so that was more distracting than helpful " "The loud beeping scared the crap out of me several times, and how it didn't display the money all the time " "Too quiet and the hardware is ugly " "That it wasn't optional " "Errors in feedback and stressful " "On the highway it seemed set too low "
How would you change to make it more effective?	"Have the sound run through the speakers of the car " "Make it so you could change the beep" "Maybe if it weren't such an aversive sound, maybe just a bell to remind you maybe it would be a little bit more acceptable " "Make it a voluntary thing, you could flip the switch and turn it on when you needed it " "Make audio alert not so annoying "a larger (visual) display " "Less aversive tone maybe ""Make it louder, and make it so it won't go away unless you do something about it " Brighter more beeps " "Make tone more annoying " "More accuracy about the speed "
How would you make it more acceptable?	"Would not change " "Offer a selection of warning tones " "Make it less aversive " "Just make the incentive to drive the speed limit more just the fact that it is the safer thing to do rather than just annoy the piss out of you " "No beeps but I don't know if it would be as effective " "Have it start beeping at 9 over instead of 6 over " "Ability to turn off and on " "Get rid of audible, just visual " "Voice instead of the beep "
Do you have any other feedback about the system?	"It would be good for if you were under the influence of drugs or alcohol so that you could know when you were speeding to avoid being pulled over " "It would also be good for informational purposes for new cities to know

TABLE 12 Continued

	speed information." "it was very straight forward it did what it was said it was going to do, I think it could be useful in certain changes and circumstances." "Second beep not as helpful because by that point I knew." "Pretty sweet, maybe a breathalyzer tied in."
What affected your decision to speed?	"Self competition and the money." "Need vs reward thing - in the moments I sped I did so knowing I would lose money but I did because I needed to be somewhere faster." "The penalty." "Trying to be successful not about money I didn't want to fail the test."

Tests of correlations

Self report and behavioral measures. At different times during the experimental trials, participants provided responses to many self-reported questionnaire items, and tests of the Pearson's correlation coefficient were completed to examine relationships of interest. These tests of correlation were completed to assess the relationships between attitudes about sensation seeking, self-reported non-speeding related risky driving behaviors, self-reported beliefs about speeding, and observed speeding behaviors. A second set of correlations assessed the relationships between self-reported computer use, general trust in technology, and ratings of trust and acceptance of the AF and MI. Tests of correlation were also completed to determine the extent of the relationship between NASA-TLX ratings and Trust and Acceptance ratings of the AF and MI. Finally, correlations were computed to assess the relationship between the trust and acceptance ratings and responses provided during the debriefing session at the end of the trials. Only relationships with a p value < .01 were considered statistically significant.

Self-reported beliefs about speeding, seatbelt and cellular phone use, observed speeding. At the end of the first week of experimental trials, participants answered questions about speeding, seatbelt use, and cellular phone use. Four questions asked participants to indicate how fast they could drive before police pulled them over for speeding on roads that were 55 mph or faster, 45 mph or faster, 40 mph or greater, and 35 mph or slower. Participants also indicated on a scale of 1 to 5 how often they wore their seatbelts, with 1 indicating never and 5 indicating always. Participants also indicated how often they talked on cellular phones while driving with 1 indicating on all trips and 5 indicating they never talked while driving. These self-report items were correlated with 12 measures of observed speeding. The 12 measures were the percentage of time spent driving (1) 1 to 4 mph over the speed limit, (2) 5 to 8 mph over the speed limit, and (3) 9 or more mph over the speed limit. There was one score for each of these percentages for each week of driving. There were few significant correlations between the self-report beliefs about speeding and observed speeding, and only the significant results are discussed in text.

There were 72 tests of the Pearson's correlation coefficient to assess the strength of the relationship between the 12 observed measures of speeding behavior and the 6 self-report measures of beliefs about speeding and use of seatbelts and cellular phones. There was one significant positive correlation between the self report measures of driving behavior and observed speeding. The two correlated variables were self-reported frequency of seatbelt use and the percentage of time driving 5 to 8 mph over all speed limits during Week 4, $r(50) = .33$, $p < .01$. Drivers who indicated that they wore their belt more frequently tended to spend a greater amount of time driving 5 to 8 mph over all speed limits during Week 4.

Sensation seeking and observed speeding. At the end of the first week of the four week trial, participants completed an abbreviated 4-item sensation seeking measure. Scores for these four items were correlated with 12 observed measures of speeding. The measures of observed speeding were the percentages of time spent driving 1 to 4 mph over the limit, 5 to 8 mph over the limit, and 9 or more mph over the limit. The statement, "I like to explore strange places" was significantly negatively correlated with the percentage of time spent driving 1 to 4 mph over the speed limit during Week 2, $r(50) = -.38$, $p < .01$. Drivers who indicated a preference for exploring strange places tended to spend less time driving 1 to 4 miles per hour over the limit during the second week of driving. The statement, "I like new and exciting experiences even if I have to break the rules" was significantly positively correlated with the percentage of time driving 9 or more mph over the limit during Week 4, $r(50) = .37$, $p < .01$. Participants who indicated a preference for new and exciting experiences tended to spend more time driving 9 or more mph over the limit during the final week of driving.

Correlations between acceptance of technology and trust and acceptance of AF. At the end of the first week of the trials, participants completed five questions about the extent to which they felt comfortable using a computer for browsing the web, writing email, programming, gaming, and word processing. Three additional questions were included to gather data about participants' trust and acceptance of technology in general. These additional questions included preference for self checkout lines, manual completion of tasks, and general suspicion of new technologies. There was one significant positive correlation between preference for using self checkout lines and how agreeable the participants found the AF system, $r(50) = .37$, $p < .01$. Individuals who found the AF system to be agreeable tended to indicate a preference for self checkout lines.

Correlations between Perceived Mental Workload and Trust and Acceptance of AF. Pearson's correlation coefficients were computed to assess the relationship between the 6 dimensions of the NASA-TLX (i.e., mental demand, physical demand, temporal demand, performance, effort, and frustration) and the eight items of the trust and acceptance scale (i.e., ratings of reliability, predictability, trustworthiness, acceptability, pleasantness, annoyance, accuracy, and agreeability). Thus, there were 48 tests to compare each item on the NASA-TLX with each item of the trust and acceptance scale. Ratings of mental demand were negatively correlated with ratings of trustworthiness, $r(35) = -.44$, $p < .01$. Individuals who rated the AF system as mentally demanding tended indicate that the AF system was not trustworthy. Ratings of temporal demand were negatively correlated with ratings of predictability, $r(35) = -.59$, $p < .001$. Individuals who rated the AF system as temporally demanding tended to give low ratings for predictability.

Correlations between trust, acceptance, usefulness, and willingness to keep AF. Pearson's correlation coefficients were computed to test the relationships between the eight ratings of trust and acceptance of the AF system and six ratings provided by participants at the end of the experimental trials. The six items were to gather data about perceived use and willingness to keep the system. Participants rated the following statements, “I found the system useful;” “The system improves traffic safety;” “The system makes me a better driver;” “I would keep the system if I had to pay for it;” “I would keep the system if it were free;” and “I would keep the system if offered an insurance discount.” There were no significant correlations between the trust scale and the ratings of perceived usefulness and willingness to keep.

Correlations between perceived mental workload, usefulness, and willingness to keep. A final set of significance tests of Pearson’s correlation coefficients assessed the relationships between mental workload ratings of the AF system and the six ratings of perceived usefulness and willingness to keep the system. Ratings of mental demand were positively correlated with perceived improvement to driving, $r(40) = .55$, $p < .001$. Participants who indicated that the AF system was mentally demanding tended to report that the system improved their driving. Ratings of temporal demand were also positively correlated with perceived improvement to driving, $r(40) = .56$, $p < .001$. Participants who indicated that driving with the AF system was temporally demanding tended to indicate that the system made them better drivers. Ratings of effort were positively correlated with perceived improvement to driving, $r(40) = .55$, $p < .001$. Participants who found driving with the AF system to be effortful tended to perceive that the system improved their driving.

Summary of Results

The four sets of eight ANOVAs that tested the effects of MI and AF on the proportion of time in various speed ranges indicated several significant effects for the incentive and limited effects for the automated feedback system. Six of eight ANOVAs indicated interactions in which drivers in the MI group significantly increased the amount of time driving at or below the limit during Weeks 2 and 3 relative to the baseline week. In contrast, the control and no-MI drivers did not change the amount of time driving at or below the limit across the four weeks. Two of eight analyses indicated that drivers increased the percentage of time driving 1 to 4 mph over the limit during Week 2.

Eight of the 16 ANOVAs that tested the percentage of time driving 5 to 8 mph over the limit and 9 or more mph over the limit indicated significant interactions between MI and AF. In each interaction, drivers in the MI group significantly decreased the percentage of time driving 5 to 8 mph over and 9 or more mph over the limit during Weeks 2 and 3. In one of these interactions (percent of time driving 5 to 8 mph over all speed limits combined), drivers in the MI group spent a lower percentage of time during the week with AF than Week 3 with MI only. Otherwise, the differences between MI + AF and MI only conditions were not statistically significant. Four of these eight interactions indicated that drivers in the no-MI group decreased the percentage of time spent driving in these speed ranges during Week 2 when they drove with AF. Of the eight ANOVAs that did not show a significant interaction, five indicated a significant effect for the repeated measure of Week. Drivers reduced the amount of time driving over the limit, primarily during Week 2 when the AF was active for the MI and no-MI group. Three of the eight ANOVAs that tested the effects of AF and MI on average speeds indicated that drivers in the MI group had lower average speeds in weeks 2 and 3 relative to their baseline week and to the no-MI and control groups.

The analyses of perceived mental workload as measured by the NASA-TLX included six ANOVAs to test the effects of MI and AF on each of the six dimensions of mental workload (i.e., mental demand, physical demand, performance effort and frustration.) Drivers in the MI group indicated that driving during Weeks 2 and 3 was more mentally demanding relative to Week 1 or Week 4 or to the Control or no-MI groups. The higher perceived mental workload of the MI group during Weeks 2 and 3 was apparent from the analysis of four of the six workload dimensions. Results from the analyses of the dimensions of effort and frustration provided some indication that drivers in the no-MI group found Week 2 to be more demanding than other weeks of driving. The control group's ratings of perceived mental demand generally remained unchanged during the trial.

T-tests assessed differences of perceived trust and acceptance of the AF system as a function of assignment to Incentive Group (MI or no-MI). Of the eight tests, only one was marginally significant. Participants in the MI group rated the AF system as less trustworthy than the no-MI group. Both groups of participants tended to agree that the AF system was reliable, predictable, accurate, agreeable, trustworthy, and acceptable, but they also agreed that the system was annoying and indicated it was not pleasing. Paired sample *t*-tests assessed differences in trust and acceptance ratings of the MI system as a function of the presence or absence of AF. The tests of the eight items indicated that the differences between ratings of MI during Week 2 (with AF) and Week

3 were not statistically significant. MI participants indicated a high degree of agreement with each of the eight statements, with one exception: they disagreed with the statement, "The MI system was annoying."

Several tests of correlation assessed the strength of relationships between several constructs and observed measures. Self report beliefs about speeding were generally not related to observed speeds. There were several significant correlations between sensation seeking and observed speeding, with individuals who scored high on sensation seeking items tending to spend less time speeding in the 1 to 4 mph range and more time in the 9 mph or more over the limit range. There were few significant correlations between questions about acceptance and familiarity with technology in general and trust and acceptance of the AF system, although there was some indication that acceptance of the AF system increased with preference for technology. In contrast, there were significant correlations between perceived mental workload and trust and acceptance of the AF system that indicated increases in perceived workload were accompanied by decreases in trust and predictability. Finally, there were several correlations that indicated increased mental demand was associated with increased perceived improvement to driving.

DISCUSSION

There were two linked goals in this test of a prototype ISA system. Principles of behavioral psychology were used to construct the contingency associated with the monetary incentive in such a manner that would maximize the reduction of speeding behavior. The theoretical constructs of mental workload and trust in automation were measured throughout the study to assess the extent to which the prototype system might threaten traffic safety or be unacceptable to drivers. Based on the literature review several hypotheses were generated regarding the expected effects of the automated feedback and monetary incentive on speeding behavior, mental workload, and trust and acceptance of the prototype system. Thus, the following discussion of the results is presented in conjunction with the related hypotheses.

Effects of Monetary Incentive and Automated Feedback on Observed Speeding

The first predictions were about the expected effect of monetary incentive (MI) and automated feedback (AF) on observed speeding. There was an interaction predicted between the monetary incentive (MI) and the automated feedback (AF). The combination of MI and AF was predicted to result in significantly lower speeds than the MI-only, AF-only conditions, baseline, and control conditions. The three experimental conditions (MI only, MI+AF, and no-MI + AF) were predicted to result in lower speeds during the treatment periods than the control group. The independent variables were manipulated in a manner that resulted in a 3 X 4 factorial design, with three incentive groups (MI, no-MI, and control) and 4 weeks of driving (with AF coded as occurring during Week 2 for the MI and no-MI groups). Therefore, the greatest effect was expected for the MI group during Week 2.

The results indicated large effects for the interaction between Week and Incentive group. However the interactions obtained from the inferential tests were, with one exception, different from the predicted interaction. Specifically, drivers in the incentive group dramatically changed their speeding behavior during Weeks 2 and 3, relative to Week 1 and to the control group's measures during all four weeks of driving measures and, typically, the no-MI group's measures at all four weeks. The incentive was in place during Weeks 2 and 3 only. The reduction in speeding behavior during these two weeks was manifested by several measures. These measures included speeding at 5 to 8 mph over the limit, 9 or more over the limit, driving at or below the speed limit, and analyses of average speed at several different speed limits. In fact, drivers in the MI group essentially eliminated speeding that would have resulted in a reduction to their bonus amount: these drivers drove at 9 or more mph over all speed limits less than 1% of the time during Weeks 2 and 3. The change in the MI group's speeding behavior during Week 2 was very similar to the change observed during Week 3. There was only one instance in which the combination of MI and AF resulted in less speeding than the MI condition alone.

Given the results, it is clear that there was little added effect of the AF system for the participants in the incentive group, and it is reasonable to conclude that the incentive condition as used in the current study (to include the incentive display) provided strong motivation to adhere to the speed limits. This finding was the primary difference between the predicted and observed results. The hypothesized interaction was based on literature that indicates pairing feedback in conjunction with a reward results in optimal behavior change (e.g., Balcazar et al., 1986). One possible explanation for the lack of difference between the MI-only and the MI +AF conditions could be the design of the MI system. The incentive amount was displayed to drivers in the MI group at the start and end of every trip made during Weeks 2 and 3. This manner of presenting information about the incentive to the drivers may have constituted a form of immediate feedback to the drivers. In other words, providing the incentive amount at the start and end of every trip may have been sufficient information for participants to gauge their performance on maintaining speed limits, and thus the incentive display may have become a stronger conditioned reinforcer than the AF system. An interesting research question is the extent to which speeding behavior differed as a function of the presence or absence of this incentive display. It would be necessary to demonstrate that the change in speeding behavior without the incentive display was similar to the change with the display to conclude that the incentive alone was the causal mechanism.

As to whether the change in speeding behavior observed among the drivers in the MI group was due to the incentive alone or the combination of the incentive display and incentive itself, there were several comments made by the participants made during the debriefing interview that support the conclusion that the incentive condition effectively changed behavior. However, the comments reveal differing explanations for why the incentive condition affected their driving. Some participants in the incentive group indicated that the agent for their behavior change was self-competition. These individuals indicated that what changed their behavior was the notion that they were trying to "win" or trying not to "fail", which the drivers defined as keeping the full incentive. Thus, it appears that for some participants in the MI group, driving and keeping the incentive became a form of internal motivation. Researchers such as Deci et al (1999) argue that external motivators undermine intrinsic motivation, stating that the rewards undermine self-determination and competence. However, in the current project, the presence of the external motivator seems to have resulted in exactly what Eisenberger and Cameron (1996) argue in opposition to theorists such as Deci. Specifically, the comments made by participants suggest that the incentive presented an opportunity for them to use the incentive to bolster their self-determination to observe the speed limit. Thus, the external reward actually increased intrinsic motivation for these individuals.

In contrast to drivers in the MI group who indicated they changed speeding behavior as a result of making the contingency a challenge, other drivers in the MI group indicated that it was either the opportunity to earn money or the threat of losing it that caused them to change their speeding behavior. These findings do not support opponents of external motivators, nor do these statements indicate that the quality-dependent reward led to an increase in intrinsic motivation. However, the results do support Benabou and Tirole (2003), who reviewed studies in which monetary incentives were used to motivate behavior. The reviewers concluded that when an individual finds a task to be relatively unpleasant, such as helping someone move furniture, incentives are successful in motivating individuals to complete the desired task. In the current project many drivers indicated that they would have preferred to speed but were motivated by the incentive to adhere to the posted speed limits.

A potential future application of this research, provided that the technology continues to become more viable, is for insurance companies to offer premium discounts for drivers who have this type of alerting technology in their vehicles. The current results have implications for the structure of the incentive system. Specifically, the responses indicate that some drivers changed their behavior because of the intrinsic reward of "performing well" rather than "making twenty-five dollars." The motivation to change driving behavior for the former reason may allow a reward structure that maximizes behavior change with minimal cost to insurers. For example, drivers may be motivated if performance and any subsequent discount were based on the percentage of time that they were within a certain range of the speed limit, rather than a finite dollar amount. However, future research would be needed to determine optimal incentive structure because only a segment of the participants indicated that there was intrinsic motivation to lower speed.

Minimizing the cost to insurers would be a key factor if this type of system were to be applied in real world settings because the results provided mixed support for a persistence effect of the incentive. If the change to speeding behavior exists only in the presence of the incentive then the implications for insurance discounts are clear – the incentive may have to be offered indefinitely. In the current project during the return to baseline period, speeding frequently returned to levels recorded during the first week of the trial. However, there were several analyses in which levels of the dependent variables for drivers in the incentive condition during Week 4 indicated less speeding than Week 1. Thus, the prediction of no residual effects during Week 4 was not entirely correct, and these findings contrast with Regan et al. (2006) who found no persistence effect in their study of advisory and interactive ISA.

One explanation for the finding of some persistence effect in the current study may be that the presence of the monetary incentive led to a lasting behavior change for individuals in the MI group. Another reason for the finding is that the return to baseline period in the current project was not as long as those in the Regan et al. study. A final explanation for the limited persistence effect is that a portion of drivers in the MI group made a lasting change to their speeding behavior, and the remaining participants in the MI condition returned to baseline speeding behaviors. This explanation would be supported by Geller, Berry, Ludwig, Evans, et al. (1990) who suggest that lasting safety related behavior change takes varying degrees of effort, with significantly more effort needed for high risk individuals than low risk individuals. Further research would be needed to determine which of these explanations for the persistence effects is valid. However, the mixed support for lasting behavior change and the large effect that the incentive had when in place during Weeks 2 and 3 indicate that it may be necessary for real world insurance premium reductions to be in place for a long period of time to maintain the change in speeding behaviors. For example, it may be necessary to keep such a system in place from age 16 to 24, when crash rates are highest, to achieve continued behavior change.

The incentive had a clear, strong impact on speeding behavior, but the same conclusion cannot be made about the AF system. Based on previous research on advisory level ISA (e.g., Biding and Lind, 2002; Harms et al. 2007) and on research that suggested a significant portion of drivers ticketed for speeding were unaware of the speed limit when they were caught, it was hypothesized that there would be a reduction in speeding due to the AF alone. There was limited evidence to suggest that the presentation of the alert provided an added benefit to drivers in the MI group, and there was limited evidence to suggest that the AF alone had the predicted reduction in observed speeding. For example, across all speed limits drivers in the no-MI condition decreased the amount of time spent driving 9 or more mph over the limit during the week with the system relative to the 3 weeks when these drivers drove without the system. In contrast, drivers in the control group did not significantly change the proportion of time driving 9 or more mph over the speed limit. There were also findings that indicated drivers in the no-MI group significantly increased the amount of time spent driving 1 to 4 mph over the limit. This speed range was the speed at which one could speed without activating the alert system. Thus, it appears that the participants in the no-MI group changed their speeding behavior to avoid the alert, which corresponds with comments made about the aversive nature of the alert provided by the AF during the debriefing interview.

However, the reduction in speeding among the no-MI participants during the AF period was not as consistent as predicted based on the results of European studies that tested the effects of advisory level ISA. For example, Harms et al. (2007) and Biding and

Lind (2002) completed field experiments that found consistent, significant reductions in speeding behavior when drivers experienced advisory level ISA. In fact, the Harms et al. study had several similarities to the current project, including a condition in which participants were offered economic incentives to reduce speeding. However, the researchers reported that the reductions in speeding during the ISA-only condition was greater than the incentive-only condition, whereas the current project found that the monetary incentive alone had nearly the same large effect as the incentive plus feedback condition.

The divergent results between the current and previous field experiments caution against assuming that findings in one culture will consistently apply to others. Cultural differences abound in many realms of human behavior, including traffic safety. For example, Warner, Ozkan, and Lajunen (2009) completed a study that compared cultural differences between Turkish and Swedish drivers with regard to attitudes about speeding and self reported speeding behavior. The researchers found that drivers in Sweden indicated a greater degree of compliance with speed limits and favorable attitudes towards their country's speed limits than drivers in Turkey. Warner et al. suggested that a primary reason for the differences in attitudes about speeding is that the roadways are much safer in Sweden than Turkey, as evidenced by the lower fatality rate in Sweden. As a result, Swedish drivers perceive that it is normal to obey laws of the road, including speed limits, whereas Turkish drivers perceive the norm to be to violate speed limits. A similar difference in attitudes about speeding may exist between drivers in the United States and Sweden, the country in which Biding and Lind completed the large scale evaluation of ISA, and between the United States and Denmark, where Harms et al. completed their field test of advisory ISA and incentives. Specifically, if Danish and Swedish drivers' attitudes are more favorable toward obeying the speed limit than drivers in the United States, then they may have been more likely to reduce their speeds when alerted by the advisory ISA.

An alternative explanation for the limited effect of the AF system on reduced speeding may be the "cry wolf" effect. As reviewed by Bliss, Gilson, and Deaton (1995), the cry wolf effect describes the non-responses to alerts that occur due to alarm mistrust. Alarm reliability is one factor shown by Bliss et al. to result to induce this effect. In the current project, participants indicated that the speed warning was generally accurate, but some individuals stated that the alert was occasionally inaccurate. There is the possibility that drivers who experienced false alerts may have ignored the true alerts as a result. However, participants did not explicitly state that they purposely ignored alerts because of false alarms.

In summary, the monetary incentive had a powerful effect on speeding behavior, whereas the AF system had some evidence to indicate it resulted in a moderate reduction in speeding. Thus, there was partial support for the hypotheses made about the separate and combined effects of MI and AF on speeding behavior. The results clearly indicate that a speed monitoring and incentive system can be an effective countermeasure. However, other results from this experiment, specifically those related to perceived mental workload, indicate that there could be some drawbacks to implementing the AF with or without incentives.

Perceived Mental Workload

Several hypotheses were made about the expected effects of MI and AF on drivers' perceived mental workload. Specifically, drivers in the MI and no-MI conditions were expected to indicate that workload increased during the period that they drove with AF. Individuals in the no-MI condition were expected to indicate higher levels of frustration and temporal demand relative to the control groups and individuals in the MI condition. Drivers in the MI group were expected to indicate a higher degree of effort and mental demand than the control group because of the extrinsic motivation to reduce speeds. Further, drivers in both MI and no-MI conditions were expected to indicate lower effort and mental demand during the AF period because of the expectation that they would be able to offload the task of speed monitoring.

The results clearly support the hypothesis that the extrinsic motivation of the cash incentive resulted in an increase in mental workload for the participants in the MI group. Drivers in the MI condition indicated that the two weeks when they had the opportunity to earn the incentive resulted in increased mental demand, temporal demand, frustration, and effort relative to the first and last weeks of the trial and, generally, to the control and no-MI participants. Drivers in the no-MI condition indicated that effort and frustration were the only dimensions affected by the presence of AF. There was a slight trend for drivers in the MI group to indicate that frustration was lower and mental demand, temporal demand, and effort were higher when they were in the MI-only condition relative to the MI + AF condition. However, while these findings were in the direction that would suggest that drivers offloaded the speed monitoring task and experienced lower workload as a result, none of these trends were statistically significant.

In contrast to the limited evidence to suggest that AF lowered mental workload, the hypothesis that AF would increase frustration was supported. There was a clear increase in the no-MI and MI participants' ratings of frustration during the week they drove with AF relative to the baseline week and to the control group. However, this increase in frustration was not predicted for drivers in the MI group. Rather, it was expected that the presence of the AF would be desirable because the system would make observing the speed less frustrating, and the drivers in the MI group would realize that the alert was helping them keep the cash incentive. A related hypothesis that did not receive support was the expectation for temporal demand to increase for drivers in the no-MI group during the AF period (Week 2). A possible explanation for the failure to confirm this hypothesis may be that drivers in the no-MI condition ignored the AF in many instances. In other words, it was expected that temporal demand would increase to the extent that drivers reduced their driving speed. If drivers in the no-MI group were frequently ignoring the alert by failing to adjust their speed when alerted, then they may not have felt temporal demand to be any different than when they were driving in the absence of AF. This explanation is supported by the results of observed speed of drivers in the no-MI condition and the drivers in the MI condition, with the latter condition having rated temporal demand significantly higher during Weeks 2 and 3 and also having reduced their speeding behavior significantly during the same measurement periods.

Considering the above, four of six dimensions of perceived mental workload measured by the NASA-TLX increased significantly as a result of the monetary incentive, and there were increases to frustration and effort as a result of the automated feedback system. These changes were relative to perceived workload during baseline periods and to the control group. Although the effect sizes of significant analyses were rather large, the absolute values on the NASA-TLX rating scale may not indicate extreme levels of mental workload. The finding that participants who were in the MI group rated each dimension as more demanding during the weeks when they were offered the bonus suggests that keeping their speed within the tolerance range increased the overall processing demands of the driving task. Further, the lack of a significant reduction in the workload indices during the AF period suggests at least two possible conclusions about speed monitoring, which is the primary function of the AF. These conclusions are based on the work of Parasuraman and Riley (1997) who predicted that automation can lower workload if individuals trust a system and allocate what was a manual task to the system. Given the results, drivers either (1) failed to allocate speed monitoring to the system or (2) allocated this task to the system, but failed to realize a benefit to processing resources. The first conclusion is discussed further in the trust and acceptance section.

The increase in frustration and effort observed with the no-MI group during the AF period was significant; however, the highest ratings did not exceed the mid-point anchor of 5 on the NASA-TLX dimensions. This relatively low subjective rating provides support that the task of speed monitoring, in the absence of an incentive to refrain from speeding, may require limited processing demands compared to other aspects of the driving task. Finally, the increases in frustration and effort associated with the no-MI group during the AF period might be closely linked with the auditory component of the system. Specifically, during the debriefing interview, several participants commented that the auditory component was stressful and annoying. Thus, it is interesting that there was a failure to find some of the predicted correlations between the workload dimension of frustration and some of the measures of driver trust and acceptance of the system.

Trust and Acceptance

Ratings of automated feedback. The favorable ratings that participants in both incentive conditions provided about reliability, predictability, accuracy, agreeableness, trustworthiness, and acceptability indicate that the AF system may be acceptable if it were to be deployed widely, particularly if the auditory signal could be redesigned. Based on some of the comments during the debriefing interview, participants did indicate there were a few instances when the system was inaccurate, i.e., participants stated that the AF system occasionally indicated that the speed limit was different than the posted limit. Despite these few errors, the high ratings for system reliability and accuracy suggest that participants felt that the system generally worked as designed. However, the ratings of the remaining two items on the scale, those regarding how pleasing and annoying drivers found the system, suggest that auditory component of the system needs considerable attention.

In the current project, an original design goal was to create a graded auditory signal that would alert drivers to moderate and egregious speed limit violations, so the project team decided that the temporal patterns of the two signals would be manipulated to differentiate the two levels of speed limit violations. A second goal was to create an auditory signal that would be considered relatively pleasing. Both design goals came directly from participant feedback from the European studies of advisory ISA (e.g., Biding & Lind, 2002; Harms et al., 2007; Hultkrantz & Lindberg, 2003). The first design goal was achieved by altering the pulse rate; the signal for the moderate violation had two pulses per burst, whereas the signal for the egregious violations had three pulses per burst. The four members of the design team and three pilot participants agreed the two signals were distinct, and the signal for the egregious violation was more urgent than the signal for the moderate violation. However, the goal of using a mellow or pleasing tone was not met due to time, budget, and physical constraints. The hardware and software purchased and used for the study had limited capability to annunciate the warning; the system was limited to playing pure tones rather than “softer” chimes or bongs. The costs to upgrade the hardware and the time and cost required to recode the software were prohibitive. This limitation resulted in the selection of a relatively harsh beep. The physical environment presented an additional obstacle to the generation of a pleasing tone. Specifically, the masking potential of the test vehicles’ stereo systems and other ambient noise resulted in the need to amplify the AF speakers so that the warning would be heard in worst case scenarios, such as listening to loud music with the windows down and the experimental vehicle next to a loud truck. This created an auditory stimulus that had a presentation level that was well over the masked threshold in many situations, and this situation likely explains a great deal why the participants rated the AF as annoying and displeasing.

The negative ratings about how annoying and displeasing drivers found the AF system were somewhat expected given the characteristics of the auditory component, yet it was surprising to find that there were few differences between the incentive conditions with respect to the other six items rated on the trust and acceptance scale. The one item that was rated differently indicated that drivers in the no-MI condition found the AF system to be more trustworthy than drivers who received the incentive. This difference in the ratings may help explain the failure to find the predicted reductions in perceived mental workload ratings among the drivers in the MI condition during the week that they drove with AF. As discussed in the section about findings associated with mental workload, Parasuraman and Riley (1997) state that experimenters could expect a benefit to workload in situations when individuals trust a system sufficiently to allocate tasks to the system. The marginal ($p < .025$) finding that drivers in the MI group rated the AF system as less trustworthy would support the hypothesis that mental workload was higher for the incentive group because they were reluctant to allocate the task of speed monitoring to the AF system and continued to perform it manually. In addition to the difference between the incentive groups and their ratings of trust, the significant correlations between items on the trust and acceptance scale and the mental workload scale also support Parasuraman and Riley's hypothesis. The negative relationships that existed between mental demand, temporal demand, trustworthiness, and predictability further suggest that participants who found the AF system to create higher levels of workload tended to have less trust in the system.

Trust and Acceptance of Monetary Incentive. The ratings of trust and acceptance of the MI system that drivers provided at the end of Weeks 2 and 3 lead to the conclusion that the experience with the system was very favorable. During the debriefing period, a few drivers indicated that there were a couple times when their bonus decreased because of an error in the speed limit data base. However, based on the high ratings of the acceptance and trust in the system, these errors appear to have been anomalies. In sum, the drivers in the MI condition found the prospect of earning a weekly incentive to keep their vehicle speed within the tolerance range used in the current study to be acceptable.

Perceived Usefulness and Willingness to Keep

At the end of experimental trials, participants completed a debriefing session, which included a segment of questions to provide further information about the system's overall acceptability. Based on responses provided by the individuals in the no-MI condition, the deployment of the AF system would not be considered useful. The responses also suggest that drivers would not pay to have the AF system in their vehicle, unless they were to receive an insurance discount. Given the moderate effect on speeding behavior found for the automated feedback alone in the current project, it is doubtful if any insurance company would want to give a discount in the absence of some contingency. Drivers in the no-MI and MI groups indicated that novice drivers would benefit from the AF system. However, only drivers in MI group indicated that they believed their driving improved during the two weeks they drove with the incentive.

The significant correlations between responses to questions in the debriefing interview and ratings of trust and acceptance were straightforward. Individuals who agreed that the system was useful and improved their driving tended to rate the system as pleasant and acceptable. However, the significant positive correlations between the debriefing questions and mental workload were somewhat surprising. Specifically, drivers who found the AF system to be mentally and temporally demanding, frustrating, and effortful indicated that the system was also useful and improved their driving. These correlations may have implications for deploying safety based technologies on a wide scale. If a system can be shown to have some inherent worth, then drivers may grow to accept them over a period of time. For example, the general attitude toward wearing seat belts during the 1970s and 1980s was negative, and use rates were approximately 15%. Drivers complained about the discomfort of wearing belts and some argued that wearing them could be less safe than driving unbelted, e.g., by getting trapped in a vehicle after a crash. However, belt use in 2010 is estimated to be 85% nationally, and many drivers now express discomfort when they are *not* wearing their seat belt (NHTSA, 2010a).

Implications from Correlational Analyses

A number of predictions about relationships between self reported and observed dependent variables were made prior to the data collection process. One set of tests concerned testing relationships between self reported attitudes and behaviors about speeding and observed measures of speeding. The failure to find a significant relationship between self reported and observed speeding may be evidence of the social desirability bias, which describes situations when individuals self report answers are dishonest because they believe that the experimenter would view them disfavorably (see Fisher, 1993). This phenomenon occurs frequently in traffic safety research. Specifically, the traffic safety community acknowledges that individuals under-report behaviors that are perceived as negative (speeding, talking on a phone while driving) and over-report behaviors seen as positive (buckling seatbelts). For example, Li, Kim, & Nitz (1999) reviewed the over-reporting of seatbelt use in police reports and conclude that it is a significant enough problem to warrant a statistical procedure to adjust for the over estimate. Similarly, NHTSA (2010b) acknowledges that estimates of cell phone use during crashes are like to be underestimated due to the same phenomenon.

Finally, the lack of relationships between self-reported and observed speeding call into question some of the research discussed in the literature review. Specifically, Blincoe et al. (2006) reported that a significant proportion of 500 drivers ticketed for speeding indicated that the reason they were speeding was that they were unaware of the speed limit. The findings of Blincoe et al. provided partial support for predicting an effect of the AF system in the current project. The results of observed speeding behavior and the lack of a correlation between observed and self reported speeding call into question the value of self report information, particularly when individuals are reporting about behaviors that might result in a negative judgment about them.

In contrast to the lack of a relationship between self reported and observed speeding, there were several significant relationships between the short, four item sensation seeking scale and observed speeding. These findings provide further validation for the abbreviated sensations seeking measure. These relationships may indicate that those who score relatively high on self reported sensation seeking have a propensity to engage in risky driving behaviors relative to individuals with lower scores. Future research might determine the extent to which this relationship extends to other traffic safety behaviors. This finding may have implications for further research about systems designed to improve safety. For example, rather than examining correlations, it may be of interest to block a sample of participants into groups based on sensation seeking scores to determine if behavior change varied as a function of this trait.

Future Research

Mental Workload. This project was a first test of ISA in the United States. Thus, there are many future research projects that could and should follow the current effort. One future endeavor should be to look more closely at the effect of ISA on mental workload to understand whether the changes in subjective workload measures evidenced in this project present a situation that would offset the safety benefits of reduced speeding. Secondary task paradigms would be difficult to carry out in field settings, as these methods typically are designed to introduce some performance decrement. The current project was completed on public roadways; to add a secondary task paradigm in the same field settings may present a safety risk to drivers.

In contrast, it may be possible to conduct a study to determine whether a physiological measure of workload, such as heart rate variability, changes as a function of the variables tested in the experiment. The need for more in-depth research concerning the impact on mental workload would be particularly crucial in situations that include external motivation because the push to refrain from speeding may conflict with a driver's desire to speed, as indicated in the current study. Given the results that suggest the increase in perceived workload, future research must thoroughly evaluate the effect of this prototype system on processing resources before it might be recommended for wide scale deployment.

Other unintended consequences. In addition to increased mental workload, other unintended negative consequences could negate the safety benefits of ISA. One concern is that the level of automation may remove the driver from loop of speed monitoring. Sheridan (1980) discussed several reasons why individuals may become alienated by automation. Some of these reasons discussed by Sheridan are particularly threatening for automation that assumes control over decision making processes and would not apply to the level of automation studied in the current project. For example, in some human machine interactions in which the human simply activates a system, the operator may not experience the end product, resulting in alienation. In contrast, the alienation that might occur from the advisory level speed feedback studied in the current project may result from individuals becoming resentful because the AF system is perceived as a threat to replace the monitoring completed by the driver. An additional cause of concern discussed by Sheridan is that the AF system may degrade skills because the nature of the driver's task has changed. Some of the European ISA researchers indicated that skill degradation of speed monitoring occurred. Drivers committed mode errors when they assumed that their ISA systems were active when, in fact, the vehicles were in the inactive mode (Hjalmdahl & Varhelyi, 2004).

In addition to the potential for driver alienation and complacency, a host of negative behaviors could be predicted from risk homeostasis theory (Wilde, 1988). According to Wilde, individuals seek a certain level of risk. If a person perceives that a given situation has a perceived risk that is lower than the optimal level, then the individual will make some behavioral change to increase the risk to the homeostatic level. Thus, for the current study Wilde might predict that drivers who reduce speeding might increase red light running or tailgating or reduce seatbelt use. As discussed in the literature review, Comte (2000) completed simulator research that provided some support for Wilde's predictions.

The work of Geller and colleagues contrasts with risk homeostasis theory. Geller suggests that specific safety behaviors may transfer to others and provides interventions that should increase the likelihood of their generalization. The example in the previous paragraph presents a situation in which the driver reduces speeding but continues to tailgate. However, Geller and colleagues would predict the opposite occurrence. Based on findings that indicate a correlation among safety behaviors, Ludwig and Geller (Geller et al., 1990; Ludwig & Geller, 2000; Ludwig, 2001) provide support for the NHTSA (2007) report that indicates a relationship between speeding and other crash risk factors. Geller and colleagues argue that risky driving behaviors cluster together, and that any one behavior, i.e., speeding, is a component of a general behavior pattern. These authors worked to improve the safety behaviors of delivery drivers and implemented interventions using verbal feedback to target specific behaviors such as making full stops at stop signs. The intervention successfully changed the target behavior, and the authors noted changes in other safety relevant driving behaviors such as an increased use of turn signals. Thus, a possible effect of ISA would be that driving more slowly may generalize to other safe driving behaviors such as increased following distance and increased seatbelt use. Future research could include video recording in a research design that is otherwise similar to the current study. Such a project might provide support for risk homeostasis theory or support the work of Geller and colleagues. The presence of video would also allow researchers to filter out situations in which drivers did not have the opportunity to speed, such as heavy traffic, or to determine if the reduced speeds of participants introduced conflicts with other vehicles in the traffic flow.

Testing Other Levels of ISA Automation. This demonstration indicated that an incentive and advisory ISA effectively reduced speeding of a small sample of young US drivers while showing a fair degree of driver acceptance. The findings support further testing of these systems in the United States. One research area that would provide valuable information would be the testing of additional levels of ISA automation. Sweden's ISA effort showed that advisory, interactive, and mandatory ISA systems significantly reduced speeds (Biding & Lind, 2002), while also showing that each level had some negative effects. Carsten and Tate (2005) recommended that the United Kingdom adopt mandatory ISA. Future research should investigate these other levels within the United States. The moderate effect found for the automated feedback in the current study conflicted with results reported in European studies and underscores the importance of studying the effect each level of automation has on United States drivers. NHTSA is currently testing an interactive level ISA system in which drivers will experience counter force to accelerator pedals when they exceed the posted speed limit. Future research on ISA could also test the effect of ISA among different sub-populations within the United States. For example, the "average" driver may benefit from and even desire an automated feedback, particularly if the system included a monetary incentive such as insurance discounts. Further, if automated enforcement continues to increase, then so would the probability of being caught speeding. In this circumstance, drivers may desire such an automated feedback. In contrast, parents or government officials may mandate higher levels of ISA automation for novice drivers, reckless drivers, or perpetual speeders.

Future projects using the independent variables used in the current project could address many unanswered research questions. Regarding the monetary incentive, insurance companies may be interested in knowing the price point necessary to induce customers to install this sort of monitoring system and to make enough profit to keep their business thriving. Researchers might also use different reinforcement schedules, although the current project achieved near complete extermination of observed speeding using the current delayed incentive contingent upon avoiding an immediate disincentive. An important research question that should be answered is how speeding behavior would be affected by the incentive and ISA over a longer period of time. The trial period in the current project was one month, and this time included a baseline, treatment, and return to baseline periods. Understanding the effects of incentive and ISA over a longer time would be essential before any recommendation could be made about deploying this system. Future research endeavors should certainly include development of a more acceptable auditory warning. The technology currently exists to present an array of signals to drivers, and the feedback from the participants clearly indicates that efforts to present different alerts are warranted. Given individual tastes, designers might create a number of warnings from which drivers could select the most pleasing to them. Alternatively, research could test a more aversive stimulus than the graded alert used in the current project. For example, an auditory signal could be presented that does not go away until the drivers slow the vehicle, and some currently available off-the-shelf systems purposely present such an aversive stimulus to drivers. However, given the negative reaction that drivers had to the current system, using a harsher stimulus might annoy or anger a driver to the point of automation disuse. In fact, the results of this study seem to indicate that participants perceived the auditory component of AF to be more urgent than the actual situation. Thus, making the alert even more urgent would counter researchers who advise designers to map the urgency of a signal to the true urgency of the situation (see Edworthy et al., 1991 and Marshall et al., 2007). Additionally, the alert is supposed to advise drivers that they are over the limit, and the choice to adjust speed is then placed upon the driver. Given that the capabilities exist for mandatory ISA, it would make more sense to use this higher level of automation if the goal is to force drivers to drive at the posted speed limit rather than forcing them to do it by presenting an aversive alert.

Conclusion

Speeding is a serious threat to traffic safety. Thirty-one percent of fatal crashes in the United States in 2008 were related to speeding. This percent means that in 2008 nearly 12,000 people were killed in the United States in speeding related crashes (NHTSA, 2009). This project tested the effects of a monetary incentive and automated feedback on speeding behavior, and the results indicate that the drivers who received a monetary incentive to drive within 4 mph of the speed limit complied almost completely with the behavioral contingency. Moderate reductions in speeding resulted from the automated feedback system. In addition to the near elimination of speeding, drivers indicated a high degree of acceptance for the MI system. If further research indicates that behavior change endured beyond the one month period in this study, then providing a modest cash incentive, possibly in the form of an insurance discount, could prove to be an effective countermeasure for speeding.

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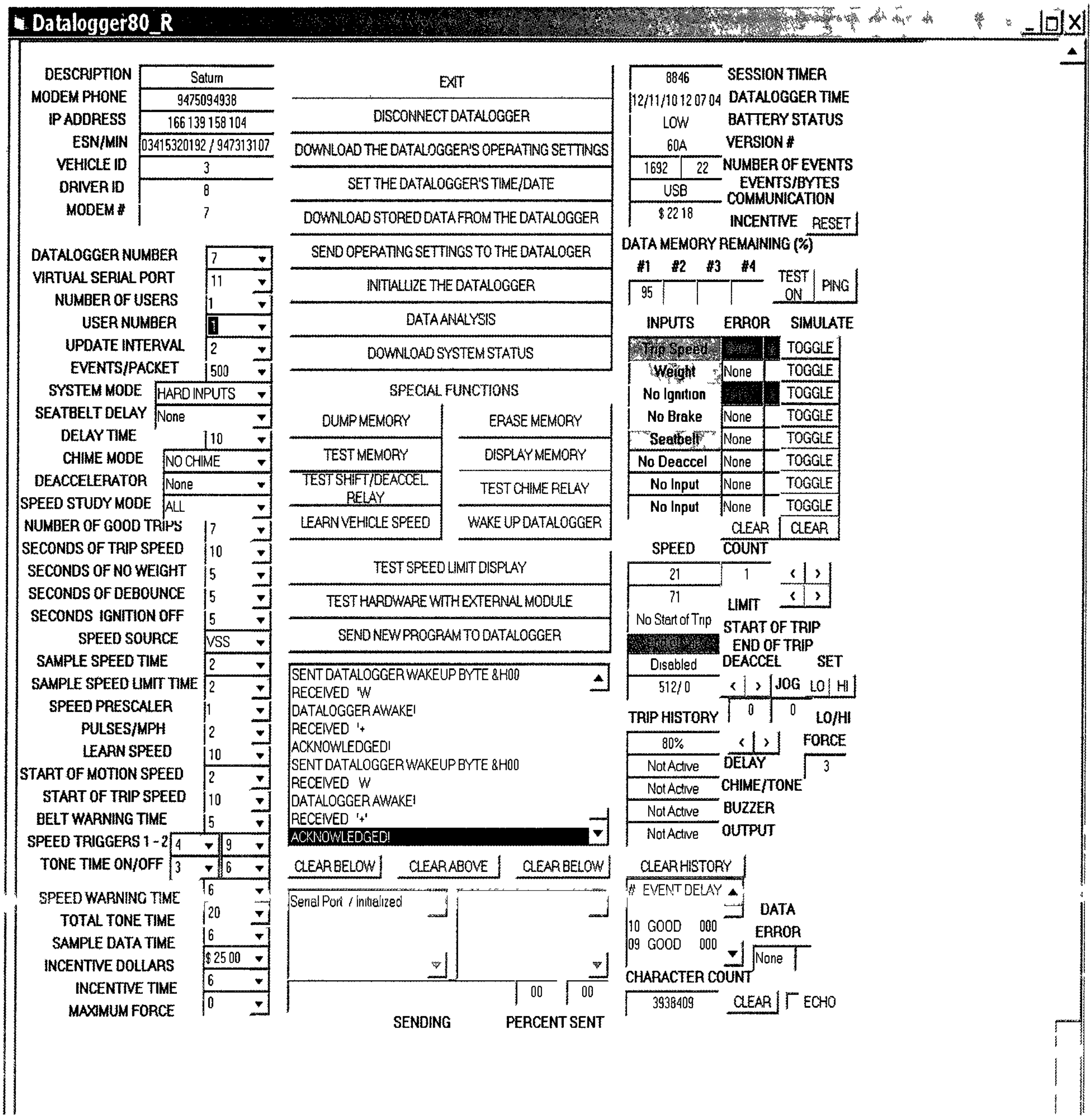
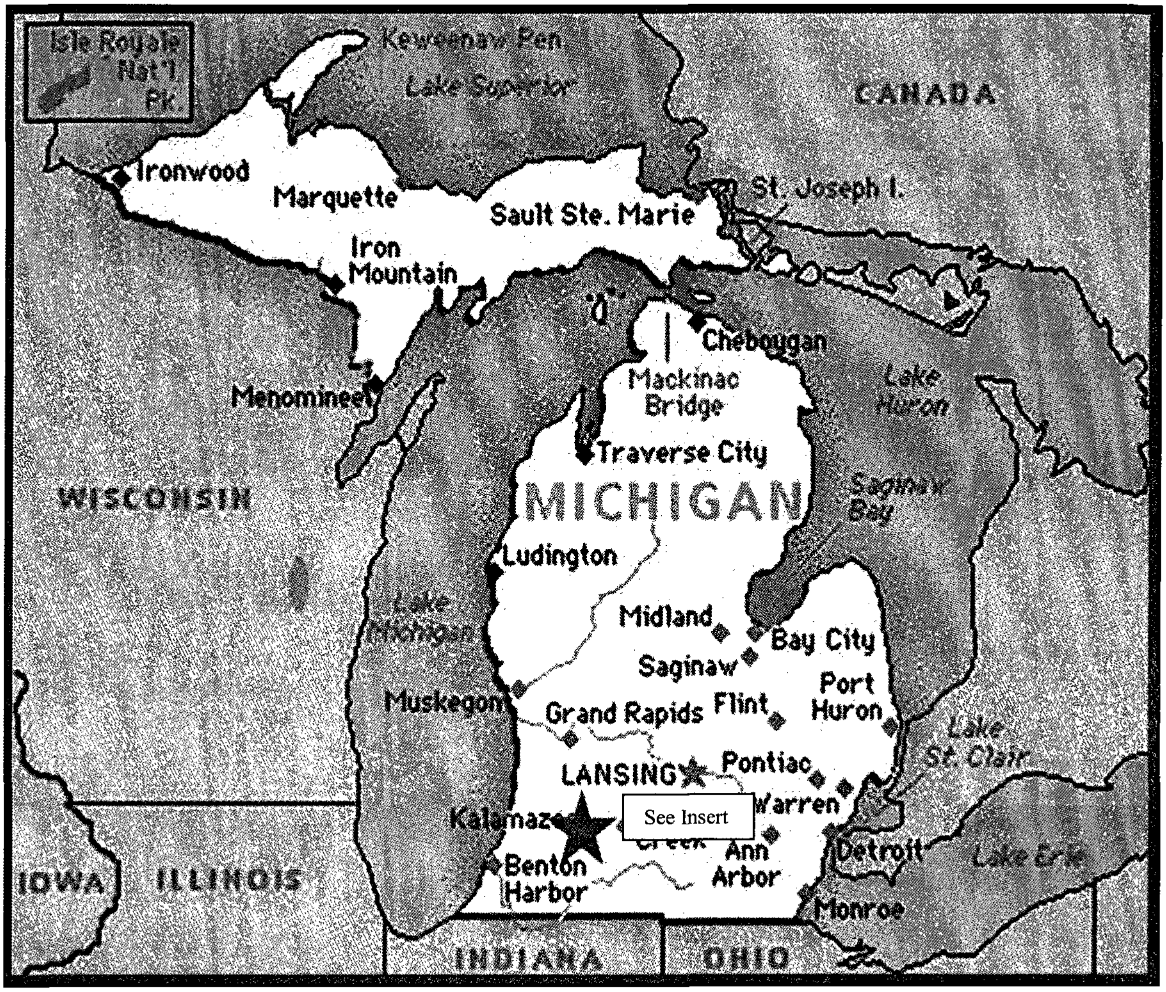
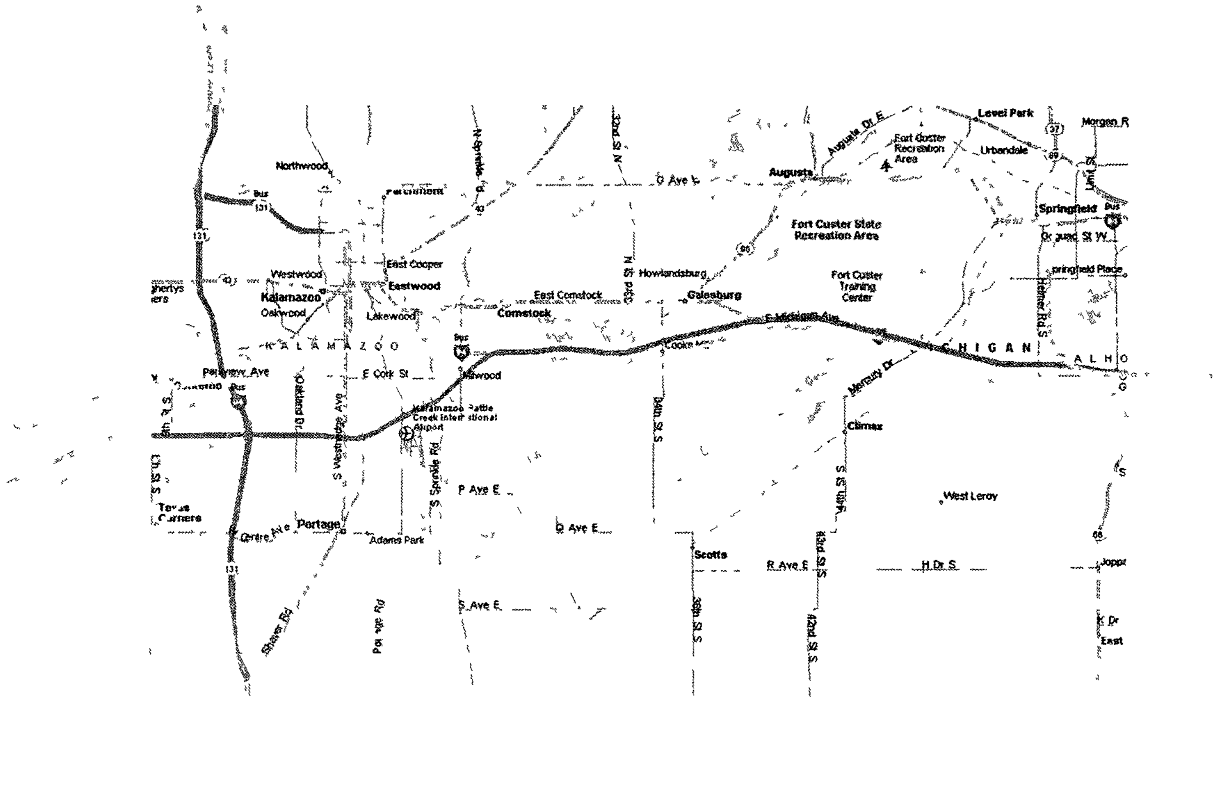
Appendix A. Screen Shots of Visual Basic Interface for Datalogger, Michigan Map, and Speed Mapped Area of Kalamazoo/Portage.




Isle Royale Nat'l. Pk.
Keweenaw Pen.
Lake Superior
CANADA
Ironwood
Marquette
Sault Ste. Marie
St. Joseph I.
Iron Mountain
Cheboygan
Mackinac Bridge
Lake Huron
Menominee
Traverse City
WISCONSIN
MICHIGAN
Saginaw Bay
Ludington
Lake Michigan
Midland
Bay City
Saginaw
Port Huron
Muskegon
Grand Rapids
Flint
Lake St. Clair
LANSING
Pontiac
Warren
See Insert
Detroit
Lake Erie
Ann Arbor
Benton Harbor
Monroe
IOWA
ILLINOIS
INDIANA
OHIO


Northwood
East Cooper
Westwood
Kalamazoo
Eastwood
Oakwood
Lakewood
East Comstock
Comstock
K A L A M A Z O O
E Cork St
Oakland Dr
S Westnedge Ave
Kalamazoo Battle Creek International Airport
S Sprinkle Rd
N Sprinkle Rd
P Ave E
Q Ave E
S Ave E
Portage
Adams Park
Shaver Rd
Centre Ave
Scotts
R Ave E
H Dr S
33rd St N
34th St S
36th St S
42nd St S
43rd St S
44th St S
Howlandsburg
Galesburg
Augusta
Augusta Dr E
Fort Custer Recreation Area
Fort Custer State Recreation Area
Fort Custer Training Center
Level Park
Urbandale
Springfield
Springfield Place
Helmer Rd S
E Michigan Ave
Mercury Dr
Climax
West Leroy
C H I G A N
A L H O
Morgan R
Texas Corners
Parkview Ave
Portage Rd

Appendix B: Self report data elements

Screen Questionnaire

Thank you for your interest in participating in this study of on-road driving behavior. How did you hear about the study?

There are 4 eligibility requirements that will need to be verified with your driving abstract. To obtain the abstract we will need your driver's license number. Your DL# will be kept completely confidential. If you participate we will assign you a unique code. Most results of the study will be discussed in terms of how the whole group of drivers performed. Information about individual drivers will refer only to the unique code. Absolutely no information from this study can or will be used against you in any way.

Before I get your DL#, I quickly want to review the requirements listed on the recruitment flyer, and then ask a few other questions and we'll be finished, ok?

- Male or Female ___
- List your age ___ (must be between 23 & 40 to be eligible participate)
- List # of years with driver's license? ___ (Must have license for 5 years to be eligible)
- Has it been suspended for moving violations? (stop if "yes")
- Have you been convicted of either impaired or reckless driving? (Stop if "yes")
- Do you drive 20 miles per day or more at least 5 times per week? (stop if "no")
- Do you share your vehicle with another individual or use your vehicle for work purposes (i.e., delivery driving)? (stop if yes)
- Do you drive 8 miles per day on roads with speed limits of 45 mph or greater?
- If you participate would you agree to be the sole driver of the car you get assigned?

Ok, just a few more questions. Please answer them as truthfully as possible, as there is no right or wrong answer.

1. Before getting your driver's license, did you take a driver's education course?
   1 Yes 2 No

2. Which of the following statements best describes your driving?
   a. I tend to pass other cars more often than other cars pass me
   b. Other cars tend to pass me more often then I pass them
   c. (Both/About equally)

3. Thinking of a typical week, how often do you drive on the following types of roads? Do you drive on this type of road:

   1 Frequently (at least 5 times a week) ___ 2 Sometimes (at least 2 times a week)___
   3 Rarely (no more than 1ce a week) ___ 4 Never___

i. Multi-lane interstate-type highways with posted speed limits of 55 miles per hour or above _____
ii. Two-lane roads, with one lane of traffic traveling in each direction, with posted speed limits of 45 miles per hour or higher ____
iii. Local streets with posted speed limits of 35 miles per hour or less ___
iv. Non-interstate, multi-lane roads with posted speeds of 45mph or greater ___

4. In your opinion, how many miles per hour OVER THE SPEED LIMIT can you go before police will normally give you a speeding ticket if they see you on the following roads and speed limits:

    1. Interstates 55mph or greater ___
    2. Two lane roads 45mph ___
    3. Non-interstate roads 45mph or greater___
    4. local roads 35 mph___

5. How often do you wear your seatbelt?
   (5) Always (4) Frequently (3) sometimes (2) rarely (1) never

6. When you drive a motor vehicle, do you usually have a wireless phone of some type in the vehicle with you? Yes ____ No ____

7. How often do you talk on the phone while you are driving? Would you say you talk on the phone while driving during................?

1 All trips
2 Most trips
3 About half your trips
4 Fewer than half your trips, or
5 Never

8a When you are talking on the phone while driving, do you tend to hold the phone with your hand or do you tend to use the phone hands free?
1 Hold phone
2 Use hands free

Appendix B: Self report data elements (Cont.)

End of Week 1 Questionnaire.

Participant Code _____

I. Demographics:

d) How many miles do you drive during a normal week? ___

e) How many trips do you make during a normal week (count a round trip as 2 trips)? ___

f) Please circle the highest level of education completed.

1) High school/ GED	2) Some college courses
3) Associates degree	4) Bachelor's degree
5) Some graduate courses	6) Master's degree
7) Some post-masters courses	8) Post-master's degree

II. Please rate the following statements. Mark 5 to indicate the statement is "very much like me" and 1 to indicate the statement is "not like me at all"

(a) I would like to explore strange places ___
(b) I like to do frightening things ___
(c) I like new and exciting experiences, even if I have to break the rules ___
(d) I prefer friends who are exciting and unpredictable ___

Appendix B: Self report data elements (Cont.)

Acceptance & Trust completed via phone at the end of the AF week and MI weeks.

Consider the speed warning system. Rate the following statements on a scale of 1 to 10, with "1" indicating complete disagreement and "10" indicating complete agreement.

1) The speed warning OR incentive OR speed warning & incentive system was reliable.

1____10
Disagree Agree

2) The speed warning OR incentive OR speed warning & incentive system was predictable.

1____10
Disagree Agree

3) The speed warning OR incentive OR speed warning & incentive system was trustworthy.

1____10
Disagree Agree

4) The speed warning OR incentive OR speed warning & incentive system was acceptable.

1____10
Disagree Agree

5) The speed warning OR incentive OR speed warning & incentive system was pleasing.

1____10
Disagree Agree

6) The speed warning OR incentive OR speed warning & incentive system was annoying.

1____10
Disagree Agree

7) The speed warning OR incentive OR speed warning & incentive system was accurate.

1____10
Disagree Agree

8) The speed warning OR incentive OR speed warning & incentive system was agreeable.

1____10
Disagree Agree

Appendix B: Self report data elements (Cont.)

NASA-TLX (to be explained and filled out by hand at end of week 1 before the ISA instructions and completed via phone at the end of weeks 2 and 3. Also filled out by hand at end of week 4.)

Four times during the experiment you will be asked to complete ratings of mental workload demand associated with the overall driving task (steering, navigating, maintaining speed, avoiding hazards, and so forth). You will complete the ratings at the end of each week of driving. There are 6 mental workload dimensions to rate, and the definitions are provided below. Before completing the rating, think about the mental workload you experienced when driving throughout the week taking into consideration the vehicle you operated.

The first time they fill it out, the participant will place an "X" on each line to indicate the rating for each dimension. The second and third time they respond to the survey will be over the phone. The experimenter will explain that they will have to provide these phone interview ratings verbally. The final time it will be completed by hand when they return the vehicle.

(1) Mental demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.) Was the task Easy or demanding, simple or complex, exacting or forgiving? Low/High

1____10

low High

(2) Physical demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious? Low/high

1____10

low High

(3) Temporal demand: How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic? Low/high

1____10 low High

(4) Performance: How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals? Poor/good

1____10

low High

(5) Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance? Low/high

1____10

low High

(6) Frustration level: How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task. Low/high

1____10

low High

APPENDIX B (continued)

Final Debriefing Questionarre
Participant Code______

End of week 4. For individuals assigned to the AF condition: We value your opinion about the system you experienced. Please indicate the extent to which you agree with these statements.

1) "I found the system useful."
1____10

strongly disagree — Strongly Agree

2) "The system improves traffic safety."
1____10

strongly disagree — Strongly Agree

3) "The system makes me a better driver."
1____10

strongly disagree — Strongly Agree

4) "I would keep the system if it were free."
1____10

strongly disagree — Strongly Agree

5) "I would keep the system if I had to pay for it."
1____10

strongly disagree — Strongly Agree

5a. If answered yes - How much would you pay?

6) "The system would be helpful for novice drivers."

1____10

strongly disagree — Strongly Agree

7) I would keep the system if I were offered an insurance discount.

1____10

Strongly Disagree — Strongly Agree

For MI and No-MI participants:

8) What features of the system did you like?
9) What features of the system did you dislike?
10) How would you change the system to make it more effective?
11) How would change the system to make it more acceptable?
12) Do you have any other feedback about the system?

For MI participants only:

13) Did you feel that the incetive lowered your speed?
14) If 13 = yes, then, think about how the bonus system was structured. What affected your decision not to speed?

Appendix B (Continued)

Complete Responses to Debriefing Questionnaire
Speed Study Final Questionnaire Subjective

P1

Q7. A. Information of speed limits.
Q8. A. Did not dislike.
Q9. A. Have the sound run through the speakers of the car.
Q10. A. Would not change.
Q11.A. It would be good for if you were under the influence of drugs or alcohol so that you could know when you were speeding to avoid being pulled over. It would also be good for informational purposes for new cities to know speed information.

Further Questions are N/A

P2

Q7.A. It was effective and I liked the visual and auditory component that acted as a flag.
Q8.A. It was not build into the vehicle. Auditory component was punishing.
Q9.A. see the dislikes (q8) and make the display bigger and salient.
Q10.A. put the display in the dashboard and offer a selection of warning tones like ring tones.
Q11.A. No other feed back.

Further Questions are N/A.

P3

Q7.A. The incentive and the ability to control the amount received through feedback.
Q8.A. The beep
Q9.A. I would make it so you could change the beep.
Q10.A. Same as above question
Q11.A. Over the speed limit more accurate triggers. I would try to self compete even when the system was inactive.

Incentive Questions

1. yes
2. self competition and the money. I was more restrictive on my driving when the incentive was in play.

P5- Final Questionnaire N/A

Appendix B (Continued)

P6

Q7.A. I liked that it would tell me the speed I'm supposed to be going because a lot of the time I'm not sure about that.
Q8. A. The beep was pretty annoying, sometimes it would make me feel a little stressed out.
Q9.A. Maybe if it weren't such an aversive sound, maybe just a bell to remind you maybe it would be a little but more acceptable.
Q10.A. I guess id make it a little less aversive
Q11.A. over all think it was pretty accurate and I think that is about all I have to say.

P7

Q7.A. it was helpful to know how fast I was going and what the speed limit was when I didn't know, about the system that is about it
Q8.A. I didn't like that once I was over it would immediately take money it would be nice if I could slow down if there was a time delay. Because sometimes you don't really know how fast you are going and you would have to slam on your brakes, or not slam on them, or pump them which was a little annoying and dangerous depending on where you were.
Q9.A. I would give a time delay to get back to your speed a to the correct speed so if you were passing some one or you had to spped up you could slow down without losing money.
Q10.A. I was thinking during the excperiement if it were tied into the insurance.
Q11.A.no.

Q1. It for sure lowered the peeding, but for sure I was trying to cover the cost of gas to ride for free for the month.
Q2. The price of gas.

P9

Q7.A. I think that I liked the incentive based part of the system, but I also liked that the tone wasn't overwhelming.
Q8.A. the inability to turn the system off
Q9.A I think I would make it a voluntary thing, you could flip the swicth and turn it on when you needed it. But if you were in the city driving you could turn it off
Q10.A. I think it was acceptable

Q11.A no

Q1 yes
Q2 It became a sort-a need vs reward thing so in the moments when I sped I did so consciously knowing I would lose money but I did because I needed to be somewhere faster.

P11

Q7.A. I liked that it was very accurate and reliable
Q8.A I disliked the audio tone there was some situations that I just made the decision tthat I would rather speed and take the risk but I just couldn't because of the irritation of the noise
Q9.A. I would give a visual indication that you were speed 5 miles over and then maybe set the tone at 10 miles over
Q10.A again just make the incentive to drive the speed limit more just the fact that it is the safer thing to do rather than just annoy the piss out of you. Because when you are irritated by something you tend to drive more aggressively at least that is what I felt
Q11.A. other than that no it was very straight forward it did what it was said it was going to do, I think it could be useful in certain changes and circumstances

Q1 yes somewhat I'm not saying the effect was all due to just wanting to avoid the noise the money definitely did help.
Q2. The decision not to speed was based mostly on not listening to the noise, but also the knowledge I was getting the money. At the end of the two weeks id say my driving was where is was going to be regardless of the money incentive.

P13

7. uhm, I liked being notified immediately when I was speeding. I didn't like that it persistent when I was aware when I was speeding.
8.i didn't like that the tones persistent when letting me know I was speeding
9.i would make it, an option to control the volume of the speaker unit so it goes under the music accordingly
10same thing
11.nope

P14

Q7.A. uhm I mean know when to slow down when I was speeding.
Q8.A. it was annoying
Q9.A. maybe more a tune or some kind of audio alert that was something that wasn't so annoying as this was.

Q10.A. maybe more like a radio tune or something
Q11.A. it was useful if definitely let me know when I was speeding or going to fast. Uhm, there was actually some not precise areas there was areas where it went from 25 to thirty five and it would take like a mile to switch over, but other than that it was pretty good.

P15

Q8.A. The visual display is good it was like "here is the speed limit"
Q9.A. the beeps they were annoying.
Q10.A. a larger display in or on the dash
Q11.A. no beeps but I don't know if it would be as effective.
Q12.A.no, not really. Just the beeps messed with my radio time. The visual was beneficial, sometimes I wasn't aware or the speed limit and it let me know.

P16- baseline
P18- baseline

P19

Q8.A. I liked that I knew when I was going too fast.
Q9.A the noise, it was annoying
Q10.A. I would probably have it start beeping at nine instead of 6 over
Q11.A I would change the system to have it start beeping at 9 over instead of 6 over.
Q12.A no

P21.

8.um I liked be told I was going over the speed limit because sometimes I don't relize it or am too distracted to realize it
9. some times the numbers were innacuarte so that was more distracting then helpful uhm for instanve if it was telloing me it was a 25 zone whennit was really 35 so I didn't like that very much, but I liked it when it was accurate
10.first I would make sure everything it right and accurate with all the different zones, I would also change the sound that comes out because it is pretty aberasive and it could be distracting in that kind of a oud an abrasive sound sortalike the alarm youdont want to hear in the morning soyou would listen tonthe radio
11.make sure everything was accurate with hnumbers and then also possibly the placement as well, it was a little distracting to have something by your face so maybe something lower by the dash or the radio so it isn't distracting
12.
1. it did

2. just knowing there was an incentive and knowing if I would stay withing the four miles an hour and still stay there so I wlouldmgomas fast as I could to still not lose anythi9ng and definitely not go higer in the 5-8 so not lose more than three cents.

P22

Q8.A. The incentive
Q9.A. Beeping
Q10.A. less aversive tone maybe
Appendix B (Continued)

Q11.A.it is acceptable
Q12.A. The incentive is what controlled my driving, the beeping is good for teaching. Once the incentive is gone I went back to regular driving.

S1.A. yes

S2.A the penalty.

P23

8. I guess, like, the flashing
9. the beeping
10. probably do it with a wider range of speed like 8 over than 5
11.same answer
12.no

1. yeah
2. the money.

P24

8. I liked the fact that it displayed the number every time I turn on the car of how much money I had. I liked the fact it told me I was speeding in week two, I think that is when it beepedbut after a while the beeping got annoying.
9. Definitely the loud beeping scared the crap out of me several times, and I guess I didn't like how it didn't display the money all the time when it didn't do that
10. make the beeps less annoying or maybe some other type of npoise or vibrate or something and have the money displayed all the time
11. the same
.12. no, it was interesting

1. uhm yeah it definitely lowered my speeding

2. obviously the money and knowing if I did not have to be somewhere then there is no reason for me to be speeding and losing money, if I had to be somewhere and was running late then maybe I will just let go of the 50 cents or whatever it might be for me to get there.

P29

8. the feedback was ok, but I don't know if anything else I found liking
9. too quiet and the hard ware is ugly
10. louder, and make it so it wont go away unless you do something about it.

Appendix B (Continued)

11. make the hardware more a part of the car. During the day it was sametimes hard to see the display.
12. no, it was ok,- no complaints.

P34

8. incentive, uhm, when it did beep and also It would tell me the speed

9. when it beeped at a stop light.
10 sometimes I would get on a road it would tell me the speed w/o seeing a sign or reminders.
11. it didn't bother me but the box location on the dash . maybe a louder beep that I could turn (change).
12. There were a few times if it would beep it would last very long. To be honest it would have been interesting if I were just on the beeping – for me it was the money.

1. yes
2. I feel it worked for me, I don't know if I would change anything.

P35.

8. it was very acurate. Useful going down hill with speed change.
9. that it wasn't optional
10. n/a
11. option of volume control
12. I don't think so, I think it is effective.

P37

8. liked the limit alert and beeping and incentive.

9. I would like the incentive feedback continually even if not beeping
10. increase incentive loss per 6 seconds
11. different beep
12. not that I can think of

1. yes
2. avoid bonus reduction to get the bonus, but mostly I didn't want to hear the beep.

P38

8. some roads had no signs I liked knowing the limit.
9. heard to see or hear because I am short
10. raise volume
11. keep volume the same
12. if more effective make louder and display higher or in the dash.

P39

8. I liked participating
9. I didn't like it announcing at me
10. gps more accurate in spped limits
11. make it quieter and shut of after a certain point
12. no

1. yes
2. I wanted the money.

P40

8. notification of speeding
9. if I were in a rush I intended to speed and didn't want to hear the beeps
10. brighter more beeps
11. adjust the beep for speed to your choice (of speed)
12. second beep not as helpful because by that point I knew – maybe just an occasional reminder.

P41

8. getting paid to do normal behaviors – made me more cognizant of how fast I was going and speeding.
9. errors in feedback and stressful
10.
activate audible feedback always. Help to keep FB illuminated over a longer time
11. get more money

12. pretty sweet, maybe a breathalizer tied in.

1. yes
2. the money and trying to keep it.

P45

8. let me know when I was speeding a lot when I didn't know
9. hard when you are going with the flow of traffic
10. ability to turn off and on
11. ability to turn off and on
12. no, I think we covered it.

P48

Appendix B (Continued)

8. notification alert
9. how loud it was
10. n/a
11. make it quieter
12. no

p49

8. good to get reminders of speeding.
9. the level over when you would get the buzzer
10. make the tone more annoying

11. get rid of audible, just visual
12. no, there were a couple errors.

P51.
8. alert
9. frequency of the tones
10. change the tone
11. less time, maybe 1 burst
12. really annoying

p52.
8. that I knew when I was speeding
9. the non-stop annoying tone – incessant
10. none

11. more pleasant tone, less frequent – once you hear it you know.
12. I didn't like no front speakers.

P53

8. audible beeping to alert you when you were speeding
9. nothing
10. on/off button like traction control
11. see above
12. no

1. no
2. n/a

p56

8. incentives
9.some places need more flex time for the posted speed changes
10. none

Appendix B (Continued)

11. make the incentive more
12. no

1.yes
2. just the money

p54

8. I don't know
9. noise level too loud, warning period was too short, you cant respond in time with out slamming on the breaks
10. longer warning period, choose tones or vocal or voice saying you are speeding. (maybe "caution")
11.same as last
12. make it something similar to a gps system that was built in – similar to the ford flex

1. yes
2. trying to be successful not about money I didn't want to fail the test.

P58.

8. I liked that it beeped and gave me enough time as a buffer
9. on the highway it seemed set to low

10. display could be bigger
11. different tone, not so annoying
12. no

p59

8. the beeping telling me to slow down
9. none
10. more accuracy about the speed
11. none
12. I think it helped me to know when to drive slower

1.yes
2. I think the deduction was so minor I didn't slow down, I didn't freak out – if I lost I would increase the deduction.

P61

8. none

Appendix B (Continued)

9. the sound
10. make it more accurate
11, not such an obnoxious beep
12. no

p62

8. none
9. beeping
10. don't know
11. quieter
12. no

p64
8. that it would tell me the speed limit with the alert.
9. I felt pressure to get the incentive.
10. none
11. I would like a voice instead of the beep.
12. no

1. yes

2. when the chime went I felt that I was losing money

p65

8. it did not make me aware of how fast I was going especially around school zones.
9. the beeping consistently
10.
a bigger visual, eliminate sun glare and make it more accurate.
11. a different tone, possibly a voice. The beeping was punitive
12. no.

p66

8. incentive
9. the feedback
10. just give an incentive and leave the decision to the driver
11. no feedback.
12.no

1. yes
2. incentive

Appendix C Informed Consents and Participant-Experimenter Agreements

PROJECT TITLE: National Highway Traffic Safety Administration Driving Study

INTRODUCTION

The purposes of this form is to give you information that may affect your decision whether to say YES or NO to allow us to evaluate whether you qualify to participate in this study and to give you an overview of the study.

RESEARCHERS

Responsible Principal Investigator: Ron Van Houten, PhD, Arts & Sciences, Psychology, Western Michigan University
Co-Responsible Principal Investigator: James P. Bliss, PhD, College of Sciences, Psychology, Old Dominion University
Other Investigators: Ian J. Reagan, College of Sciences, Psychology, Old Dominion University and the National Highway Traffic Safety Administration
Bryan Hilton, Arts & Sciences, Western Michigan University

DESCRIPTION OF PRE SCREENING PROCEDURE

Prescreening will involve two elements. First we need to check your driving abstract with the Department of Motor Vehicles to ensure your driving license is valid and that you have not been convicted of Impaired Driving, more than 3 moving violations in the preceding 12 months, Reckless Driving, or previous suspension of your license for repeated driving infractions or any other safety issue that would disqualify you from participating in the study. This information will be kept entirely confidential. An isolated traffic offence will not exclude you from participation.

We also are requesting permission to collect some survey material to indicate the amount of driving you do and other driving related information. The survey information is also entirely confidential.

CONFIDENTIALITY

The researchers will take reasonable steps to keep private information, such as questionnaires, driving history. These steps include removing identifiers from the information, destroying driving records after coding the necessary information, and storing information in a locked filing cabinet in the Dr. Van Houten's office. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you.

OVERVIEW OF THE STUDY

The purpose of this study is to test a new traffic safety system in a real word-driving environment. If you qualify to participate in the study you will be given a vehicle to use for up to a month. To qualify you must pass the screening procedure mentioned above and drive at least 20 miles per day. You may take passengers in the vehicle provided you do not let them drive but you may not use it for trips beyond a 50 mile radius from

Appendix C (continued)

Western Michigan University. You will be given a free tank of gas and do not need to refill the vehicle before returning it. Various driving behaviors will be digitally recorded throughout the study such as seatbelt use, braking information, vehicle speed, and trip duration. All of the logged data will be kept anonymous and confidential. Some participants will drive vehicles that will provide an audible and visual alerts while you are driving. These will be fully explained to you before they are introduced and you may withdraw from the study at any point. Other drivers will simply drive the provided vehicles for the duration of the study without experiencing the alerts. We will randomly assign drivers to different groups and you will find out which group you were assigned to after the first week of the study. Participants will receive $20 for completing a one week version of the study and a minimum $60 for completing the 4 week version of the study. If you participate in the study you will complete a few questionnaires on driving and your trust in technology at the start of the study and two 7 minutes telephone questionnaires during the study. You will be paid $10 for completing each telephone questionnaire.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and terminate the involvement in the study at any time. Your decision will not affect your relationship with Western Michigan University, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, you may contact : Dr. Ron Van Houten, 269 387 4471; Bryan Hilton, 269 387 4471.

And importantly, by signing below, you are telling the researcher YES, that you agree to allow us to determine whether you qualify to participate in this study. The researcher should give you a copy of this form for your records.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

Appendix C (continued)

HSIRB Contact Information

You may also contact the Chair, Human Subjects Institutional Review Board (387-8293) or the Vice President for Research (387-8298) if questions or problems arise during the course of the study

Subject's Printed Name & Signature	**Date**
Witness' Printed Name & Signature (if Applicable)	**Date**

<u>INVESTIGATOR'S STATEMENT</u>

I certify that I have explained to this subject the nature and purpose of screening. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	**Date**

Appendix C (cont.)

Main Informed Consent Document

PROJECT TITLE: National Highway Traffic Safety Administration Driving Study

INTRODUCTION

The purposes of this form is to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This research project will take place in the Kalamazoo and Portage areas.

RESEARCHERS

Responsible Principal Investigator: Ron Van Houten, PhD, Arts & Sciences, Psychology, Western Michigan University
Co-Responsible Principal Investigator: James P. Bliss, PhD, College of Sciences, Psychology, Old Dominion University
Other Investigators: Ian J. Reagan, College of Sciences, Psychology, Old Dominion University and the National Highway Traffic Safety Administration
Bryan Hilton, Arts & Sciences, Western Michigan University

DESCRIPTION OF RESEARCH STUDY

Several studies have been conducted looking into the subject of new technologies that may improve highway traffic safety. The technology that is the focus of this study has not been evaluated in the United States but has shown promise in Europe and Australia.

If you decide to participate, then you will join a study involving research of driving behavior in a real world setting. The research is to test a new traffic safety system. You will be provided a vehicle that you will drive for the duration of the study. The study will last either one or four weeks. Participants are randomly assigned to different groups after the first week. Various driving behaviors such as miles driven per trip, time of trip, vehicle speed, and seatbelt use will be digitally recorded throughout the study. The experimenter will explain the forms of compensation to the participants. You will need to provide subjective answers at 4 separate times during the study; twice in person and twice via phone. The risks associated with the study are no more than those present during the participants normal daily driving. One group of drivers will drive cars that have a system that gives auditory (sounds) and visual alerts to drivers while driving. Other drivers will simply drive the provided vehicles for the duration of the study without experiencing the alerts. We will randomly assign drivers to the different groups, and you will find out the condition to which you are assigned after the first week of the study. When you are assigned to the group, further information will be provided. If you say YES, then your participation will last between one to four weeks. At the end of the fourth week of the study we will interview you about your experience during the study and will tape record the interviews. Approximately 50 participants will be participating in this study.

Appendix C (Continued)

EXCLUSIONARY CRITERIA

You should have completed the telephone screening instrument. The fact that you are here indicates that you met the criteria associated with your driving record (age, years of licensure, no impaired driving citations, no reckless driving citations, and no license suspensions for moving violations.) Additionally, to the best of your knowledge, you should drive at least 20 miles per day, and you should drive at least half of these miles on roads with speed limits of 45 mph or greater. Not meeting these criteria would keep you from participating in this study. You also must agree to sign a statement that says you will be the only person who drives the vehicle. You may take passengers in the vehicle provided you do not let them drive but you may not use it for trips beyond a 50 mile radius from Western Michigan University.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of becoming involved in a car crash in the provided vehicle. However, this risk should not be more than your normal driving risk. If you are involved in a crash you will be covered by the Insurance policy (a copy is in the glove compartment). The collision deductible will be paid by the research contract and the remainder by the insurance policy. As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to you except as otherwise stated in the consent form. The vehicles are equipped with standard safety equipment (air bags, seatbelts, and antilock brakes.) You will be familiarized with the vehicle and the operation of the various options such as lights, windshield wipers, etc. Regarding the feedback systems, the researcher took steps to reduce risks by minimizing startling responses associated with the sound alerts and by limiting opportunities for visual distraction. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified. If the vehicle is damaged in a crash the Grant will pay for repairs up to the deductible limit and the insurance will pay for the remainder of the repairs.

BENEFITS: The main benefit to you for participating in this study is that it may assist you in being a safer driver and it may help the National Traffic Safety Administration in selecting improved safety standards for vehicles

COSTS AND PAYMENTS

The researchers want your decision about participating in this study to be absolutely voluntary. Yet they recognize that your participation may pose some inconvenience,

Appendix C (continued)

such as time to respond to various questionnaires and not letting others drive the test vehicle. To help defray your costs you will receive $20 for completing the one-week version of the study and a minimum of $60 for completing the 4 week version of the study. In addition, individuals in the 4-week version of the study can receive $20 for completing 2 short telephone questionnaires ($10 each; each lasting about 7 minutes). You will receive a free tank of gas in the vehicle you will drive during the month. You will pay for any gas required beyond this, but you will not

need to fill the vehicle up upon return. Because you are driving the government owned vehicle during the study, you will save wear and tear upon your personal vehicle.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY

The researchers will take reasonable steps to keep private information, such as questionnaires, driving history, and research findings, confidential. The researcher will remove identifiers from the information, destroy driving records after coding the necessary information, and store information in a locked filing cabinet in the Principal Investigator's office prior to its processing. All data will be stored in a locked filing cabinet in the principal investigator's office for 3 years after which time it will be destroyed. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Western Michigan University, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of harm, injury, or illness arising from this study, Western Michigan University, nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact Dr. Ron Van Houten at 269 387 4471 who will be glad to review the matter with you.

Appendix C (continued)

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, you may contact : Dr. Ron Van Houten, 269 387 4471; Bryan Hilton, 269 387 4471.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Appendix C (Continued)

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

Subject's Printed Name & Signature	**Date**
Witness' Printed Name & Signature (if Applicable)	**Date**

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	**Date**

Appendix C (cont.) Non-Disclosure and Initial Debrief Document

At the end of the study you will receive a debriefing summary that will inform you of the results of the study. This summary will be a couple of pages long and will include some graphs of the results.

Please, indicate whether you want the debriefing summary sent via email or regular mail.

Regular mail__________ e-mail__________

Please provide the corresponding address:

I pledge that I will not discuss the details of the study until I receive the debriefing summary.

________________________	________________________	____________
Printed Name	Signed Name	Date

<u>Agreement between the study participant and Western Michigan University.</u>

I ______________________________ agree that I will not allow anyone else to drive the test vehicle. I also agree not to drive the vehicle outside of a 50 mile radius from the main Western Michigan University campus. I further agree to lock the vehicle when it is not in use and to immediately report any damage to the vehicle. I have been informed that I am permitted to drive with passengers provided they do not drive the vehicle.

Signature____________________________ Date______________

Appendix D: Technical and procedural issues during data collection and resolutions.	
Issue	**Action**
1. Misaligned memory chip caused missing raw data in pilot participant 1 baseline week beginning in row 2048 and 6144.	Data logger boxes were returned to Novatronix to adjust one memory line of chip so the second half of data could be accessed properly. Data was retrieved without adding extra days of data collection
2. Pilot participant 1 drove outside of speed mapped area; default speed limit became 25mph, but actual speed zone was higher, so "incentive remaining" reduced incorrectly, e.g., the participant was in a 55mph zone and driving 55mph but the datalogger said speed was 25.	Automate (the company that made the speed limit/GPS system) made all areas outside the speed zone "0 mph" and the project engineer essentially turned the speed monitoring off when speed zone input was 0mph.
3. Accuracy of dependent variables proportion of time over the limit, mean speed, time in speed limit zone in data reduction analysis program.	Data were spot checked and proportions were computed by hand until high degree of correlation (r=.998) was found between hand and automated proportions.
4. Coding of intersecting roads with 2 different speeds. Higher speed was chosen so as not to trigger false alarms. This created some incorrect data points for 70mph roads (participant never drove on interstate)	Examined summary data. If data indicated participant drove less than 20 seconds on 70 mph roads in a day then removed that data.
5. Time stamps out of order for P9 Week 1 Day 8 @15:30. This is the same point in time when the GRA explained Week 2 instructions, but didn't start Week 2 treatment until beginning of day 9	Deleted all data that occurred after 15:35 on week 1 day 8. This happened periodically during the study. Experimenter manually re-ordered raw data and research assistant re-ran data analysis program
6. Driving exposure. Concern that drivers may not use the vehicle enough or may not speed enough.	Although the incentive was not given to participants until weeks 2 and 3, the data logger tracked what the incenitve amount would be if they had been given the incentive. participant had lose 8.00 during week 1 to continue into weeks 2, 3, & 4. Twenty-three individuals completed the first week of driving but did not meet the exposure criteria.

7. Some participants traveled out of town and left the vehicle (e.g., went home for the holidays).	Such participants picked up where they left off. To the extent possible we tried to schedule such that the stoppage occurred at the end of a week/condition
8. Deleted data	P2 - Drove out of zone and the system should have swithched to 0 mph but instead got a faulty 25 mph zone. This resulted in false alarms.
9. Inclement weather made driving at normal speeds impossible.	GRA accessed data loggers and switched speed study mode to "0" for the period of time that the roads were poor. GRA notified any participant in the treatment period of the action. For each of the 4 weeks, Participants had the vehicle for 7 days when the roads were ok for travel. Similarly, if participant went out of town or had a prolonged illness, days were added onto each week of driving to allow for 7 days.
10. Faulty or bad input or connection to autounit	Speed limit Code 71 - not communicating with autounit ex. Cable unplugged- Speed limit Code 72 - No GPS lock on autounit; 0 = outside of zone.
11. Participants in first cohort drove out of geofence and the system did not shut down - speed zones outside the geofence were supposed to turn to zero, but instead they defaulted to 25mph. In some instances the actual speed limit was much higher than this. This resulted in an over-calculation of the percentage of time the participants sped. The GPS coordinates that were written into the datalogger were scrambled, which prevented inputing data points to determine if the participant was inside or outside the geofence. This resulted in deleting the data of one participant (P2 see above). Three participants were kept because it was possible to match the data recorded by the data logger to the data recorded by the GPS system.	1. Phone conference with GRA to determine exact boundaries of geofence and exceptions (for example certain areas of battle creek, a city about 20 miles from Kalamazoo were included in the speed data base.) 2. Matched Datalogger data to GPS data. GPS time stamp was in GMT datalogger time stamp was in EDT and EST. In addition to the 4 & 5 hour time difference, there were time differences that varied from a few seconds to a few minutes. Data sets had to be matched by taking sections of data where there were transitions between speed limit zones other than 25 mph. For example, the datalogger file might have the person in a 30 mile per hour zone for 185 seconds, then a 45 mph zone for 55 seconds, followed by a 35 mph zone. To match the data, I would inspect the GPS data file, starting by looking at times that were 4 hours later than the datalogger timestamps. A match was defined as the data from the GPS file being approximately 4 hours (or five for the week that was driven during EST) having the same pattern of transitiions from speed limit zone to speed limit zone as the data logger file, the same amount of time spent in each speed limit zone, the acceleration/deccelation patterns, and the same max speed (plus 3 mph, as the GPS did not always match the speed recorded by the datalogger.) Once the match was made, each time that the datalogger data indicated that particpants were in a 25 mph zone and had a travel speed greater than 30mph for 2 consecutive data points, these points were then found in the GPS file and the corresponding GPS coordinates were put into mapquest to determine if the participant was inside or outside of the zone. There were 15 instances of participants having traveled outside of the geofence when the system failed to shut down. For these intances, I manually changed the datalogger speed limit to zero and set the bits that track "over limit", "over speed trigger 1". and "over speed trigger 2" to zero to indicate that the participant was not speeding.

	These raw data files were then run through the data reduction/ summary analysis program. GPS auto serial number and logger serial numbers were added to facilitate tracking from the raw data.
12 Sometimes impossible speeds would be picked up (>175mph). Occurs less than .01% of time.	If participant speed is >100 then Code speed limit at 73; speed from previous speed reading (one second before hand) would be recorded in the data; this data point is effectively eliminated from the raw data.
13. Participant 28 was slated to receive feedback only condition during week 2 (the feedback only intervention is counterbalanced between weeks 2 and 3). The experimenter gave the proper instructions about the feedback system but set the program that initiates the experimental condition as the baseline condition. Therefore the system did not activate during the week. I noticed a problem when the speed profile of week 2 was essentially the same as the week 1 baseline. I noticed that the summary datafile name, which is generated by visual basic based on the input provided during the initiation of each week, did not match the counterbalance sheet. The	I first confirmed that the participant was supposed to be in the feedback only group. I implemented a procedure in which the GRA sends me the file name generated by the VB program. I verify that the file name matches the counterbalance sheet. This procedure builds in some redundancy to keep the error from recurring. For participant 28, we activated the feedback for week 3 and the GRA repeated the instructions; week 2 was coded as a 'no treatment' week. And a later participant slated to receive the feedback during week 3 will receive the feedback during week 2 to re-balance the potential confound of feedback order.

filename references the P number, experimental condition, vehicle, and week number.	

VITA

Ian J. Reagan

EDUCATION

1998 Bachelor of Science: Psychology Major / Sociology Minor, 3.2 GPA, Old Dominion University, Norfolk, Virginia. (120 semester hours)

2005 Master of Science, Experimental Psychology, 3.88 GPA Old Dominion University, Norfolk, Virginia. (36 semester hours)

2011 Ph.D., Human Factors Psychology, 3.89 GPA Old Dominion University, Norfolk, Virginia.

WORK EXPERIENCE

October 2006 – Present: Research Psychologist, Office of Behavioral Safety Research, National Highway Traffic Safety Administration. Responsibilities: Manage behavioral traffic safety research projects; Develop research projects for upcoming fiscal years; Disseminate findings via technical reports, journal and proceedings articles, and presentations; Review reports for scientific integrity.

PUBLICATIONS

Peer Reviewed Journal Articles

Van Houten, R., Malenfant, J.E., Reagan, I., Sifrit, K., Compton, R, & Tenenbaum, J. (2010). Pilot tests of a seat belt gearshift delay on the belt use of commercial fleet drivers. *Journal of Applied Behavior Analysis, 43*(3), 369-80.

Baldwin, C.L., & Reagan, I. (2009). Individual differences in route-learning strategy and associated working memory resources. *Human Factors, 51*(3), 568-577.

Reagan, I. & Baldwin, C.L. (2006). Facilitating route memory with auditory route guidance systems. *Journal of Environmental Psychology, 26*(2) 146-155.

Conference Proceedings

Reagan, I. & Bliss, J.P. (Accepted). Effects of an Advisory Warning and a Cash Bonus on Speeding Behavior. Submitted for the *Proceedings of the 55th annual conference of the Human Factors and Ergonomics Society.*