Driving While Under Control: The Effects of Self-regulation On Driving

Behavior

by

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ABSTRACT

Modern day driving continues to burgeon with attention detractors found inside and outside drivers' vehicles (e.g. cell phones, other road users, etc.). This study explores a regularly disregarded attention detractor experienced by drivers: self-regulation. Results suggest self-regulation and WMC has the potential to affect attentional control, producing maladaptive changes in driving performance in maximum speed, acceleration, and time headway.

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Chapter 1

WORKING MEMORY CAPACITY, ATTENTION, & DRIVING

Since the introduction of the automobile more than a century ago, the core interaction between driver and vehicle has stayed relatively the same. But with the environment inside and outside personal vehicles becoming more complex, (Cnossen et al. 1997; Miura 1990; Summala, Nieminen, & Punto, 1996; Young et al. 2009) drivers' ability to appropriately allocate attention has become challenged, resulting in inferior driving performances, injury, or even death. Most studies seeking to identify attention detracting effects while driving use secondary attention consuming tasks (e.g. cell phones, in-vehicle manipulations, etc.). This study will seek to identify a more insidious attention depleting manipulation most drivers have dealt with on a daily commute: self-regulation before and while driving.

The ability to control attention while driving is imperative (Johannsdottir & Herdsman 2010). This ability to process and store information while under concurrent cognitive load is commonly referred to as working memory capacity (WMC; Baddeley & Hitch 1974). Following the pioneering work of Baddeley and Hitch (1974), numerous results have suggested that WMC is a mental "workspace" through which storage and processing exact upon the same limited resource. Once this resource is overloaded, either through interference from a concurrent task or a distractor, a decrease in processing (or increases in difficulty of processing) occurs, which usually results in a loss of information from short-term memory (Anderson, Reder, & Lebiere, 1996; Case, Kurland, & Goldberg, 1982; Conway & Engle, 1994; Daneman & Carpenter, 1980; Just & Carpenter, 1992). However, a more current conception of WMC redefines the system not as simply a "resource," but rather, as an "ability" to control attention (Cowan, 2005; Kane et al., 2001) or manage executive control functions (Miyake et al. 2000). Individual differences are widely accepted to be synonymous with this ability. As such, those with higher WMC are thought to be better able to command attention despite the proactive interference of irrelevant information (Engle, Tuholski, Laughlin, & Conway, 1999; Friedman & Miyake, 2004). As such, WMC is considered the locus of attentional control (e.g., Kane et al., 2004).

Increasing demands on attention almost always decreases one's ability to safely operate a vehicle. For example, Recarte & Nunes (2003) found that subjects who drove an instrumented vehicle through real traffic conditions experienced impairments in their spatial gaze concentration and visual-detection when mental workload was increased. Ocular behavior analysis revealed that this impairment was due to late detection and poor identification. Similarly, driving while attending to a secondary task that overwhelms mental capacity has been shown to cause changes in driving behavior such as improper yielding to right-of-way traffic, dangerous interactions with other road users, and increases in speed (Antilla & Luoma 2005).

Neurophysiological measures of spatial attention have illustrated that this ability to resist attentional capture from distracting information varies depending on individual differences in WMC (Fukada & Vogel, 2009). Individuals with high WMC were much more capable of resisting attentional capture compared to low

WMC individuals. Correspondingly, individuals with low WMC involuntarily reallocated spatial attention away from the salient task when distractors were presented. These results suggest that individual differences in attentional control affect vigilant focus on the primary driving task.

This evidence illustrates the powerful association between attentional control and driving. However, if driving is considered solely with this calculated perspective, behavioral allocation would be directly dependent on the relevance and appropriateness of the driving goal. Assuming that each driver's goal is to arrive at their destination timely and safe, under normal cognitive demands individuals should only demonstrate driving behaviors conducive to safe and efficient travel. Unfortunately, this is simply not the case, and dangerous, irrational behaviors frequently occur despite commutes requiring relatively low levels of cognitive effort. What then is influencing drivers to behave in irrationally (and ultimately unsafe) inattentive ways despite these cognitively manageable conditions?

Chapter 2

SELF-REGULATION & DRIVING

Research in self-regulation and rational choice suggests that the ability to control one's self (i.e., behave rationally) stems from the same ability to exact cognitive action, and this effort to self-regulate can persist over time, affecting subsequent measures of attentional control (Baumeister et al., 1998; Ward & Mann 2000; Schmeichel, Vohs, & Baumeister 2003). This maladaptive effect of self-regulation on subsequent attention demanding tasks is commonly referred to as ego depletion; that self-regulative ability is drawn from a limited resource, and when exhausted, mental activity requiring further self-regulation is impaired (Baumeister et al. 1998). Recently, the notion of self-regulation capabilities has been refined beyond the notion of just action through a limited resource, and instead now includes the ability to direct self-regulation resources (Baumeister & Vohs, 2007; Muraven & Baumeister, 2000).

Self-regulation's influence on attention control has been demonstrated across numerous studies. Schmeichel, Vohs, & Baumeister (2003) were able to show evidence that WMC and self-regulation are in fact dependent upon the same cognitive resource. In their experiments, subjects who initially self-regulated by actively ignoring words on the bottom of a video exhibited reduced ability to divide attention during a subsequent test of WMC on the Operation Span task (OSpan; Turner & Engle, 1989). Further examination found that this effect also worked in reverse, with tests of divided attention negatively affecting subsequent suppression of emotion. Similarly, individual differences in self-regulative ability show “high” ability self-regulators as better able to focus on goal-directed behaviors bringing about desirable long-term results (Baumeister, 2005; Fishbach & Labroo, 2007). Conversely, “low” ability self-regulators are more likely to succumb to impulse and immediately gratifying desires (Metcalfe & Mischel, 1999).

This sharing of attentional resources is further supported by physiological measures of subjects after self-regulation, whom showed a significant depletion in blood glucose levels compared to control subjects (Gailliot et al. 2007). Numerous studies highlight the role of glucose in proper cognitive function as a vital source of energy (e.g., Laughlin, 2004; McNay, McCarty, & Gold, 2001; Siesjo, 1978; Weiss, 1986; Reivich & Alavi, 1983). Similarly, glucose is shown to have significant correlations with cognitive functions such as WMC (Foster, Lidder, & Sünram, 1998; Martin & Benton, 1999; Krebs & Parent, 2005).

Taken together, these cognitive and physiological measures suggest that self-regulation does deplete the same cognitive resource required for proper control of attention. Relevant to the current project, this proposes then that drivers who have been (or are currently) self-regulating could be under higher attentional demands than outwardly perceptible. Importantly, it is possible that self-regulation demands are different from other secondary tasks typically used in driving research (e.g., talking on a cellphone) in that self-regulation could simultaneously impact rationality, in addition to core attentional processing.

For example, in a study by Shiv & Fedorikhin (1999), evidence was found supporting the maladaptive effects of relatively low-level mental rehearsal on rational choice self-regulation. Subjects were either given two digits or seven digits to store and subsequently recall after a short period of rehearsal. While subjects were in the processes of rehearsal, they were offered a choice of either fruit (self-regulating choice) or chocolate cake (impulsive choice). Subjects with more digits to rehearse more frequently chose the impulsive choice, while subjects with fewer digits to rehearse were more likely to chose the self-regulating choice. Thus, individuals whose attention was placed under load through simple mental rehearsal were less able to rationalize the dietary consequences of consuming high-calorie foods, and the subsequent suppress of irrational behaviors (Ward & Mann 2000). This study highlights how relatively low demand cognitive tasks can negatively affect self-regulation, leading individuals to select impulsively and irrationally. Further, investigations into the relationship between ego-depletion and aggression (an impulsive emotion) propose that when self-regulating (e.g. through abstinence from the urge to eat tempting food or suppression of physical and emotional responses to a film), subjects produce more aggressive reactions when provoked compared to those who were unregulated (Stucke & Baumeister, 2007; DeWall et al., 2009). This likelihood to commit aggressive actions seems especially important considering the frequency of instances of such phenomenon like ‘road rage’ that happen every day on populace roadways. Despite the commonplace occurrence of such impulsive and irrational behavior on roadways (i.e., tailgating, speeding, erratic lane changes, etc.), knowledge on the effects of self-regulation on attentional control within the context of driving behavior is sparse.

Relative to driving behaviors, this research proposes that self-regulating drivers, while traversing relatively low-level secondary task conditions, may actually be under more attentional demands than outwardly evident. In other words, should individuals feel the need to self-regulate before (or during) their commute, their ability to effectively allocate attention towards rational highway behavior might be affected, in addition to their ability to operate the vehicle itself. It is important to understand how these findings may affect drivers because the need for self-regulation is actually fairly common in everyday driving scenarios. For example, self-regulation over one's emotional state might be necessary across several scenarios routinely encountered while in-vehicle such as following a slow-moving lead vehicle in a no-passing zone, having to stop at a prolonged traffic-light, following questionable traffic regulations, etc. It is also possible that self-regulation on the roadway can be activated by the individual themselves (independent of the driving task) should they be driving during or after denial of certain pleasures in their personal lives (e.g. dietary regulation, emotion suppression, unpleasant working conditions, etc.). While troubling, it is entirely possible drivers could be experiencing these situations (and thus need to self-regulate) *multiple* times during the same trip for *multiple* different reasons.

Further, it is reasonable to assume that the cognitive processing ability needed to command a vehicle negatively interacts with self-regulation demands, and vice-versa. As such, drivers' maladaptive behaviors could be a result of not just a failure to control attention relative to the driving task itself, but also a failure to control attention as a result of self-regulation. This begs to ask the following questions: if self-regulation uses the same ability of attention control as cognitive activation, could the combination of low demand cognitive activation and low influence self-regulation produce maladaptive driving behaviors?

Chapter 3

METHODS

Pretest

Participants' WMC was determined using a computerized assessment of WMC, Automated Operation Span (AOSPAN; Unsworth, Heitz, Schrock & Engle, 2005). AOSPAN is a computerized version of the original Operation Span task (Turner and Engle 1989), which has been shown to be reliable and diagnostic for determining WMC differences (Unsworth et al., 2005). In AOSPAN participants were asked to determine the validity of a series of simple math equations. After each equation participants were presented a letter to remember for a later recall. Upon completion of a trial, participants identified the presented letters in the correct presentation from a matrix of 12 possible choices. Participants completed three sets of each trial size, resulting in 75 total items. Trial sizes were varied from three to seven math equations. The AOSPAN session was self-paced and lasted (on average) approximately 20 minutes. All administration and scoring followed the recommendations of Unsworth et al. (2005).

Driving Simulator

Driving performance was evaluated using the DS-600c Advanced Research Simulator by DriveSafety™. Participants were surrounded by a 300 deg wraparound display as they sat inside a full-width automobile cabin (Ford Focus) mounted on a motion platform. The motion platform provided appropriate inertial cues for the replication of longitudinal acceleration and deceleration. Dynamic torque feedback from the steering wheel and vibration transducers mounted under the driver's seat provided tactile and proprioceptive feedback. Software provided by DriveSafety™ captured salient driving performance elements such as velocity, time headway, and lane variance at 60 Hz. Driver's current speed was displayed in the car cabin dashboard through an integrated speedometer.

The driving course featured a two lane road (two lanes going one way and another two lanes going the other way) with a stop light before each provoker. Throughout the course, in every condition, participants encountered common transgressions by other vehicles and traffic regulations. These encounters were included to serve as provokers, which have been shown to activate aggressive behavior in self-regulating participants (Gal & Liu, 2007; DeWall et al, 2007; Stucke & Baumeister 2006). Subjects first drove to the first stop light. Stopped for approximately two (2) seconds then drove through an open, two lane stretch of road. Subjects average speed and maximum speed was measured at this point to serve as control. Upon taking a banked left turn, subjects encountered another stop light, which lasted for approximately two (2) seconds at which point they encountered mild, obstructing traffic moving at 45 mph. Subjects maximum acceleration was measured at this stop light. Once subjects were 3 seconds to the rear of the traffic obstruction, a tailgating SUV was programmed to begin following subjects at a THW of one (1) second. The tailgating vehicle was visible in the driver's rear view mirror and audibly present. During this provoker manipulation, subjects average THW and shortest THW was measured. This provoker was followed by an open two lane stretch of road and a banked turn.

Subjects average speed and maximum speed were measured at this stretch. Next subjects encountered a slow moving lead vehicle moving at approximately 35 mph. Subjects average and shortest THW was measured while dealing with this provoker. This was followed by an open, two lane stretch of road where subjects average and maximum speed was measured. Then finally, after taking another banked turn, subjects encountered a prolonged stop light. This light lasted approximately one (1) minute with little to no traffic going in the perpendicular direction. Throughout the course, traffic going the opposite direction was programmed to be medium congestion travelling at speeds of 45-55 mph. A speed limit ranging from 40 to 60 MPH was explicitly stated to the subject before each run.

Procedure

Thirty-two (N = 32) undergraduates from a large public university participated in this experiment. All participants were compensated with course credit in an introductory psychology class. Participants first completed a practice run to familiarize themselves with the dynamics of the driving simulator, followed by a control run (run 1), a digits rehearsal run (run 2), and a combination digits rehearsal + self-regulated run or digits rehearsal + unregulated run (run 3). In the control condition, participants drove through the course under instruction to follow normal, lawful driving convention as they would should they be commuting a familiar road. This instruction was repeated before each subsequent run after subjects had completed a five minute break. In the digits rehearsal run, participants traversed the course while mentally rehearsing a random five digit number and letter combination, which was presented on the driving simulator screen at the beginning of the drive. Five digits were chosen because of its low demands on attentional control (Miller 1956; Cowan 2001). Consequently, this condition was not expected to significantly differ from control and was included to observe if attentional control through mental rehearsal is affected by self-regulation. Afterwards, were randomly assigned to either the self-regulation group or the unregulated group. Participants were sat in front of a computer screen and asked to watch a slideshow consisting of a series of emotionally evocative images. Participants in the self-regulation group were instructed to regulate all facial, emotionally, and bodily reaction while watching the slideshow. This activity has been shown to be sufficient in exacting ego-depletion on subjects (Dewall et al. 2007; Glass et al. 1969). Participants in the unregulated group were instructed to react as they saw fit to the slideshow content. Finally, the self-regulation group and the unregulated group returned to the driving simulator and completed a combination digits-rehearsal + self-regulation or non-regulated run. Participants' driving performances on the variables of average and maximum velocity, acceleration, and time headway were measured for each run during and after each manipulation. Upon completion of the final run, subjects were instructed to grab a debriefing slip next to a bowl of chocolates on their way out. The number of chocolates they took was counted as an implicit measure of the slideshow's effectiveness in inducing self-regulation.

Chapter 4

RESULTS & DISCUSSION

Average & Maximum Speed, Acceleration & THW

We compared the control group and self-regulating group's average and maximum speed at each provoker location (i.e. slow lead vehicle, tailgaters, and long stop light) from run 1 to run 3. Average and shortest THW was measured and compared in the same way at provoker locations where subjects encountered a a tailgating rear vehicle and slow moving lead vehicle.

Tailgaters. During this provoker manipulation, subject's average THW to the lead vehicle was measured. Average THW was significantly different when comparing run 1 to run 3 (F (1, 32) = 3.09, p = 0.05), with subjects shortening average THW in run 3 compared to run 1. See Figure 1. This was not mitigated by WMC ($F(3,32) < 1$, $p = .84$). The control group and self-regulating group, with the covariate of WMC, showed no difference in average THW while following a lead vehicle and dealing with a tailgating rear vehicle ($F(1,32) < 1$, $p = .93$). After dealing with the tailgating rear vehicle, subjects encountered an open, two-lane road where average speed was measured. There was no significant difference in average speed from run 1 to run 3 (F(1,32) = 2.48., $p = .13$). There was no interaction with WMC (F(3,32) < 1, p = .67), but there was a significant difference between groups (F(3,32) = 3.50, p = .03), with the low span control group driving at significantly faster speeds compared to the others. There was no difference on average acceleration from run 1 to run 3 (F(1,32) < 1, p = .40) and no interaction with WMC (F(3,32) < 1, p > .53). Also there was no significant difference between groups ($F(3,32) = 1.07$, $p > .38$). Maximum accelerator pressure not significant when comparing run 1 to run 3 ($F(1, 32) = 4.02$, $p = .06$) with no interaction with WMC ($F(3, 32) < 1.00$, $p = .60$) and no difference between groups ($F(3,32) < 1$, $p = .83$).

However, comparing the low WMC, self-regulated subjects to the low WMC control group, the former showed a significant increase in accelerator pedal pressure from the control run compared to the final run $F(1,11) = 7.53$, $p = .03$) with a significant interaction ($F(3,11) = 8.50$, $p = .02$). There was no significant difference between the two low span groups ($F(1,11) < 1$, $p = .91$). See Figure 2. There was no difference from run 1 to run 3 on the variable of shortest THW ($F(1, 32) = 1.60$, $p = .22$), no interaction with WMC ($F(3, 32) = 1.07$, $p = .38$). There was no difference between groups ($F(3,32) = 1.07$, $p = .38$). No significant difference from run 1 to run 3 on the variable of maximum speed ($F(1,32) = 3.04$, $p = .09$), no significant interaction with WMC ($F(3, 32) = 1.09$, $p = .37$). There was a significant difference between groups ($F(3, 32) = 6.24$, $p = 0.00$), suggesting that low span control subjects tend to drive faster. See following Figure 3.

Slow lead vehicle. Average THW, when comparing run 1to run 3, was not significantly different ($F(1,32) < 1$, $p = .33$), there was no interaction with WMC ($F(3,32) < 1$, $p = .59$). There was no significant difference between groups while following a slow moving lead vehicle ($F(3,32) = 2.31$, $p = .10$). There was a significant difference from Run 1 to Run 3on the measure of average speed ($F(1,32) = 9.05$, $p =0.005$), unexpectedly showing a decline in speed from run 1 to run 3. This is suspected to have occurred due to influence from the slow moving lead vehicle in association of proper speed. See Figure 4. This was not affected by WMC ($F(3,32) < 1$, $p > .5$). There was no significant difference between groups ($F(3,32) < 1$, $p = .51$). There was no significant difference in maximum speed from run 1 & run 3 ($F(1,32) = 2.17$, $p = .15$), with no interaction with WMC ($F(3,32) = 1.03$, $p =.40$) But the groups showed a significant difference between subjects in maximum speed ($F(3,32) = 3.24$, $p =.04$). See Figure 5.

No significant difference from Run 1 to Run 3 with the variable of shortest THW ($F(1,32) = 3.30$, $p = 0.08$), with no interaction with WMC ($F(3,32) < 1$, $p = .48$), and no difference between groups ($F(3,32) = 1.15$, $p = 0.35$). Maximum acceleration was not measured at this provoker manipulation.

Long stop light. After enduring a seemingly useless, prolonged stop light, subjects' average and maximum speed was measured. Average speed from run 1 to run 3 was significantly different ($F(1,32) = 4.67$, $p = .04$). See Figure 6. However there was no interaction with WMC ($F(3,32) = 1.49$, $p = .24$) and no difference between groups ($F(3,64) < 1$, $p = .45$). There was no significant difference from run 1 to run 3 on the variable of maximum speed ($F(1,32) = 1.44$, $p = .24$). There was no interaction with WMC ($F(3,32) = 1.20$, $p = .33$) and no significant difference between groups ($F(3,32) = 1.63$, $p = .21$). Average acceleration was not significantly different from run 1 compared to run 3 ($F(1,32) = 3.41$, $p = .07$) with no interaction with WMC ($F(2,32) = 1.95$, $p = .14$). There was no significant difference between groups ($F(2,32) < 1$, $p > .57$). There was significant difference in maximum acceleration from run 1 to run 3 ($F(1,32) =$

9.96, $p = .004$). But no interaction with WMC ($F(3,32) < 1$, $p = .73$). No significant difference between groups ($F(3,32) < 1$, $p = .73$). See Figure 7.

Self-regulation. The self-regulation group took twice as many chocolates from the bowl (14) compared to the control group (7). Given research regarding glucose and self-regulation, it is within reason to assume that this self-regulation manipulation supports current interpretation of self-regulation efficacy.

These results suggest that subjects tend to display maladaptive driving behaviors after a few sessions of driving. This maladaptive change in driving behavior is hypothesized to be due to complacency or practice effects, as a result of attention demands from the driving task. However, despite the shortcomings and limitations of this study, some of the results suggest that self-regulation & WMC may have some affect should the limitations be addressed.

Limitations

A couple limitations of this study should be considered for future research. One such limitation was the low number of subjects with some groups. This affected power of the findings and this author believes that addressing this issue will show a stronger affect to driving variables relative to WMC and self-regulation. The final limitation was the driving course itself. Due to shortcomings in the programming software, we were forced to use an environment that some subjects believed to suggest a cityscape with transitions to highway sections. It is likely that this may have moderated selection of driving speeds within subjects. The optimum environment would not have these implicit cues. It would be interesting to see how this research would translate to a driving course that was purely seen as highway given that current highways show the most variability in driving behaviors amongst commuters. Further experimentation should be performed to assess the efficacy of self-regulation on attentional control ability as it affects driver behavior.

Chapter 5

FIGURES & CHARTS

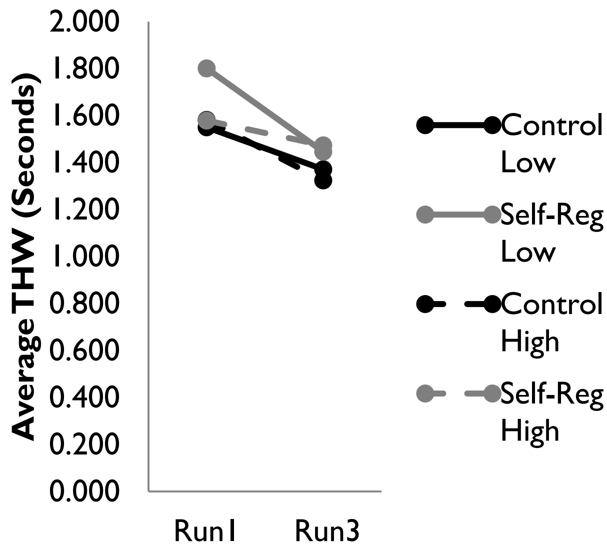

Figure 1: *Subjects Average THW was significantly different from run 1 to run 3 (F (2, 32) = 3.09, p = 0.05), with all groups showing a decrease in THW presumed to be due to practice effects.*

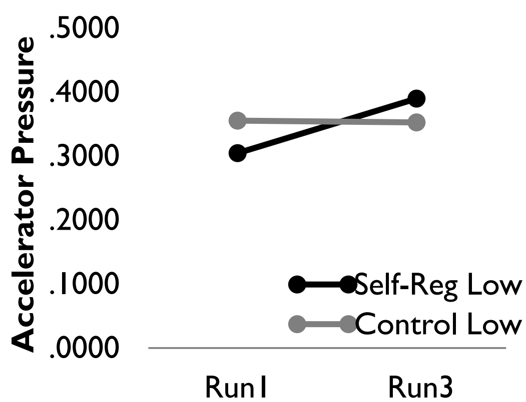

Figure 2: *When comparing the low WMC, self-regulated subjects to the low WMC control group, the former showed a significant increase in accelerator pedal pressure from run 1 to run 3* (F(1,11) < 1, p = .91).

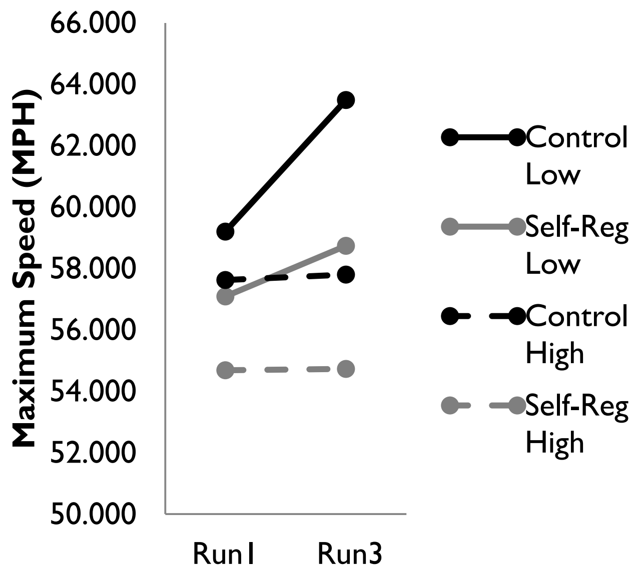

Figure 3: *There was a significant difference between groups (F(3, 32) = 6.24, p = 0.00) on the variable of maximum speed, suggesting that low span control subjects tend to drive faster after dealing with a tailgating vehicle compared to the other groups.*

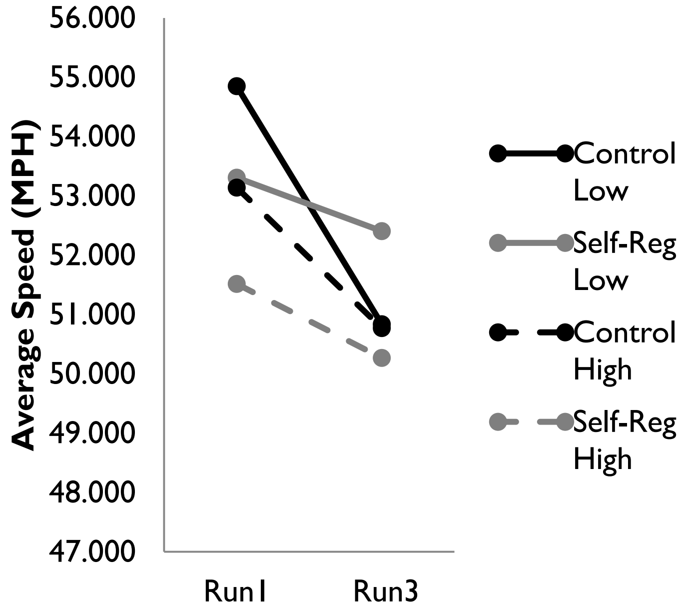

Figure 4: *Significant difference from run 1 to run 3 (F(1,32) = 9.05, p <=.005) on the variable of average speed after following a slow moving lead vehicle. Unexpectedly, subjects decreased average speed from run 1 to run 3.*

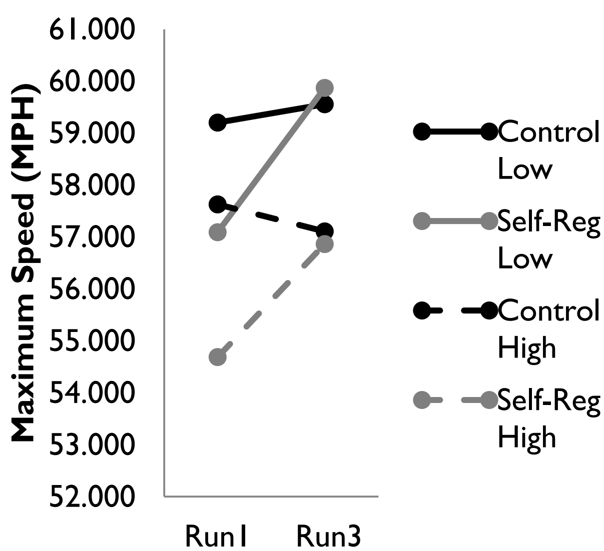

Figure 5: *The groups showed a significant difference between subjects in maximum speed (F(3,32) = 3.24, p =.04, with the control groups starting at faster speeds in run 1 compared to the self-regulated groups).*

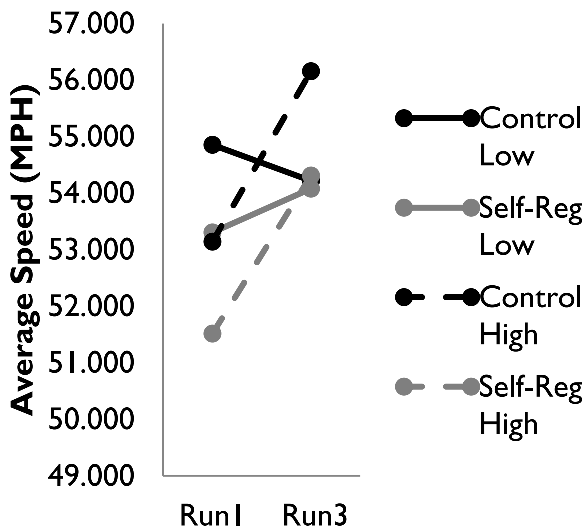

Figure 6: *Subjects showed significant difference in average speed from run 1 to run 3 after waiting at a prolonged stop light with no cross traffic present (F(1,32) = 4.67, p < .05), increasing maximum speed for all groups except the low WMC control group.*

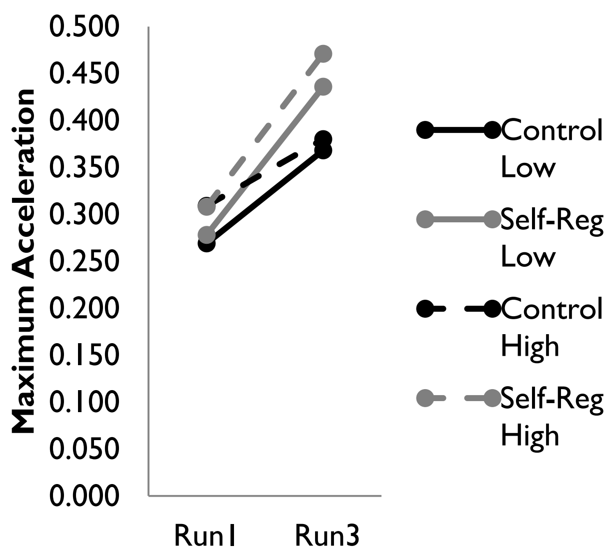

Figure 7: *There was significant difference in maximum acceleration from run 1 to run 3 ($F(1,32) = 9.96$, $p = .004$), after waiting at a prolonged stop light.*

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