2014

Caffeine and Human Perception of Time

Trevor Fry
Eastern Washington University

Recommended Citation

Fry, Trevor, "Caffeine and Human Perception of Time" (2014). *EWU Masters Thesis Collection*. 226.
http://dc.ewu.edu/theses/226

Caffeine and Human Perception of Time

A Thesis

Presented To

Eastern Washington University

Cheney, Washington

In Partial Fulfillment of the Requirements

for the Degree

Master of Science

By

Trevor N. Fry

Spring 2014

THESIS OF TREVOR FRY APPROVED BY

_______________________________________ DATE___________

JONATHAN W. ANDERSON, GRADUATE STUDY COMMITTEE

_______________________________________ DATE___________

AMANI EL-ALAYLI, GRADUATE STUDY COMMITTEE

_______________________________________ DATE___________

DORIS MUNSON, GRADUATE STUDY COMMITTEE

MASTER'S THESIS

Signature____________________

Date________________________

Abstract

The purpose of this study was to investigate the effect of caffeine on several components of time perception in an attention-demanding task. Review of the current literature shows that the rhythm of the brain's internal clock, controlled by the suprachiasmatic nucleus (SCN), which is believed to mediate the perception of short durations, is sensitive to a variety of stimuli including stimulants. This study expands on previous research on the effect of caffeine on prospective time estimation by having participants estimate multiple short durations while completing a cognitively complex time estimation task involving math. The study included a moderate dose caffeine condition and a placebo condition. Previous findings have shown that a moderate dose of caffeine, coupled with a relatively complex information-processing task, limits individuals' ability to allocate cognitive resources necessary for accessing the internal clock (Gruber & Block, 2005). It was hypothesized that with a more complex cognitive task, participants given caffeine would make shorter temporal predictions than those given a placebo. Contrary to expectations, the results suggest that a 200mg dose of caffeine does not have an impact on an individual's ability to accurately estimate short durations of time while completing an attention-demanding task. Limitations to these findings are discussed and although the results were counter to the hypotheses, they help to provide scaffolding for future research investigating similar effects of caffeine on the ability to accurately estimate durations of time.

Keywords: caffeine, time estimation, prospective judgment duration, impulsivity, executive function

Table of Contents

List of Figures

Caffeine and Human Perception of Time

Does it feel like busy mornings go by faster with a cup of coffee in your hand? From coffee to tea, to soda pop and 5-Hour Energy shots, caffeine is present in a broad variety of foods and beverages in the United States (Barone & Roberts, 1996). However, the cognitive effects of this drug are not yet fully understood. Prior research on time estimation has suggested that the biological rhythm of the brain's internal clock, which is moderated by the suprachiasmatic nucleus (SCN), is sensitive to a variety of stimuli, including temperature, emotions, drugs, and diet (Cheng, Meck, & Williams, 2006; Droit-Volet & Meck, 2007; Wearden & Penton-Voak, 1995). Previous findings from research in this area have produced conflicting results, but it has been argued that caffeine can sometimes have a negative impact on our perception of time (Gruber & Block, 2005).

Past research has demonstrated that caffeine does not have an impact on time estimation in tasks involving little cognitive demand, but it does affect time estimation in tasks involving higher cognitive demand (Gruber & Block, 2005). The purpose of this study was to further explore the effect that caffeine has on time perception by examining time estimation during a task with high attentional demands. The study design seeks to replicate and extend earlier findings by Gruber and Block (2003, 2005) on the effects of caffeine on prospective duration judgments. Furthermore, Hancock and Block have recommended that further research on this topic begin to focus on variables that account for individual differences in time estimation (2012), so this study also explored relationships between caffeine and time estimation and executive function and impulsivity. Perception of time is critical to many aspects of life including hunger and sleep cycles as well as communication techniques, and completion of tasks through systematic processes. As caffeine is widely considered to be the most abundant and most frequently consumed stimulant substance in the United States (Barone & Roberts, 1996), understanding how this substance affects our perception of time during everyday tasks should be a topic that is more globally understood.

A wealth of research has been conducted on the physiological effects of caffeine, noting its influence on increases in blood pressure (Childs & De Wit, 2006) and improvements in physical endurance (Graham, Rush, & Soeren, 1994). However, there is still some inconsistency as to how much of an effect caffeine has on human time perception across different circumstances and whether or not its cognitive effects should be considered beneficial. Some research has suggested that caffeine may impact perception of time as a consequence of the influence it has on attention (Gruber & Block, 2003). Furthermore, the frontal lobe is regarded as the area of the brain responsible for executive functioning, which manages the regulation of attentional resources, and therefore plays a critical role in perception of time.

Time Estimation

Several theoretical models have been proposed to clarify understanding of time perception in humans. Although no model is perfect, there are a few that are particularly relevant to the present purpose and have helped to develop a framework for understanding people's perception of time. These models are important as they distinguish the relationships between memory, attention, and time perception in cognitive science.

Duration judgment paradigm. First proposed by William James (1890), the duration judgment paradigm stresses the importance of memory and attention in the perception of time. The duration judgment paradigm involves two types of time estimation: retrospective time estimation and prospective time estimation. Retrospective time estimation (also known as remembered duration) refers to a circumstance where participants are not aware that they will be asked to recall a particular duration of time until after it has passed. This type of duration judgment can be best explained through memory models of time perception. A person has to use cues from memory to put together a temporal order of events that have already passed. By nature, retrospective judgments are shorter and less reliable than prospective time estimates (Block & Zakay, 1997).

On the contrary, prospective time estimation (also known as experienced duration) is defined as participants being aware of time estimation demands beforehand so they pay deliberate attention to time as it passes. Prospective duration judgments are best explained by executive models of time perception as they involve acute attentiveness to the passage of time. A previous meta-analysis of the literature supported that prospective timing involves an increase of cognitive resources devoted to temporal elements during tasks that involve time estimation (Block & Zakay, 1997). In addition to the duration judgment paradigm, several other theories of time perception have been proposed.

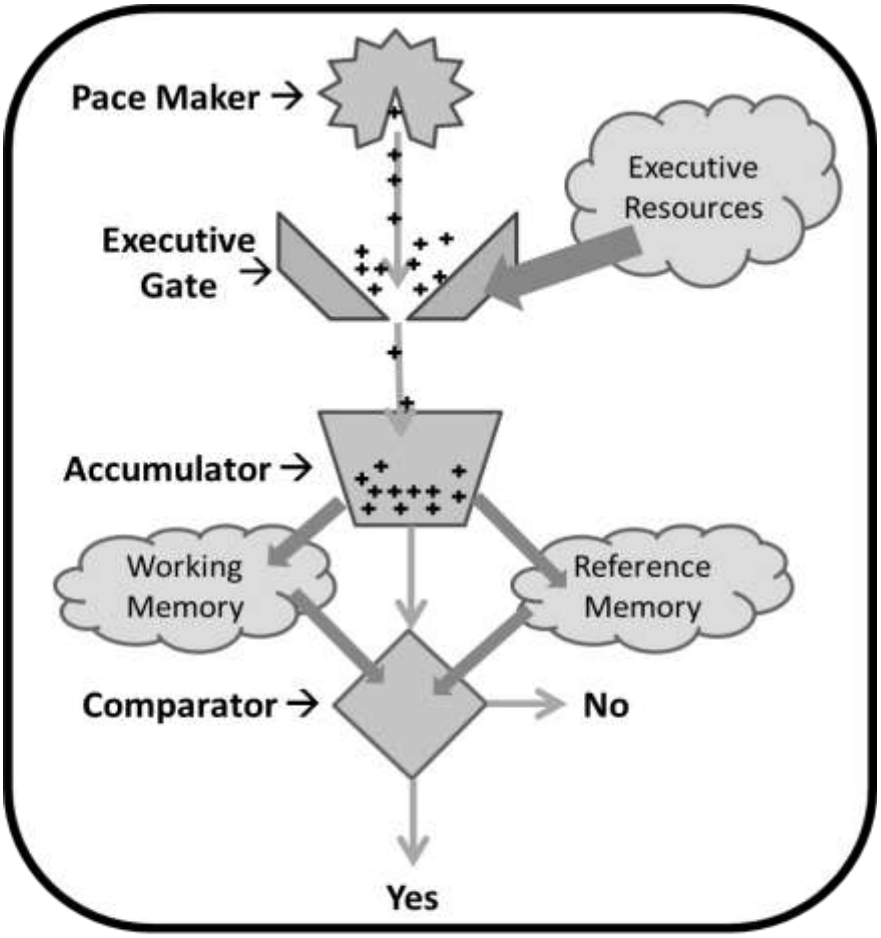
Internal clock model. The idea of an internal clock mechanism in the brain was first proposed by François (1927) and Hoagland (1933). Theoretically, this arrangement of interworking mental systems involves a pacemaker, an accumulator, and a comparator mechanism. The pacemaker mechanism produces periodic impulses that are relayed to the accumulator. As these neural pulses are stored in the accumulator, longer perceived durations are positively associated with the number of pulses stored. The comparator, the decision making element, is involved in comparing the number of pulses in the accumulator to a standard interval in order to determine specific durations (Hoagland, 1933).

The SET model. The Scalar Expectancy Model (SET) was developed as a more official internal clock model and has been successful in studies that have investigated timing in animals (Gibbon, 1977). The SET model involves three similar components: clock, memory, and decision making. In this model, the clock and memory components are similar to the pacemaker and accumulator described in the internal clock model such that they provide the cognitive structure for a linear temporal model. The decision making mechanism incorporates information from memory and a hypothetical neurological clock to determine whether a given duration of time is longer, shorter, or the same as previously experienced durations. Although this has been a successful tool for the study of timing in animals (e.g., rats and pigeons), this model has been criticized for use with humans because it does not account for the role that cognition plays in perception of time (Wearden, 2003).

Executive Gate Model. The Attentional Gate Model (AGM) (Block & Zakay, 1997) was evolved to include a central executive component similar to those demonstrated in working memory models (Block, Hancock, & Zakay, 2010). Evolving from the AGM, the Executive Gate Model (EGM) was developed to incorporate the role that attention and other higher-level cognitive functions have been found to play in people’s perception of temporal durations (Block & Zakay, 1997; Zakay & Block, 1996). The EGM extends the SET model by also involving an "executive gate" positioned between the pacemaker and accumulator mechanisms (Block et al., 2010; Figure 1). The more cognitive resources devoted to time, the wider the gate becomes, allowing the accumulator to store a greater number of temporal cues for future discrimination. In a recent review, Block and colleagues (2010) argued that time estimation is significantly influenced by cognitive load, and that increased cognitive load results in a larger subjective to objective duration ratio (i.e., estimates are faster and less accurate). That is, the gate between the pacemaker and accumulator mechanisms is thought to be influenced by a range of high-level executive functions.

Figure 1.

The Executive Gate Model.



In recent analyses of attention and working memory, Baddeley emphasized that the controlling central executive is a limited capacity attentional system (2000, 2002). Previous studies have found time estimation to be related to the amount of attentional resources allotted to estimate experienced durations of time (Block & Zakay, 1997; Block, Zakay, & Hancock, 1999). The influence of attention on time estimation has demonstrated that people will become considerably less accurate as demands for their attentional resources increase (Burnside, 1971; Chaston & Kingstone, 2004). Specifically, a study by Burnside (1971) found that participants who simply read numbers aloud provided relatively accurate time estimates compared to those who performed mental calculations with the same number set in a prospective time estimation task. Furthermore, it was observed that as the complexity of the mathematics increased from adding to multiplying numbers, participants' temporal estimations became shorter and less accurate (Burnside, 1971). Further research has continued to support that increased attentional involvement to stimuli other than time results in increased underestimation of prospective durations (Chaston & Kingstone, 2004). Prospective duration judgments primarily involve the control of attention, as well as other higher level executive functions, to the passing of time as it takes place. The internal clock accumulates a bank of cues relative to the amount of executive resources allocated to temporal stimuli and is considered to be regulated by the executive gate.

Prospective duration judgments primarily involve the control of attention, as well as other higher level executive functions, to the passing of time as it takes place. The internal clock accumulates a bank of cues relative to the amount of executive resources allocated to temporal stimuli and is considered to be regulated by the executive gate. Consistent with Gruber and Block's (2005) results, in this study it was expected that people in a cognitively complex task will, by nature of the task, present shorter time estimates than the actual time presented. The present study sought to explore the effects of caffeine on individuals' ability to accurately evaluate the passing of time. This contributes to the current body of literature on the effects of caffeine on time estimation by including a range of time intervals between 10 and 60 seconds.

Effects of Caffeine

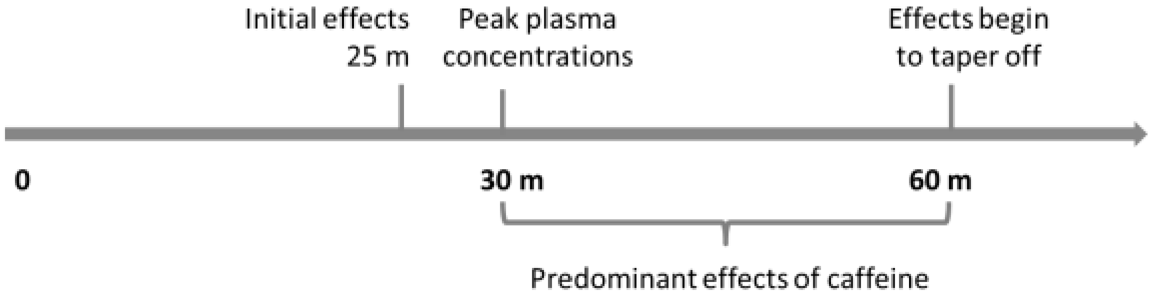
Statistics regarding caffeine usage are extremely limited despite the wide range of products available that contain caffeine. The estimated per capita caffeine intake for adults is roughly in the range of 3.0-4.0 mg/kg (caffeine/body weight) daily (Barone & Roberts, 1996). In other words, a person weighing 150 pounds consumes on average about 238 milligrams of caffeine, or about 2 cups of coffee, per day. In laboratory settings, caffeine has been found to elicit a number of physiological and psychological effects in both humans and animals. Research investigating the effect of caffeine on specific adenosine receptors, and the subsequent activation of dopamine receptors (Chen et al., 2001; Strömberg, Popoli, Müller, Ferré, & Fuxe, 2000), has alluded that people taking caffeine experience an overall psychostimulant effect (Nehlig, Daval, & Debry, 1992) and also may demonstrate improvements in attention and other cognitive processes (Chen et al., 2010).

Physiological actions of caffeine. As evidenced throughout the literature, the physiological and molecular effects of caffeine have been a topic of rigorous study and the drug is widely known for its physically arousing properties. Caffeine targets adenosine receptors of all kinds which have subsequent effects on neural systems throughout the central nervous system (Ribeiro & Sebastio, 2010). In a review of research examining the psychomotor, arousal, and cognitive effects of caffeine on genetic knockout mice, researchers concluded that the molecular receptor primarily targeted by caffeine is the adenosine A_{2A} receptor (Chen et al., 2010). The adenosine $\mathrm{A}_{2\mathrm{A}}$ and dopamine D_2 receptor sites have been found to be co-localized in the central nervous system, and as caffeine blocks adenosine $\mathrm{A}_{2\mathrm{A}}$ receptors, there is an agonistic effect on dopamine D_2 receptors (Shen & Chen, 2009). These actions facilitate increased arousal levels that have successive effects on many other behavioral functions. The effect of caffeine on specific adenosine $\mathrm{A}_{2\mathrm{A}}$ and dopamine D_2 receptor sites suggests that people given caffeine may have greater ability in regard to selective attention (Chen et al., 2010).

The timing of caffeine’s molecular action was important in the development of the current study. Research has found that 25 minutes after administration, the arousal effects of caffeine are predominant for 30 minutes (Barry, Clarke, Johnstone, & Rushby, 2008), with the drug reaching its peak plasma levels approximately 30 minutes after administration (Blanchard & Sawers, 1983; Figure 2). Furthermore, it has been suggested that caffeine doses that exceed 500mg are likely to cause negative side effects (Hasenfratz & Battig, 1994). Known side effects of caffeine can include nervousness, irritability, sleeplessness, and rapid heartbeat in some cases (Barry, Clarke, Johnstone, & Rushby, 2008).

Figure 2.

Molecular Timing of Caffeine.



Psychological effects of caffeine. Caffeine has also been shown to have a number of potentially beneficial mental effects. In 2002, the U.S. military reported caffeine to be the preferred substance for temporarily counteracting cognitive deficits (Vanderveen et al., 2002). In the general population, caffeine has been presented as a mechanism to facilitate improvement of simple reaction time scores (Adan & Serra-Grabulosa, 2010). Other researchers found that heavy caffeine consumers exhibited quicker simple and choice reaction time and reported more positive mood compared to moderate caffeine consumers (Attwood, Higgs, & Terry, 2007). Childs and De Wit (2006) presented evidence that the amount of caffeine found in one cup of coffee is an ample dose to elicit stimulant-like effects and improvements of mood and cognitive performance in caffeine users, even in the absence of withdrawal. Another similar study that investigated people under normal caffeine use and those experiencing withdrawal from caffeine found that caffeine improved selective attention in both those under the influence of caffeine and those in withdrawal conditions (Addicott & Laurienti, 2009). Another recent experiment comparing the effects of black tea and placebo on objective attention and subjective measures of alertness found that caffeine yielded better accuracy on an attention measure and higher self-reported alertness (De Bruin, Rowson, Van Buren, Rycroft, & Owen, 2011).

In this study, it was expected that people given caffeine would allocate more attentional resources to processing a complex task than individuals not given caffeine, resulting in fewer attentional resources available to devote to the passing of time and in the production of shorter time estimates.

Previous Studies on the Effects of Caffeine on Time Estimation

There have been several previous studies investigating the effects of caffeine on perception of time, yielding a body of somewhat mixed results. Many interesting effects have been discussed in the literature and some authors have suggested that caffeine has an effect on time perception whereas others have argued that it does not. For example, a study investigating the effect of caffeine on time estimation in rats concluded that a low dose of caffeine will speed up the timing process whereas very high doses slow the process down, suggesting that different neuronal mechanisms are involved (Prouty, Burgette, Thomas, Keen, & Erturk, 2008). Prouty and colleagues (2008) suggest that the differences in low and high doses of caffeine may be a result of the sequence in which caffeine binds to specific adenosine receptors in the central nervous system. McClellan-Stine and colleagues (2002) found that the relationship between caffeine use and accuracy of time estimation could be portrayed as an inverted-u shaped quadratic function, meaning that those in a low dose condition perceived the passing of time more accurately than those in a high dose or placebo group (McClellan-Stine et al., 2002). Another recent experiment reported that a moderate dose of caffeine (200mg) had little effect on those who reported consuming at least 120mg of caffeine per day. However, participants who had presumably not developed a tolerance to caffeine had time estimates that were shorter and less accurate when under the influence of caffeine (Hunt, Momjian, & Wong, 2011).

Further muddying these mixed findings, one paper suggested that in order for caffeine to significantly impact an individual’s time estimation, one would have to consume roughly “3-4 cups of brewed coffee, 6 cups of instant coffee, 9 cups of tea, or 16 cans of soda" (Buffalo, Gillam, Allen & Paule, 1993). Additionally, another recent study that investigated the effects of both caffeine and alcohol on time discrimination found there to be no significant effects of caffeine alone (Terry, Doumas, Desai & Wing, 2009).

However, in other recent studies, researchers have demonstrated that in some circumstances caffeine does have an effect on time discernment. In a study measuring retrospective and prospective verbal estimates of time duration in a relatively complex task, researchers found a significant effect of caffeine and a significant interaction between duration paradigm (retrospective and prospective duration judgment) and caffeine as evidenced by prospective time estimates being shorter and less accurate among those given caffeine (Gruber & Block, 2003). Whereas, in the retrospective condition, no differences emerged between participants given caffeine and individuals not given caffeine.

A series of follow-up studies by Gruber and Block (2005) looked at caffeine's effect on judgment duration in attention-demanding and non-attention-demanding tasks. Researchers administered either 200 milligrams of caffeine or a placebo to participants and then had them take part in an attention-demanding or non-attention-demanding task involving time estimation. The attention-demanding task used in that study involved a simulated driving video game in which participants were required to use a steering wheel and gas and brake pedals to control a vehicle in a virtual environment. For the non-attention-demanding task, participants watched a video of a car driving that was recorded from a camera mounted to the dashboard. Individuals were asked to provide time estimates for randomized intervals of 15, 60, and 300 seconds. Those authors found that caffeine decreased time estimates in a demanding task but not in a non-demanding task.

The Role of Individual Differences

In a recent review by Hancock, Block, and Zakay (2012), it was noted that the most crucial issue in the study of psychological time concerns individual differences and that future research in this field should seek to illuminate sources of this variability. This study sought to further investigate whether impulsiveness and executive function are variables that can account for some individual differences observed in time estimation. Furthermore, for those not in the caffeine condition, an exploratory analysis of retrospective versus prospective time estimation accuracy was conducted between data collected from the participants' temporal estimates of the length of video clips.

Evidence of caffeine having different effects between genders has been noted but not substantiated. In one study, there was no overall difference between time estimates by males and females in a prospective time estimation paradigm, but a significant difference in the retrospective paradigm, which suggests that females tend to overestimate short durations to a slight degree (Block, Hancock, & Zakay, 2000). More specifically, the authors concluded that females tend to give time estimates that are on average 10% longer than the objective duration, and males tend to underestimate the objective duration by about 2% (Block, Hancock, & Zakay, 2000). A subsequent experiment found that sex differences in duration judgments were removed by moderate doses of caffeine (Botella, Bosch, Romero, & Parra, 2001). A study by Botella and colleagues (2001) revealed that females made significantly more accurate temporal estimates than males overall, and the effect of caffeine on time estimation was significant. Other research presented that females who consumed caffeine had a higher sensitivity to the caffeine effect than men when estimating a one-minute duration (Arushanyan et al., 2003). It has also been argued that caffeine's effect on time estimation is dependent on a list of factors including gender, temperament, and type of working efficiency (Arushanyan et al., 2003). This study also sought to explore potential gender differences in the effects of caffeine on time estimation.

Investigating relationships with impulsivity. Previous findings have suggested that impulsivity has a significant effect on time estimation accuracy in tasks involving time reproduction (Glicksohn, Leshem, & Aharoni, 2006). Glicksohn and colleagues (2006) found a negative correlation between time reproduction accuracy and measures of impulsivity. The Barratt Impulsiveness Scale (BIS-11) was developed to measure impulsivity among clinical and inmate populations (Barratt, 1959) and has since been revised and used among general populations (Gruber & Block, 2003). Gruber and Block (2003) found impulsivity, as measured by the BIS-11, to be a non-significant predictor of time estimation scores in the negative direction when individuals completed a relatively complex attention-demanding task. A goal of the present study was to extend these findings by looking at longer lengths of time and by looking at a variety of durations in a prospective time estimation task. It was predicted that with the inclusion of a larger sample size, a significant interaction between caffeine condition and impulsivity on time estimation accuracy would emerge. Specifically, it was predicted that individuals given caffeine who reported higher levels of impulsivity would provide shorter verbal time estimates than individuals on caffeine with lower levels of individual impulsivity, and with individuals who were not given caffeine regardless of their individual impulsivity levels.

Investigating relationships with executive function. Executive function is seen as a central component in the regulation of attentional resources (Block, Hancock, & Zakay, 2010). In a review of literature on using functional magnetic resonance imaging to investigate timing deficits, it was noted that the dorsolateral prefrontal cortex (DLPFC), a region of the brain highly involved in executive functions such as working memory, is directly involved in the perception of short durations (Noreika, Falter, & Rubia, 2013). This is further supported by the EGM, as that model takes into account the importance of working memory in our perception of time (Block, Hancock, & Zakay, 2010). The Dysexecutive Function scale (DEX) has been demonstrated to be a reliable measure of subjective executive function (Simblett & Bateman, 2011). In a study involving individuals with traumatic brain injuries and healthy controls, executive function and accuracy of time perception were shown to be positively correlated, particularly in the domains of cognitive inhibition and updating abilities (Mioni, Stablum, McClintock, & Cantagallo, 2012). This study investigated whether or not individuals' self-reported sense of executive function has a similar impact on the psychological experience of time that has been observed in those with traumatic brain injuries. Specifically, it was predicted that individuals with higher levels of executive function would provide more accurate estimations of short durations in an attention-demanding task.

The Current Study

To investigate the questions of interest, an experimental design in a double-blind fashion was used. Participants were randomly assigned into one of two caffeine conditions. After researchers administered the drug condition, participants filled out a series of three short surveys used to assess subjective impulsivity (Barratt Impulsiveness Scale), subjective executive function (Dysexecutive Function scale) and demographic information. Then, following a distraction task that involved watching two video clips and making retrospective and prospective time estimates, participants completed a 16 trial prospective time-estimation task that involved serial addition of single digit integers with a temporal range of 10, 25, 45, or 60 seconds per trial. The inclusion of the serial addition component in the task facilitated a higher level of cognitive demand than if participants simply read numbers out loud.

It was predicted that individuals would provide larger time estimates as the presented duration to be estimated increased. Based on Gruber and Block's (2005) study, it was hypothesized that participants would underestimate durations across conditions. Furthermore, it was predicted a two-way interaction between caffeine condition and time interval to emerge, such that those in the caffeine condition would underestimate durations to increasingly greater degrees than those in the placebo condition at the 25, 45, and 60 second intervals.

Method

Participants

One hundred thirty-nine undergraduate students (62 males, 77 females) from a Northwestern university participated in the present study. The mean age of the participants was 20.51 years (*SD* = 3.68). All participants were able to use their time spent in the study to earn course credit for various psychology courses. Individuals who were under the age of 18, allergic to caffeine, or reported regular avoidance of caffeinated products were not allowed to participate.

Design

The study implemented a 2 (drug condition: caffeine or placebo; between-subjects) × 4 (time interval: 10s, 25s, 45s, & 60s; within-subjects) mixed model factorial design. Separate analyses also investigated the role of subjective impulsivity and executive function on prospective time estimation with and without caffeine. A drug condition × time interval × BIS-11 (continuous) mixed model design was used to evaluate potential effects of subjective impulsivity. Similarly, a drug condition × time interval × DEX (continuous) mixed model design was used to evaluate potential effects of subjective executive function.

Materials and Procedure

A participation announcement was posted on the Psychology Department’s Sona online research pooling system. Readers were informed that the study was designed to “investigate how caffeine affects one’s cognitive perceptions in various tasks” and that the study’s purpose was to “help advance knowledge regarding caffeine use and mental perceptions.” The announcement asked potential participants to refrain from using caffeine for at least five hours prior to taking part in the experiment so that individuals were not under the influence of caffeine prior to their participation in the study. Upon arrival to the lab, the participants were asked to remove any watches or electronic devices for the remainder of the study and were then given the consent form. After reviewing and signing the consent form, all participants were informed that they would be given a pill that either was or was not caffeine.

Participants randomly assigned to the caffeine condition consumed one 200 mg caffeine pill, while those randomly assigned to the control condition consumed one non-caffeinated sugar pill. Participants were then instructed to fill out the questionnaire packet which included a brief demographic questionnaire that encompassed no identifying information, the Barratt Impulsiveness Scale (BIS-11), and the Dysexecutive Scale (DEX). The first questionnaire assessed demographic information (age, gender, year in school), estimation of daily caffeine use, and amount of time (in hours) since caffeinated products were last consumed.

The Barratt Impulsiveness Scale (BIS-11) included 30 items (α = .77) and measured subjective impulsivity on a 4-point Likert scale (e.g., “I am a careful thinker” and “I buy things on impulse”). Scores ranged from a low score of 1, Rarely/Never, to a high score of 4, Almost Always/Always. After reverse scoring 11 of the 30 items, an average of item scores was calculated to derive an overall subjective impulsivity composite (Patton, Stanford, & Barratt, 1995). Participants reported an average BIS-11 score of 2.07 (*SD* = .29). The Dysexecutive Scale (DEX) included 20 items (α = .81) and used a 5-point Likert model that measured subjective levels of executive function (e.g., “I find it hard to stop repeating saying or doing things once I’ve started,” and “I will say one thing, but will do something different”)(Wilson et al., 1996). Total DEX scores were calculated by averaging the 20 survey items and represent participants’ subjective levels of executive function (Simblett & Bateman, 2011). Participants reported an average DEX score of 2.10 (*SD* = .46).

At the start of each trial, researchers administered the drug condition and the questionnaires. Participants then watched two videos as a distractor task. After viewing the first video, “A: This Computer Could Beat You at ‘Jeopardy!’, Q: What is Watson?”, participants were instructed to make a retrospective estimation of the video's duration (8min 49sec). After viewing the second video, “Portland: The Trip Not Taken,” participants were instructed to make a prospective judgment of that video’s duration (7min 54 sec). Participants viewed the videos on a laptop computer using VLC media player with all clocks and timing displays disabled. The videos were informative, did not contain sensitive content, and were selected because they were considered to be emotionally neutral.

Following the videos, it was presumed that the effects of caffeine had initiated (Barry, Clarke, Johnstone, & Rushby, 2008) in those who had consumed a caffeine pill. Participants then completed a 16 trial time estimation task involving serial addition of single digit integers. The serial addition element of the task required participants to view a number on the monitor, remember that number, add it to the following number, and continue this process for the duration of each trial. The SuperLab Pro software (SuperLab, 1999) was used to display a series of random single digit numbers one at a time with varying lengths of time between intervals. Participants were instructed to give their time estimates out loud so that their experimenter could record each verbal time estimate. Participants were also asked to provide a confidence rating for each time estimate, on a scale of 0 to 100 percent, which could later be used to evaluate participants’ self-monitoring of their time estimates. Each of the trials lasted 10, 25, 45, or 60 seconds (with four trials for each duration) and was presented in a random sequence. After completion of the time estimation trials, participants were debriefed, escorted out of the laboratory area, and given credit for their time spent participating through the Sona website.

Results

Scoring

After testing for normal distribution in each group, a series of mixed model ANOVAs were performed to explore the effect of caffeine on time estimation performance using four time estimation scores (using IBM SPSS version 21). First, raw scores were calculated using the mean number of seconds estimated for each of the four measured time intervals (10, 25, 45, and 60 seconds). Second, absolute discrepancy scores were calculated to reflect the magnitude of the participant's errors in timing. Absolute discrepancy scores were calculated as the mean number of seconds away from the presented duration of time, regardless of whether the participants underestimated or overestimated. Third, duration-judgment ratio scores were calculated by dividing time estimates by the actual time presented, and reflect the direction and magnitude of time estimation error. A duration-judgment ratio of 1 represents a perfectly accurate estimation of presented duration, whereas a score less than 1 represents an underestimation and a score greater than 1 represents an overestimation. Finally, coefficient of variance scores were calculated for each presented duration to express the variation of time estimation accuracy as a percentage of the mean (Spiegel, 1961).

Time Estimation Performance

Raw scores. A mixed model ANOVA was performed on participants' raw time estimates (Figure 3). Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5) = 352.96$, $p < .001$ ($\varepsilon = .43$). As expected, there was a significant main effect of time interval such that participants made greater time estimates as the amount of time presented increased (10s: $M = 5.29$, $SD = 2.37$; 25s: $M = 11.99$, $SD = 4.69$; 45s: $M = 19.67$, $SD = 8.40$; 60s: $M = 26.52$, $SD = 11.89$; Table 1), $F(1, 170) = 486.79$, $p < .001$, $\eta^2 = .784$. Pair-wise comparisons using Bonferroni's post-hoc analyses revealed statistically significant differences between all combinations of the presented time intervals. Participants' raw time estimates at the 10 second interval were significantly shorter than estimates at the 25 second interval ($t(134) = -23.99$, $p < .001$), the 45 second interval (*t*(134) = -24.79, $p < .001$), and the 60 second interval (*t*(134) = -23.70, $p < .001$). Raw time estimates for the 25 second interval were significantly shorter than estimates at the 45 second interval (*t*(134) = -19.09, $p < .001$), and the 60 second interval (*t*(134) = -20.22, $p < .001$). And raw estimates at the 45 second interval were shorter than estimates at the 60 second interval, *t*(134) = -15.37, $p < .001$. Counter to expectations, there was no main effect of drug condition on participants' raw time estimates, *F*(1, 134) = .39, $p = .531$, $\eta^2 = .003$. Also counter to expectations, the two-way interaction between time interval and drug condition did not reach significance, *F*(1, 170) = .21, $p = .705$, $\eta^2 = .002$. That is, time estimates at each interval did not depend on whether an individual was provided caffeine or not. This suggests that caffeine does not have an impact on individuals' estimates of time in a high attention-demanding task.

Figure 3.

Mean Raw Time Estimates Between Conditions.

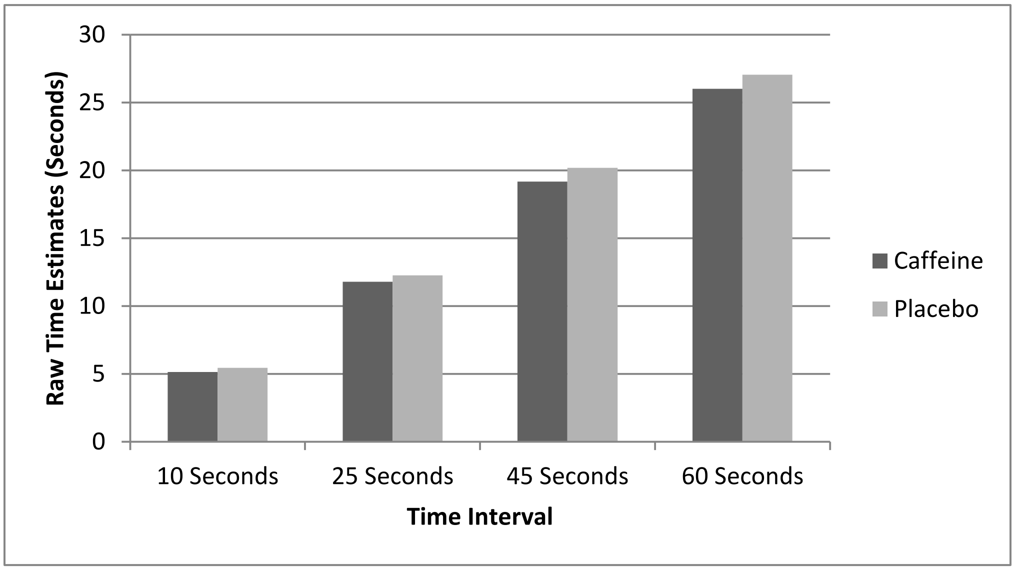


Table 1.

Mean Raw Time Estimates.

	10 s	25 s	45 s	60 s
Caffeine (*N* = 69)	5.14(1.83)	11.77(4.82)	19.16(8.13)	26.01(11.87)
Placebo (*N* = 67)	5.44(2.83)	12.22(4.59)	20.19(8.70)	27.04(11.97)
Total (*N* = 136)	5.29(2.37)	11.99(4.69)	19.67(8.40)	26.52(11.89)

Absolute discrepancy scores. A mixed model ANOVA was run on absolute discrepancy scores between drug conditions (Figure 4). Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5) = 342.28$, $p < .001$ ($\varepsilon = .44$). As expected, there was a significant main effect of time interval such that participants' time estimates deviated more from the actual amount of time presented as the amount of time presented increased (10s: $M = 4.99$, $SD = 1.71$; 25s: $M = 13.04$, $SD = 4.61$; 45s: $M = 25.50$, $SD = 7.88$; 60s: $M = 33.75$, $SD = 11.07$; Table 2), $F(1, 173) = 999.04$, $p < .001$, $\eta^2 = .882$. Post-hoc analyses using Bonferroni's pair-wise comparisons revealed statistically significant differences between absolute discrepancy scores at each of the four measured time intervals. Absolute discrepancy scores at the 10 second interval were significantly lower than scores at the 25 second interval ($t(134) = -25.42$, $p < .001$), the 45 second interval ($t(134) = -34.41$, $p < .001$), and the 60 second interval ($t(134) = -32.78$, $p < .001$). Participants' absolute discrepancy scores at the 25 second interval were lower than scores at the 45 second interval ($t(134) = -34.45$, $p < .001$), and the 60 second interval ($t(134) = -31.70$, $p < .001$). Finally, absolute discrepancy scores at the 45 second interval were significantly lower than scores at the 60 second interval, $t(134) = -19.27$, $p < .001$. Counter to expectations, there was no main effect of drug condition on participants' absolute discrepancy scores, $F(1, 134) = .15$, $p = .695$, $\eta^2 = .001$. Also counter to expectations, the two-way interaction between time interval and drug condition did not reach significance, *F*(1, 173) = .27, *p* = .665, η^2 = .002. That is, absolute discrepancy scores at each interval did not depend on whether an individual was provided caffeine or not. This suggests that in a high attention-demanding task, individuals given caffeine are not less accurate than those not given caffeine.

Figure 4.

Mean Absolute Discrepancy Scores Between Conditions.

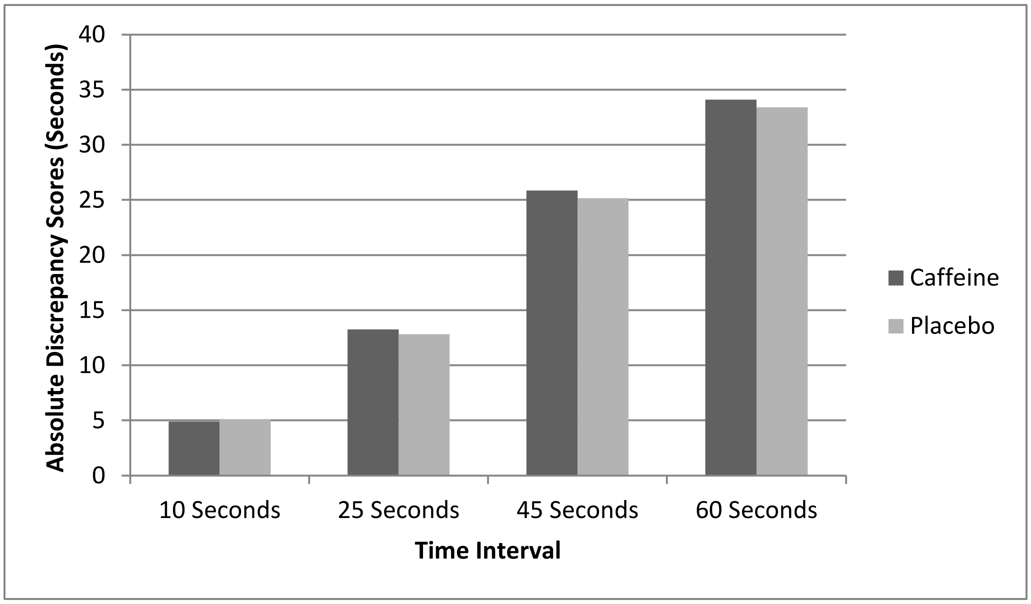


Table 2.

Mean Absolute Discrepancy Scores.

	10 s	25 s	45 s	60 s
Caffeine (*N* = 69)	4.89(1.75)	13.25(4.76)	25.84(8.13)	34.09(11.55)
Placebo (*N* = 67)	5.09(1.68)	12.82(4.48)	25.14(7.66)	33.40(10.64)
Total (*N* = 136)	4.99(1.71)	13.04(4.61)	25.50(7.88)	33.75(11.07)

Ratio scores. A mixed model ANOVA was performed to analyze potential differences in duration-judgment ratio scores between the two drug conditions (Figure 5). Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5) = 145.625$, *p* < .001 (ε = .61). As expected, there was a significant main effect of time interval such that participants made less accurate time estimates as the amount of time presented increased (10s: *M* = .53, *SD* = .24; 25s: *M* = .48, *SD* = .19; 45s: *M* = .44, *SD* = .19; 60s: *M* = .44, *SD* = .20; Table 3), *F*(2, 245) = 28.32, *p* < .001, η^2 = .174. In post-hoc analyses, Bonferroni's pair-wise comparisons revealed that participants' duration-judgment ratio scores at the 10 second interval were significantly higher than scores at the 25 second interval (*t*(134) = 3.75, *p* = .002), the 45 second interval (*t*(134) = 7.04, *p* < .001), and the 60 second interval (*t*(134) = 5.68, *p* < .001). Similarly, duration-judgment ratio scores at the 25 second interval were significantly higher than scores at the 45 second interval (*t*(134) = 5.86, *p* < .001), and the 60 second interval (*t*(134) = 4.00, *p* = .001). However, no significant differences emerged between duration-judgment ratio scores at the 45 second and 60 second intervals (*t*(134) = -.078, *p* = 1.000). Counter to expectations, there was no main effect of drug condition on participants' duration-judgment ratio scores, *F*(1, 134) = .47, *p* = .496, η^2 = .003. Also counter to expectations, the two-way interaction between time interval and drug condition did not reach significance, *F*(2, 245) = .14, *p* = .851, η^2 = .001. That is, caffeine had no impact on duration-judgment ratio scores at the four measured time intervals. This further suggests that caffeine does not influence an individual's ability to accurately estimate time in a high attention demanding task.

Figure 5.

Mean Duration-Judgment Ratio Scores Between Conditions.

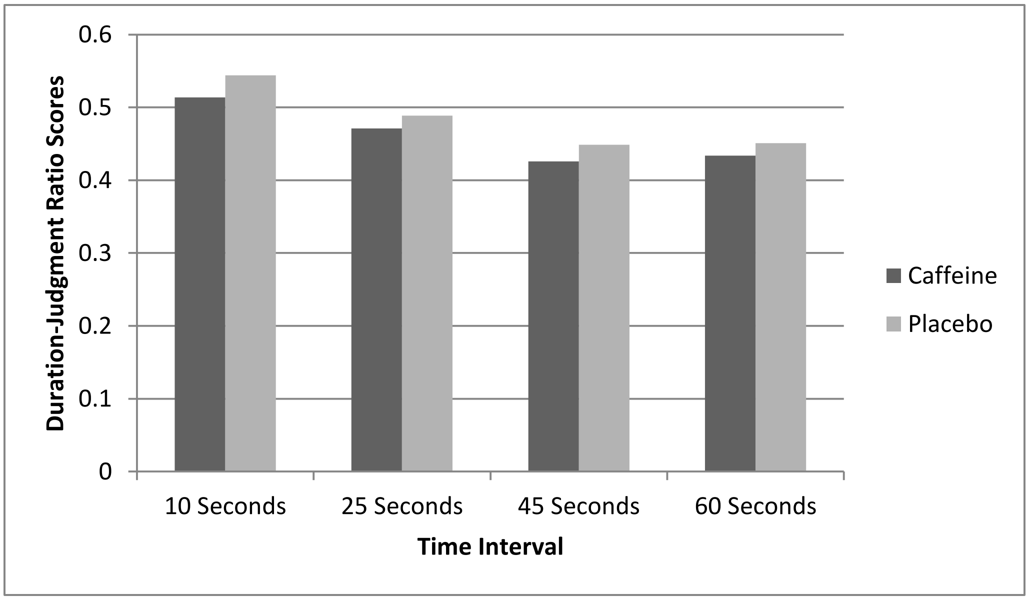


Table 3.

Mean Duration-Judgment Ratio Scores.

	10 s	25 s	45 s	60 s
Caffeine (*N* = 69)	.51(.18)	.47(.19)	.43(.18)	.43(.20)
Placebo (*N* = 67)	.54(.28)	.49(.19)	.45(.19)	.45(.20)
Total (*N* = 136)	.53(.24)	.48(.19)	.44(.19)	.44(.20)

Coefficient of variance scores. Coefficient of variance scores (Spiegel, 1961) were used as a measure of response consistency to allow for assessment of how consistent individuals were in their time estimates of a given time interval. Response consistency was compared between groups using a mixed model ANOVA (Figure 6). Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5) = 358.15$, $p < .001$ ($\varepsilon = .42$). As expected, there was a significant main effect of time interval such that participants reported more consistent time estimates as the amount of time presented increased (10s: $M = .14$, $SD = .24$; 25s: $M = .10$, $SD = .06$; 45s: $M = .09$, $SD = .06$; 60s: $M = .09$, $SD = .06$; Table 4), $F(1, 170) = 6.99$, $p = .005$, $\eta^2 = .049$. This finding is consistent with previous research which has demonstrated that coefficient of variance scores are more variable as the time to be estimated decreases (Wearden, 2003). A closer look at this effect revealed that coefficient of variance scores at the 10 second interval were significantly higher than scores at the 45 second interval ($t(135) = 2.76$, $p = .037$), and the 60 second interval ($t(135) = 3.13$, $p = .013$), but did not differ from the 25 second interval ($t(135) = 2.18$, $p = .185$). Counter to expectations, there was no main effect of drug condition on participants' coefficient of variance scores, $F(1, 135) = .86$, $p = .355$, $\eta^2 = .006$. Also counter to expectations, the two-way interaction between time interval and drug condition did not reach significance, $F(1, 170) = .56$, $p = .493$, $\eta^2 = .004$. Results revealed no significant difference between the two drug conditions at any of the four time intervals, suggesting that individuals in the two conditions provided similarly consistent time estimates across the presented time intervals. This finding supports the idea that the brain uses an internal clock mechanism to perceive the passing of time (Wearden, 1991).

Figure 6.

Mean Coefficient of Variance Scores Between Conditions.

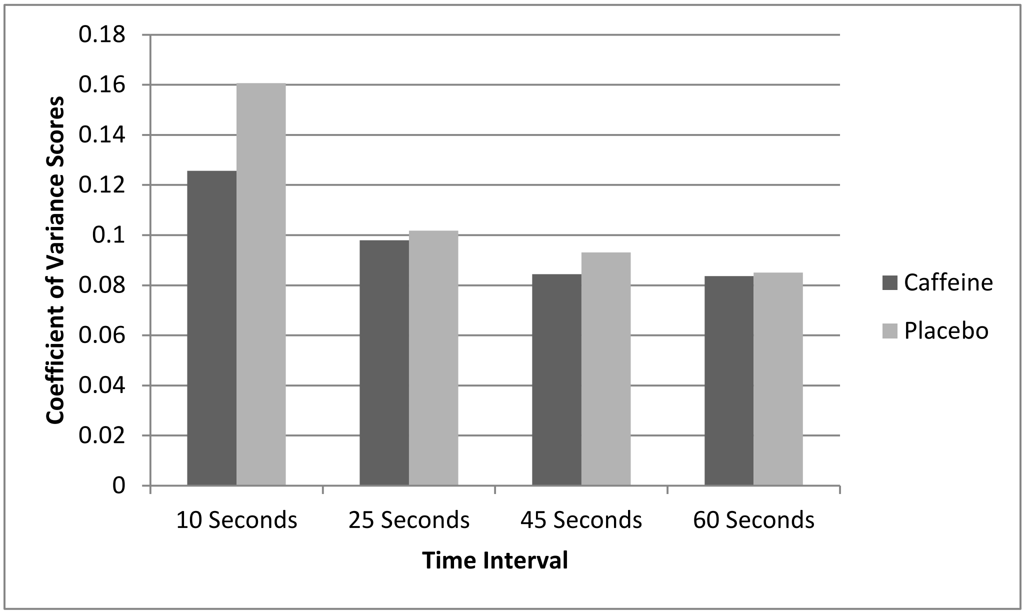


Table 4.

Mean Coefficient of Variance Scores.

	10 s	25 s	45 s	60 s
Caffeine (*N* = 69)	.13(.07)	.10(.06)	.08(.06)	.08(.06)
Placebo (*N* = 68)	.16(.33)	.10(.07)	.09(.06)	.09(.06)
Total (*N* = 136)	.14(.24)	.10(.06)	.09(.06)	.09(.06)

Supplementary Analyses

In our supplemental analyses, we tested for potential effects of self-reported impulsivity and executive functioning. Overall BIS-11 and DEX scores were used as covariates in mixed model ANOVAs to test for potential interactions with caffeine on raw time estimation scores.

In an exploratory analysis, a paired samples t-test was run between retrospective and prospective mean duration-judgment ratio scores among participants who did not receive caffeine. Contrary to previous research (Block & Zakay, 1997), the results of this analysis did not reach significance, $t(68) = -1.62$, $p = .110$. Additionally, a caffeine × time × gender mixed model ANOVA was run to explore potential effects of gender. Contrary to previous findings (Block, Hancock, & Zakay, 2000) the results revealed no main effect of gender ($F(1, 132) = 1.50$, $p = .224$, $\eta^2 = .011$) and no interaction between gender and time interval, $F(2, 239) = .24$, $p = .764$, $\eta^2 = .002$. These findings suggest that gender does not play a role in individuals' ability to estimate time accurately.

Impulsivity. To evaluate the influence of impulsivity a caffeine × time × impulsivity mixed model ANOVA was performed on duration-judgment ratio scores between groups using overall BIS-11 scores as a covariate. Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5) = 144.62$, $p < .001$ ($\varepsilon = .61$). There was a main effect of time interval (10s: $M = .53$, $SD = .24$; 25s: $M = .48$, $SD = .19$; 45s: $M = .44$, $SD = .19$; 60s: $M = .44$, $SD = .20$), $F(2, 242) = 3.60$, $p = .033$, $\eta^2 = .026$. Subsequent post-hoc analyses using Bonferroni's pair-wise comparisons revealed statistically significant differences between duration-judgment ratio scores at each of the four measured time intervals. Participants' duration-judgment ratio scores at the 10 second interval were significantly more accurate than scores at the 25 second interval ($t(133) = 3.73$, $p = .002$), the 45 second interval ($t(133) = 7.04$, $p < .001$), and the 60 second interval ($t(133) = 5.70$, $p < .001$). Duration-judgment ratio scores for the 25 second interval were significantly more accurate than scores at the 45 second interval ($t(133) = 5.92$, $p < .001$), and the 60 second interval ($t(133) = 4.06$, $p = .001$). Finally, no difference in duration-judgment ratio scores were observed between the 45 second interval and the 60 second interval, $t(133) = -.78$, $p = 1.0$. The main effect of impulsivity ($F(1, 133) = .37$, $p = .543$, $\eta^2 = .003$) and main effect of drug condition ($F(1, 133) = .50$,

p = .479, η^2 = .004) were not significant. The interaction between raw time estimates and BIS-11 scores revealed a non-significant trend (F(2, 242) = 1.61, p = .205, η^2 = .012), which was consistent with the previous findings of Gruber and Block (2003). However, the interaction between raw time estimates and drug condition did not reach significance (F(2, 242) = .12, p = .866, η^2 = .001). Thus, the null hypothesis was not rejected as impulsivity and caffeine had no significant effects on time estimation accuracy. These results suggest that when controlling for impulsivity, individuals' accuracy of time estimation decreases as the amount of time to be estimated increases for intervals less than 60 seconds.

Executive Function. In order to evaluate the influence of executive function on time estimation accuracy between groups, a caffeine × time × executive function mixed model ANOVA was performed on duration-judgment ratio scores using overall DEX scores as a covariate. Mauchley's test was significant and the Greenhouse-Geisser test was used to correct for the violation of the assumption of sphericity for within-subjects effects, $\chi^2(5)$ = 142.53, p < .001 (ε = .61). Contrary to expectations, there was no significant effect of time interval (F(2, 242) = 1.12, p = .324, η^2 = .008). The main effect of executive function (F(1, 132) = 2.01, p = .156, η^2 = .015) and main effect of drug condition (F(1, 132) = .81, p = .371, η^2 = .006) were not significant. Counter to expectations, there was no significant interaction between DEX scores on participant's raw time estimation scores (F(2, 242) = 1.70, p = .194, η^2 = .013). Also, there was no significant interaction between duration-judgment ratio scores and caffeine condition (F(2, 242) = .29, p = .729, η^2 = .002). Therefore, the null hypothesis that executive function combined with caffeine would have no effect on time estimation accuracy was not rejected. These results suggest that levels of executive function do not have an impact on time estimation or on the effect of caffeine on time estimation.

Discussion

The purpose of the current study was to test for the effect of caffeine on individuals' time perception in a high-demand task. Participants completed a prospective time-estimation task involving a high cognitive demand component requiring participants to serially add various sets of single digit integers. Results were analyzed by calculating raw scores, absolute discrepancies, duration-judgment ratio scores, and coefficient of variance scores for each of the four presented time intervals (10, 25, 45, and 60 seconds). A mixed model statistical design was used to test for within-groups effects of time interval, between-groups effects of caffeine condition, and interactions between time interval and caffeine condition.

As expected, the present study demonstrated a significant effect of time interval in all four of the calculated time estimation variables. That is, individuals’ time estimates increased as the time presented increased. Contrary to predictions, an effect of caffeine was not observed at any of the four time intervals. There were also no significant interactions between caffeine condition and time estimation accuracy for any of the calculated time estimation variables. This suggests that a 200mg dose of caffeine does not have an impact on individuals’ ability to accurately estimate short durations of time while completing an attention-demanding task.

The Executive Gate Model (Block, Hancock, & Zakay, 2010) proposes that a pacemaker mechanism produces periodic pulses with the passing of time. Those pulses are regulated by the executive gate and stored in the accumulator where an individual can then make relative comparisons to previously experienced durations in order to discriminate presented periods of time. It was expected that caffeine’s physiologically arousing properties (Shen & Chen, 2009) combined with known attentional effects (Chen et al., 2010) would cause individuals to produce shorter and less accurate time estimates than individuals not given caffeine because less attentional resources would be devoted to the executive gate. Results from the present study suggest that caffeine does not have a discernible impact on the executive gate system when used for estimating short durations of time during an attention-demanding task.

However, the present findings are consistent with some previous studies that did not find moderate doses of caffeine to have a significant impact on cognitive functioning, such as an individuals' perception of the passing of time (Botella, Bosch, Romero & Parra, 2001; Buffalo, Gillam, Allen & Paule, 1993; Terry, Doumas, Desai & Wing, 2009). Although the current research design sought to identify specific effects of caffeine on individuals' ability to accurately estimate time, the effects of caffeine on this particular executive ability remain uncertain. Explanations for the lack of observed effects, limitations of the present study, and suggestions for future research are considered.

Contrary to the present findings, Gruber and Block (2005) found that caffeine had a significant impact on individuals' time estimation accuracy in a high-demand task compared to placebo, yet the reason behind this difference is not fully clear. One explanation could be that Gruber and Block found caffeine to have the largest effect at the 300 second interval (2005). It is possible that caffeine does not have a noticeable effect on time estimation accuracy at intervals lasting 60 seconds or less. Another explanation for this discrepancy could be that the attention-demanding task used in Gruber and Block's (2005) study involved participants playing a driving simulation video game. Previous studies have shown that the passing of time seems to speed up when an individual is having fun (Danckert & Allman, 2005; Sackett, Meyvis, Nelson, Converse & Sackett, 2010), and it is possible that the presence of caffeine had an interaction with how much fun individuals had playing the game. In contrast to Gruber and Block's (2005) study, the present study used a serial addition task, and past research has suggested that when tasks are boring (Doobs, 1971), individuals may unwittingly begin to attend to time (Block, 1990; Block & Zakay, 1997). The effect of caffeine on time perception may be stronger during tasks that individuals perceive as being fun, and caffeine may have less of an effect in tasks that are perceived as more tedious or boring. Although this is a question worth investigating, no previous research exploring this interaction was found in the literature.

Another explanation for these unexpected findings could be that 200 milligrams of caffeine is simply not enough, or too much, to observe significant effects of caffeine on time perception. Previous researchers have found that small doses of caffeine speed up individuals' perception of time whereas large doses can slow down perception of presented durations (Prouty et al., 2008). A follow up to the current study could work to include a range of caffeine doses to identify the amount of caffeine needed to expose the optimal cognitive effects in an attention-demanding mathematical task.

Another similar explanation could be that 200 milligrams of caffeine is not sufficient for individuals who are regular consumers. A recent study showed that 200 milligrams of caffeine had little effect on those who consume at least 120 milligrams per day, which is approximately 1 or 2 cups of coffee per day (Hunt, Momjian & Wong, 2011). Although the number of daily caffeinated drinks that participants reported consuming did not have observable effects (a measure of tolerance), there was no attempt to calculate the precise amount of caffeine that participants were regularly consuming. In order to evaluate this appropriately it would be necessary to record not only how many caffeinated beverages are consumed on a day-to-day basis, but also the types and sizes of foods and beverages that individuals are accustomed to consuming. This explanation, however, is arguable as previous research has shown that the amount of caffeine in one cup of coffee, even in the absence of caffeine withdrawal, is sufficient to elicit stimulant-like cognitive effects (Childs & De Wit, 2006).

A likely explanation for the lack of observed effects in the present study is that participants were not allowed enough time between dose and testing for the cognitive effects of caffeine to be observed. According to previous research investigating the timing of physiological responses to caffeine administration (Barry, Clarke, Johnstone, &

Rushby, 2008), plasma concentrations of caffeine are known to peak approximately 30 minutes after ingestion and begin to taper off after 60 minutes. For this reason, the current research design sought to test the effects of caffeine 30-40 minutes following administration. Although timing of the physiological effects of caffeine have been well-documented, it is possible that the cognitive effects are not necessarily synchronous with the body's physiological response. Future research investigating the cognitive effects of caffeine should consider using a biofeedback measure, such as galvanic skin response, in order to verify that physiological effects are being experienced prior to cognitive testing. It is important to highlight that the literature on the precise timing of caffeine's cognitive effects remains unclear and warrants future research to shed light on this issue.

Furthermore, the time of day that individuals participated in the experiment was not controlled for. Prior research has shown that there is an effect of time of day (Anderson & Revelle, 1982) on an individual’s cognitive response to caffeine. As individuals may have varying time of day preferences for optimal cognitive functioning, previous research has suggested that the effects of caffeine on variables of attention also tend to vary throughout the course of a day (Hunt, Momjian & Wong, 2011). Regarding this previous literature on diurnal variation, it is likely that the effects of caffeine on time perception also vary throughout the course of a day. Although it is difficult to control for participants' individual preferences, it was assumed that these minor differences would wash out with a large sample size. Follow-up studies should seek to control for this potential confound by documenting individuals’ self-reported time of day preferences and controlling for the time of caffeine administration.

It is also unclear as to why the observed effects of impulsivity and executive function did not have a significant impact on the effect of caffeine on time estimation. Although the effects of impulsivity on time estimation accuracy trended toward significance, it is possible that a much larger sample is needed for these effects to emerge. Additionally, the results suggest that individual levels of executive function do not influence time estimation accuracy among college students. This could be due to the nature of the college environment, drawing individuals with relatively strong executive capacities compared to participants in previous research who were recovering from traumatic brain injuries (Mioni, Stablum, McClintock, & Cantagallo, 2012). More robust designs, including larger sample sizes, are needed to isolate the effects of such executive functions combined with the presence of stimulants (e.g., caffeine) on higher level cognitive processes, such as time estimation.

The foregoing arguments could help explain the lack of observed effects in the present research study. Although it would extend the amount of time needed to collect sufficient data, an ideal research design should seek to control for these variables and evaluate the precise effects of time of day, time between administration and testing, level of task demand, and dosage. Furthermore, there are several limitations to the present laboratory findings that must also be considered.

First, the present study relied on a college population to draw the sample of participants, and it is possible that the participants included in our analysis are not necessarily representative of the general population. It is also conceivable that college students may use caffeine (or similar stimulants) in a manner that is dissimilar to the general population, and that they could have higher levels of cognitive functioning as a result of their academic enrollment as well. Results from the present study revealed a similar pattern (see Figure 1) observed in Gruber and Block’s (2005) study; however, the effect of caffeine did not reach significance at any of the presented durations and a larger sample size may have been needed to reveal a significant effect of caffeine. The sample included also limits the external validity of the results by a potential geographic interaction with the effects of caffeine. It is possible that individuals living in the Pacific Northwest region of the United States may consume more caffeinated products than in other regions of the country, naturally leaving those individuals with a higher caffeine tolerance than other populations. Furthermore, these results merely provide a glimpse of the possible effects of caffeine on time perception as this study was conducted in a psychological laboratory and may not be applicable to what individuals experience in the real world. Although steps were taken to control for caffeine tolerance and caffeine consumption outside of the lab by recording the number of self-reported daily caffeinated beverages consumed and requiring participants to refrain from caffeine consumption for at least 5 hours prior to their participation in the study, it is possible that participants were not truthful in these self-reported figures or in the amount of time that they abstained from caffeinated products before participating in the study. Therefore, it is important for future research to account for these limitations in order to better understand the effects of caffeine on time perception both in and outside of the lab.

One direction for future research investigating the effect of caffeine on individuals' perception of time is to measure the average amount of time required for a caffeine dose to have an effect on executive functioning. Although time between dose and the physiological effects of caffeine are well documented (Barry, Clarke, Johnstone, & Rushby, 2008), it is unclear if the timing for cognitive effects parallel physiological effects. Our results from the present study indicate that there may be a distinct difference in the amount of time required for individuals to experience these types of effects. Psychophysiological techniques included in a methodologically sound experiment could be used to measure the potential timing discrepancy between caffeine's physiological and psychological effects.

The present analysis relied exclusively on participants’ verbal estimates of time. Recent research has suggested that verbal time estimates are optimal for measuring perception of time in the lab (Kinsbourne, 2000), primarily because verbal estimates are contingent on comparisons between subjective time and specific measurements of passing time. However, past research has demonstrated that other types of time estimation measures (i.e., production, reproduction) reveal similar patterns (Block & Zakay, 1997). Subsequent studies may benefit by exploring a range of time estimation tasks combined with randomly assigned caffeine conditions and evaluating differences in time estimation accuracy between those tasks. It is possible that other non-verbal time estimation procedures will provide further insight into potential effects of caffeine on estimating short durations of time.

Finally, the sample used in the present study was comprised of college students from a predominantly Caucasian university in the Pacific Northwestern United States. Future research may also seek to sort out potential cultural differences in the effects of caffeine on time perception by studying more diverse populations than that included in the present study. It is possible that cultural differences between groups of people may arise as a result of social differences in caffeine consumption trends. In the United States, caffeine consumption is a relatively common custom (Barry, Clarke, Johnstone, & Rushby, 2008), therefore making comparisons to individuals from populations where caffeine consumption is more or less prevalent could yield interesting results and implications for further research in this area.

In conclusion and parallel to the suggestions of previous time estimation researchers (Hancock & Block, 2012) that more research is needed to identify variables that account for individual differences in time estimation accuracy, it is suggested that future research include more experimental designs investigating possible interactions of caffeine on time perception in tasks with ranging cognitive demands. As caffeine is known to be one of the most frequently consumed stimulants in the United States (Barry, Clarke, Johnstone, & Rushby, 2008) understanding the cognitive effects of this substance have important implications in a variety of situations including educational and occupational settings. Although the results were counter to the hypotheses, they help to provide scaffolding for future research designs investigating similar effects of caffeine on cognition, specifically attention and the ability to accurately estimate durations of time.

References

Adan, A., & Serra-Grabulosa, J. (2010). Effects of caffeine and glucose, alone and combined, on cognitive performance. *Human Psychopharmacology: Clinical and Experimental, 25*(4), 310-317. doi: 10.1002/hup.1115

Addicott M.A., & Laurienti P.J. (2009). A comparison of the effects of caffeine following abstinence and normal caffeine use. *Psychopharmacology, 207*(3), 423-431. doi: 10.1007/s00213-009-1668-3

Anderson, K. J., & Revelle, W. (1982). Impulsivity, caffeine, and proofreading: a test of the Easterbrook hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 8*(4), 614. doi: 10.1037/0096-1523.8.4.614

Arushanyan, E. B., Baida, O. A., Mastyagin, S. S., Popova, A. P., & Shikina, I. B. (2003). Influence of caffeine on the subjective perception of time by healthy subjects in dependence on various factors. *Human Physiology, 29*(4), 433-436. doi: 10.1023/A:1024973305920

Attwood, A. S., Higgs, S., & Terry, P. (2007). Differential responsiveness to caffeine and perceived effects of caffeine in moderate and high regular caffeine consumers. *Psychopharmacology, 190*(4), 469-477. doi: 10.1007/s00213-006-0643-5

Baddeley, A. D.. (2000). Selective attention and performance in dangerous environments. *Journal of Human Performance in Extreme Environments, 5*(1). doi: 10.7771/2327-2937.1010

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist, 7*(2), 85-97. doi: 10.1027//1016-9040.7.2.85

Barone, J. J., & Roberts, H. R. (1996). Caffeine consumption. *Food and Chemical Toxicology, 34*(1), 119-129. doi: 10.1016/0278-6915(95)00093-3

Barratt, E. (1959). Anxiety and impulsiveness related to psychomotor efficiency. *Perceptual and Motor Skills, 9*(3), 191-198. doi: 10.2466/pms.1959.9.3.191

Barry, R. J., Clarke, A. R., Johnstone, S. J., & Rushby, J. A. (2008). Timing of caffeine's impact on autonomic and central nervous system measures: Clarification of arousal effects. *Biological Psychology, 77*(3), 304-316. doi: 10.1016/j.biopsycho.2007.11.002

Blanchard, J., & Sawers, S. J. (1983). The absolute bioavailability of caffeine in man. *European Journal of Clinical Pharmacology*, *24*(1), 93-98. doi: 10.1007/BF00613933

Block, R. A.,. (1990). *Cognitive models of psychological time.* Hillsdale, N.J.: L. Erlbaum Associates.

Block, R. A., Hancock, P. A., & Zakay, D. (2000). Sex differences in duration judgments: A meta-analytic review. *Memory & Cognition, 28*(8), 1333-1346. doi: 10.3758/BF03211834

Block, R. A., Hancock, P. A., & Zakay, D. (2010). How cognitive load affects duration judgments: A meta-analytic review. *Acta Psychologica*, *134(*3), 330-343. doi: 10.1016/j.actpsy.2010.03.006

Block, R. A., & Zakay, D. (1997). Prospective and retrospective duration judgments: A meta-analytic review. *Psychonomic Bulletin and Review, 4*(2), 184-197. doi: 10.1016/j.actpsy.2010.03.006

Block, R. A., Zakay, D., & Hancock, P. A. (1999). Developmental changes in human duration judgments: A meta-analytic review. *Developmental Review, 19*(1), 183-211. doi: 10.1006/drev.1998.0475

Botella, P., Bosch, F., Romero, F.J., & Parra, A. (2001). Sex differences in estimation of time intervals and in reaction time are removed by moderate but not high doses of caffeine in coffee. *Human Psychopharmacology: Clinical and Experimental, 16*(7), 533-540. doi: 10.1002/hup.324

Buffalo, E.A., Gillam, M.P, Allen, R.R, & Paule, M.G. (1993). Acute effects of caffeine on several operant behaviors in Rhesus monkeys. *Pharmacology Biochemistry and Behavior, 46*(3), 733-737. doi: 10.1016/0091-3057(93)90570-J

Burnside, W. (1971). Judgment of short time intervals while performing mathematical tasks. *Perception & Psychophysics Perception & Psychophysics, 9*(5), 404-406. doi: 10.3758/BF03210238

Chaston, A., & Kingstone, A. (2004). Time estimation: The effect of cortically mediated attention. *Brain and Cognition, 55*(2), 286-289. doi: 10.1016/j.bandc.2004.02.013

Chen, J. F., Moratalla, R., Impagnatiello, F., Grandy, D. K., Cuellar, B., Rubinstein, M., Beilstein, M. A., Schwarzschild, M. A. (2001). The role of the D(2) dopamine receptor (D(2)R) in A(2A) adenosine receptor (A(2A)R)-mediated behavioral and cellular responses as revealed by A(2A) and D(2) receptor knockout mice. *Proceedings of the National Academy of Sciences of the United States of America, 98*(4), 1970-1975. doi: 10.1073/pnas.98.4.1970

Chen J.-F., Yu L., Shen H.-Y., He J.-C., Wang X., & Zheng R. (2010). What knock-out animals tell us about the effects of caffeine. *Journal of Alzheimer's Disease, 20,* 17-24. doi: 10.3233/JAD-2010-1403

Cheng, R.-K., Meck, W. H., & Williams, C. L. (2006). Alpha7 nicotinic acetylcholine receptors and temporal memory: Synergistic effects of combining prenatal choline and nicotine on reinforcement-induced resetting of an interval clock. *Learning & Memory, 13*(2), 127-134. doi: 10.1101/lm.31506

Childs, E., & De Wit, H. (2006). Subjective, behavioral, and physiological effects of acute caffeine in light, nondependent caffeine users. *Psychopharmacology, 185*(4), 514-523. doi: 10.1007/s00213-006-0341-3

Danckert, J. A., & Allman, A. A. A. (2005). Time flies when you're having fun: Temporal estimation and the experience of boredom. *Brain and Cognition, 59*(3), 236-245. doi: 10.1016/j.bandc.2005.07.002

De Bruin, E. A., Rowson, M. J., Van Buren, L., Rycroft, J. A., & Owen, G. N. (2011). Black tea improves attention and self-reported alertness. *Appetite, 56*(2), 235-240. doi: 10.1016/j.appet.2010.12.011

Doob, L.W. (1971). *Patterning of time*. New Haven, CT: Yale University Press.

Droit-Volet, S., & Meck, W.H. (2007). How emotions colour our perception of time. *Trends in Cognitive Science, 11*(12), 504-513. doi: 10.1016/j.tics.2007.09.008

François, M. (1927). Contributions to the study of the sense of time: Internal temperature as a factor in the variation of the subjective appreciation of durations. *L'Année Psychologique, 28*, 186-204. doi: 10.3406/psy.1927.6412

Gibbon, J. (1977). Scalar expectancy theory and Weber's law in animal timing. *Psychological Review, 84*(3), 279-325. doi: 10.1037//0033-295X.84.3.279

Glicksohn, J., Leshem, R., & Aharoni, R. (2006). Impulsivity and time estimation: Casting a net to catch a fish. *Personality and Individual Differences, 40*(2), 261-271. doi: 10.1016/j.paid.2005.07.003

Graham, T. E., Rush, J. W., & Soeren, M. H. V. (1994). Caffeine and exercise: Metabolism and performance. *Canadian Journal of Applied Physiology, 19*(2), 111-138. doi: 10.1139/h94-010

Gruber, R. P., & Block, R. A. (2003). Effect of caffeine on prospective and retrospective duration judgments. *Human Psychopharmacology: Clinical and Experimental, 18*(5), 351-359. doi: 10.1002/hup.501

Gruber, R. P., & Block, R. A. (2005). Effects of caffeine on prospective duration judgments of various intervals depend on task difficulty. *Human Psychopharmacology: Clinical and Experimental, 20*(4), 275-285. doi: 10.1002/hup.687

Hancock, P. A., & Block, R. A. (2012). The psychology of time: A view backward and forward. *The American Journal of Psychology, 125*(3), 267-274. doi: 10.5406/amerjpsyc.125.3.0267

Hasenfratz, M., & Battig, K. (1994). Acute dose–effect relationships of caffeine and mental performance, EEG, cardiovascular and subjective parameters. *Psychopharmacology*, *114*(2), 281–287. doi: 10.1007/BF02244850

Hoagland, H. (1933). The physiological control of judgments of duration: Evidence for a chemical clock. *Journal of General Psychology*, *9*(2), 267-287. doi: 10.1080/00221309.1933.9920937

Hunt, M. G., Momjian, A. J., & Wong, K. K. (2011). Effects of diurnal variation and caffeine consumption on Test of Variables of Attention (TOVA) performance in healthy young adults. *Psychological Assessment*, *23*(1), 226. doi: 10.1037/a0021401

James, W. (1890). *The principles of psychology*. New York: H. Holt and company.

Kinsbourne, M. (2000). The role of memory in estimating time: A neuropsychological analysis. In L.T. Conner & L.K. Obler (Eds.), *Neurobehavior of language and cognition: Studies of normal aging and brain damage* (pp. 315-324). Boston: Kluwer Academic Publishers.

McClellan Stine, M., O'Connor, R. J., Yatko, B. R., Grunberg, N. E., & Cousino Klein, L. (2002). Evidence for a relationship between daily caffeine consumption and accuracy of time estimation. *Human Psychopharmacology: Clinical and Experimental*, *17*(7), 361-367. doi: 10.1002/hup.423

Mioni, G., Stablum, F., McClintock, S. M., & Cantagallo, A. (2012). Time-based prospective memory in severe traumatic brain injury patients: The involvement of executive functions and time perception. *Journal of The International Neuropsychological Society*, *18*(4), 697-705. doi:10.1017/S1355617712000306

Nehlig, A., Daval, J.-L., & Debry, G. (1992). Caffeine and the central nervous system: Mechanisms of action, biochemical, metabolic and psychostimulant effects. *Brain Research Reviews*, *17*(2), 139-170. doi: 10.1016/0165-0173(92)90012-B

Noreika, V., Falter, C. M., & Rubia, K. (2013). Timing deficits in attention-deficit/hyperactivity disorder (ADHD): Evidence from neurocognitive and neuroimaging studies. *Neuropsychologia, 51*(2), 235-266. doi: 10.1016/j.neuropsychologia.2012.09.036

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology, 51*(6), 768-74. doi: 10.1002/1097-4679

Prouty, D., Burgette, M., Thomas, B., Keen, R., & Erturk, N. (2008). Effects of high vs low dose caffeine on temporal perception. *Fourth Annual USC Upstate Research Symposium*, 39-41.

Ribeiro J.A., & Sebastio A.M. (2010). Caffeine and adenosine. *Journal of Alzheimer's Disease, 20*, 3-15. doi: 10.3233/JAD-2010-1379

Sackett, A. M., Meyvis, T., Nelson, L. D., Converse, B. A., & Sackett, A. L. (2010). You're having fun when time flies the hedonic consequences of subjective time progression. *Psychological Science, 21*(1), 111-117. doi: 10.1177/0956797609354832

Shen H.-Y., & Chen J.-F. (2009). Adenosine A_{2A} receptors in psychopharmacology: Modulators of behavior, mood and cognition. *Current Neuropharmacology, 7*(3), 195-206. doi: 10.2174/157015909789152191

Simblett SK, & Bateman A. (2011). Dimensions of the dysexecutive questionnaire (DEX) examined using rasch analysis. *Neuropsychological Rehabilitation, 21*(1), 1-25. doi: 10.1080/09602011.2010.531216

Spiegel, M. R. (1961). *Schaum's 0utline of Theory and Problems of Statistics*. McGraw-Hill.

Strömberg, I., Popoli, P., Müller, C. E., Ferré, S., & Fuxe, K. (2000). Electrophysiological and behavioural evidence for an antagonistic modulatory role of adenosine A2A receptors in dopamine D2 receptor regulation in the rat dopamine-denervated striatum. *The European Journal of Neuroscience, 12*(11), 4033-7. doi: 10.1046/j.1460-9568.2000.00288.x

SuperLab Pro Beta Version Experimental Lab Software [Computer software]. (1999). San Pedro, CA: Cedrus Corporation.

Terry, P., Doumas, M., Desai, R. I., & Wing, A. M. (2009). Dissociations between motor timing, motor coordination, and time perception after the administration of alcohol or caffeine. *Psychopharmacology, 202*(4), 719-729. doi: 10.1007/s00213-008-1352-z

Vanderveen, J. E., Armstrong, L. E., Butterfield, G. E., Chenoweth, W. L., Dwyer, J. T., Fernstrom, J. D., & Sternberg, E. M. (2001). *Caffeine for the sustainment of mental task performance: formulations for military operations*. National Academy, Washington, DC.

Wilson, B. A., & Thames Valley Test Company. (1996). *BADS : Behavioural assessment of the dysexecutive syndrome*. Bury St Edmunds: Thames Valley Test Company.

Wearden, J. H. (1991). Do humans possess an internal clock with scalar timing properties? *Learning and Motivation, 22*(1), 59-83. doi: 10.1016/0023-9690(91)90017-3

Wearden, J.H. (2003). Applying the scalar timing model to human time psychology: Progress and challenges. In: H. Helfrich (Ed.), *Time and mind II: Information processing perspectives* (pp. 21-39). Gottingen, Germany: Hogrefe and Huber.

Wearden, J. H., & Penton-Voak, I. S. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *The Quarterly Journal of Experimental Psychology. B, Comparative and Physiological Psychology, 48*(2), 129-141.

Zakay, D., & Block, R. A. (1996). The role of attention in time estimation processes. *Advances in Psychology, 115*, 143-164. doi: 10.1016/S0166-4115(96)80057-4

Appendix

Demographic Questionnaire

Age: ___________________

Sex: ___________________

Major: _________________

Year in School:
Freshman
Sophomore
Junior
Senior
Graduate

On average, how many caffeinated beverages would you say you consume per day?

__________ Caffeinated Beverages

Prior to participating in this study you were asked to abstain from using caffeinated products for at least 5 hours, and it is understood that this can be difficult for many people. From the beginning of your session time, how many hours (if any) had you gone without caffeine? Please be as accurate as possible.

_____________________ Hours

Appendix

Barratt Impulsivity Scale (BIS-11)

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

○	○	○	○
Rarely/Never	Occasionally	Often	Almost Always/Always

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

Appendix

Dysexecutive Scale (DEX)

Directions: This questionnaire looks at some of the difficulties that people sometimes experience. We would like you to read the following statements, and rate them on a five-point scale according to your own experience.

1	2	3	4	5
Never	Occasionally	Sometimes	Fairly Often	Very Often

____ 1. I have problems understanding what other people mean unless they keep things simple and straightforward

____ 2. I act without thinking, doing the first thing that comes to mind

____ 3. I sometimes talk about events or details that never actually happened

____ 4. I have difficulty thinking ahead or planning for the future

____ 5. I sometimes get over-excited about things and can be a bit 'over the top' at these times

____ 6. I get events mixed up with each other, and get confused about the correct order of events

____ 7. I have difficulty realizing the extent of my problems and am unrealistic about the future

____ 8. I am lethargic, or unenthusiastic about things

____ 9. I do or say embarrassing things when in the company of others

____ 10. I really want to do something one minute, but couldn't care less about it the next

____ 11. I have difficulty showing emotion

____ 12. I lose my temper at the slightest thing

____ 13. I am unconcerned about how I should behave in certain situations

____ 14. I find it hard to stop repeating saying or doing things once I've started

____ 15. I tend to be very restless, and 'can't sit still' for any length of time

____ 16. I find it difficult to stop myself from doing something even if I know I shouldn't

____ 17. I will say one thing, but will do something different

____ 18. I find it difficult to keep my mind on something, and am easily distracted

____ 19. I have trouble making decisions, or deciding what I want to do

____ 20. I am unaware of, or unconcerned about, how others feel about my behavior

VITA

Author: Trevor Fry

Education

2014 Eastern Washington University, Cheney, Washington.
Master of Science Degree in General/Experimental Psychology. Expected: June 2014.

2012 Eastern Washington University, Cheney, Washington.
Bachelor of Arts Degree in Psychology.

2007 Eastern Washington University, Cheney, Washington.
Bachelor of Arts Degree in Interdisciplinary Studies.
Major in Alcohol and Drug Studies with Minor in Communication Studies.

Honors and Awards

2009-2012 Eastern Washington University Dean’s List; Consecutive Fall, Winter, and Spring Quarters.

2012 Outstanding Presentation Award for poster presented at the Eastern Washington University Student Research and Creative Works Symposium.

Certificates

2010 *Treating Co-Occurring Disorders Series* (10 credits), through the Addiction Studies Department at Eastern Washington University.

2009 *Suicide Assessment, Treatment and Prevention* (10 credits), through the Alcohol and Drug Studies Department at Eastern Washington University.

2007 *Alcohol and Drug Studies Course Certificate* (62 credits), through the Alcohol and Drug Studies Department at Eastern Washington University.

Supplemental Coursework

2014 *Teaching Adults in Post-Secondary Education* (11 credits), through the College Instruction Department at Eastern Washington University.

Professional Work/ Volunteer Experience

2013 – Present *PLUS Tutoring Program in the Learning Commons – Eastern Washington University*

Served as administrative program specialist, directly assisting the program coordinator with a variety of administrative operations for the program, including the review of all student tutors' bi-weekly contact sheets, checking for accuracy and entering statistics into a database. Also worked on a comprehensive literature review of effective tutoring practices to improve the program and guide future research studies, gathered archival data for statistical program evaluation, and worked to publish results from analysis of program effectiveness.

2012 – Present *J.F.K Library – Eastern Washington University*

Assisted students in finding resources for a broad range of research topics. Provided tours of the library and assisted reference librarians with a variety of projects including operational statistics and developing presentations and training materials. Developed a survey for library administration to assess connectivity issues and student satisfaction of the library's Wi-Fi network.

2005 – 2006 *Daybreak of Spokane - Inpatient, Outpatient*

Completed ADST Practicum requirements, performed intake assessments, individual, group, and family counseling, accurately documenting sessions, and effectively teaching Dialectical Behavioral Therapy skills.

2005 *First Call for Help at Spokane Mental Health (Crisis Hotline)*

Practiced supportive listening techniques, gained understanding of local resources and providing referral, and utilizing crisis management techniques when necessary.

2001 – 2008 *Washington State Contract Liquor Store, CLS 583*

Held position of Assistant Manager for four years. Facilitated regular placing of various purchase orders, trained and supervised employees, oversaw inventory control, developed pricing models, and worked to build and manage the company's local computer network.

Technical Skills

- Training and working knowledge of Microsoft Office Suite (Word, Excel, Access, & PowerPoint)
- Training and working knowledge of SPSS software (for statistical analyses)
- Training and working knowledge of Qualtrics software (for developing and administering surveys online)
- Training and working knowledge of E-Studio Pro software (for creating experiments)
- Training in Lab Link 5 with WINDAq software (for psychophysiological recording)
- Working knowledge of Sona Systems (online research pool system)
- Working knowledge of SuperLabs Pro software (for creating experiments)

Teaching Experience

Curriculum Creation and Instruction for Psychology of Money Seminar, June 2012 – Present

- Developed lectures and activities for 10 one-hour class sessions held Winter & Spring 2014
- Designed relevant learning assessment materials

Course Facilitator, Fall 2013

- Facilitated Research Topics course for first-year graduate students
- Coordinated faculty schedules for presentation on their research during course
- Answered questions for graduate students and directed discussion regarding thesis projects

Research Lab Experience

2011-Present Cognition and Neuropsychology Lab, with Jonathan Anderson, Ph.D., through Eastern Washington University Psychology Department.

Focus: Behavioral and Cognitive Neuroscience

Served as Lab Manager for 2013-2014 Academic Year

Individual Research Project: Effects of Caffeine on Human Perception

Thesis Project: Caffeine and Human Perception of Time in a High Demand Task

Research Projects: Depression and Test Taking, Working Memory, & Subjective Age, Emotional Suppression and Time Estimation Accuracy

Management Duties: Coordinated research schedules for all members of the lab; organized and supervised procedures of various studies, including conducting all lab meetings; trained research assistants on protocol for running various studies; writing papers for publication and submitting presentations.

2012-Present Human Psychophysiology Lab, with Bill C. Williams, Ph.D., through Eastern Washington University Psychology Department.

Focus: Psychophysiology and Dark Triad Personality Cluster

Served as Co-Manager of a Master's Thesis Project: Reaction Time in Individuals with Primary & Secondary Psychopathy Traits

Research Projects: Prime Valence and Reaction Time

Management Duties: Supervised lab procedures and activities; proctored various studies to individual participants.

2010 – 2011 Happiness and Gratitude Lab, with Philip Watkins, Ph.D., through Eastern Washing University Psychology Department.

Focus: Happiness, Gratitude, and Religiosity

Individual Project: Religiosity and Emotional Well-Being

Submitted for Publication

Anderson, J., Fry, T., & Case, D.. *Self-Awareness and Self-Monitoring of Time Estimation*. (In Review)

Manuscripts in Preparation

Fry, T. & Colver, M.. *Peer Tutoring in Post-Secondary Education: Evidence to Support Peer Tutoring Programs at the Undergraduate Level.*

Kunemund, A., Fry, T., & El Alayli, A.. *The Effects of Language Errors on the Persuasiveness of Print Advertising*.

Research Presentations/ Conferences

Anderson, J. W. & Fry, T. (2013, winter). *The Relationship Between Time Estimation and Executive Functioning.* Poster presented at the 41st annual conference of the International Neuropsychological Society, Waikoloa, HI.

Anderson, J. W. & Fry, T. (2013, winter). *Are Individuals Aware that Time Flies When You're Having Fun?* Poster presented at the 41st annual conference of the International Neuropsychological Society, Waikoloa, HI.

Ellis, D., Anderson, J., Case, D., Dunlap, P., Hume, T., Fry, T., Nichols, K., Noah, C., & Thomas, L. (2012, spring). *Emotional Regulation and Time Perception.* Poster presented at the 92nd Annual Conference of the Western Psychological Association, San Francisco, CA.

Fry, T., Anderson, J., Case, D., Ellis, D., Hume, T., Nichols, K., Mattson, J., & Thomas, L. (2012, spring). *Caffeine and Our Perception of Time.* Poster presented at the 15th Annual Eastern Washington University Student Research and Creative Works Symposium in Cheney, WA.

Fry, T., Anderson, J., Joynes, C., Quinn, C., Case, D., & McCall, A. (2013, spring). *The Effect of Caffeine on Time Estimation in a High Demand Task.* Poster presented at the 16th Annual Eastern Washington University Student Research and Creative Works Symposium in Cheney, WA.

Fry, T., Armendarez, B., Pichinevskiy, S., & Watkins, P. (2011, spring). *Does Religious Orientation Predict Emotional Well-Being?* Poster presented at the 14th Annual Eastern Washington University Student Research and Creative Works Symposium in Cheney, WA.

Fry, T., Case, D., & Anderson, J. (2013, spring). *Self-Awareness of Time Estimation.* Presented at the 16th Annual Eastern Washington University Student Research and Creative Works Symposium in Cheney, WA.

Fry, T., Erickson, A., & Neinhuis, A. (2013, spring). *Machiavellianism and Psychopathy: Intertwining but Distinct Constructs.* Presented at the 16th Annual Eastern Washington University Student Research and Creative Works Symposium, Cheney, WA.

Fry, T., Erickson, A., Neinhuis, A., Stellwagen, K., & Williams, B. (2014, spring). *Machiavellianism and Psychopathy: Intertwining but Distinct Constructs.* Poster presented at the 94th Annual Conference of the Western Psychological Association, Portland, OR.

Fry, T., Kunemund, A., & Anderson, J. (2014, spring). *Learning Approach, Motivations to Learn, and Academic Entitlement.* Poster presented at the 94th Annual Conference of the Western Psychological Association, Portland, OR.

Fry, T., Kunemund, A., & Anderson, J. (2014, spring). *Learning Approach, Motivations to Learn, and Academic Entitlement.* Poster presented at the 17th Annual Eastern Washington University Student Research and Creative Works Symposium, Cheney, WA.

Fry, T., Kunemund, A., & Anderson, J. (2014, winter). *Influence of Caffeine on Time Estimation.* Poster presented at the 42nd annual conference of the International Neuropsychological Society, Seattle, WA.

Keating, C., McSwain, D., Frazier, P., Quinn, C., Zimmerman, A., Fry, T., & Anderson, J. (2014, spring). How Old We Are & How Old We Feel. Poster presented at the 17th Annual Eastern Washington University Student Research and Creative Works Symposium, Cheney, WA.

Kennedy, M., Brown, A., Fry, T., Anderson, J. W., Clover, M., Bell, J., Cornell, C., McCall, A., & Quinn, C. (2014, spring). *The Effect of Music on Depression: The Importance of Choice.* Poster presented at the 94th Annual Conference of the Western Psychological Association, Portland, OR.

Kennedy, M., Brown, A., Fry, T., Anderson, J. W., Clover, M., Bell, J., McCall, A., Quinn, C., & Cornell, C. (2014, spring). *The Effect of Music on Depression: The Importance of Choice.* Poster presented at the 17th Annual Eastern Washington University Student Research and Creative Works Symposium, Cheney, WA.

Myers, B. R., Ahrens, R., Chui, P. H., Erikson, A., Fry, T. & Neinhuis, A. (2013, spring). *Effectiveness and Credibility of Emotion Primes for Graphic Image Descriptors.* Presented at the 16th Annual Eastern Washington University Student Research and Creative Works Symposium, Cheney, WA.

Ruiz, L., Zumba, M., Quinn, C., Fry, T., & Anderson, J.W. (2014, spring). *Self-Monitoring of Time Estimation*. Poster presented at the 94th Annual Conference of the Western Psychological Association, Portland, OR.

Affiliations

2013-Present Western Psychological Association (WPA) Student Member.