PSYCHOLOGICAL AND SITUATIONAL PREDICTORS OF CAFFEINE CONSUPMTION IN DAILY LIFE

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PSYCHOLOGICAL AND SITUATIONAL PREDICTORS OF CAFFEINE CONSUMPTION IN DAILY LIFE

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SUMMARY

The stimulant effects of caffeine have been widely studied. Research on caffeine has proceeded, similar to research on other drugs, with a focus on establishing the presence and magnitude of effects on physiological, psychological and behavioral processes through placebo-control studies conducted in laboratory settings. However, there has been relatively little research on caffeine consumption as a common behavior which occurs in the context of daily life. Achievement settings like work and school are particularly interesting contexts in which to study caffeine consumption because of the demands placed on individuals to manage their energy and psychological states in service of goal accomplishment. The current study examined predictors of caffeine consumption among college students using an experience sampling methodology. One hundred and fifty students at a large public university reported on their mood, sleep, stress, workload, and caffeine consumption for a period of 14 days in order to study the psychological and situational predictors of caffeine consumption in their daily lives. Results indicated a negative relationship between mood and subsequent caffeine consumption and a positive relationship between workload and caffeine consumption. Also, the relationship between workload and caffeine consumption was stronger for individuals with positive caffeine expectancies related to work performance. The implications and limitations of these findings, as well as suggestions for future research are discussed.

CHAPTER 1: Introduction

Caffeine is a central nervous system stimulant present in a variety of foods and beverages (Nehlig, Daval, & Debry, 1992). It exerts its primary effects on the brain through the antagonism of adenosine receptors, leading to secondary effects on a variety of neurotransmitter systems (Fredholm, Bättig, Holmén, Nehlig, & Zvartau, 1999). Recent research suggests that 85% of people in the United States consume caffeine daily with consumption for older adults nearing 100% (Mitchell, Knight, Hockenberry, Teplansky, & Hartman, 2014). In the United States, caffeinated beverages account for the vast majority of caffeine consumption, with more caffeine consumed through coffee than through tea or soft drinks (Somogyi, 2010). Recent estimates of mean daily consumption for adults have been fairly consistent: 161.9 mg (Somogyi, 2010) and 178.26 mg (Mitchell et al., 2014), the amount of caffeine present in approximately 1.5 to 2 cups of regular, brewed coffee. This is well below the maximum daily consumption of 400 mg recommended by the US Food and Drug Administration, based upon the research of Nawrot et al. (2003), but sufficient to evoke the stimulant effects typically attributed to caffeine (Smit & Rogers, 2000).

There has been a great deal of research on the effects of acute caffeine consumption. Commonly observed physiological effects include increased blood pressure (Childs & de Wit, 2006, 2008; Rogers, Smith, Heatherley, & Pleydell-Pearce, 2007), increased electrodermal activity, and EEG activity consistent with a state of increased arousal (Barry et al., 2005). Positive subjective effects have been consistently observed, including improved mood, decreased subjective fatigue and increased perceived alertness

(Ruxton, 2008; Smith, 2002). Caffeine consumption is also beneficial for performance of a variety of simple cognitive tasks like simple and choice reaction time tasks (Ruxton, 2008) and tasks requiring vigilance and psychomotor speed (Smith, 2002). While the cognitive effects of caffeine can be observed in both fatigued and well-rested individuals, the effects tend to be larger for the former group (Nehlig, 2010).

Up to this point, the scientific study of caffeine has proceeded in a fashion similar to the study of other drugs. The primary emphasis for researchers has been on understanding the acute and long-term effects caffeine has on the brain and body. Because of this, the vast body of scientific research on caffeine is largely limited to a few types of studies. Research focused on the acute effects of caffeine has tended to employ laboratory studies in which the effects of one or more doses of caffeine are compared to the effects of a placebo on various physiological, subjective, and behavioral outcomes. Research on the long term effects of caffeine has typically used prospective designs where individuals' caffeine habits are assessed at the beginning of the study, with years of follow-up measurements that allow scientists to compare the prevalence of certain diseases among high, moderate and low caffeine users. This approach is in some ways quite appropriate. Caffeine does exert physiological and psychological effects, however mild, that need to be understood so that individuals can be advised regarding the consequences of caffeine consumption. However, caffeine differs from many other drugs in a number of ways, which should lead scientists to augment the dominant drug research paradigms with other methods that illuminate the role of caffeine in people's lives.

Caffeine is more widely available and more widely used than other stimulant drugs (Hodge, Scanlon, Corbett, & Sorensen, 2011). Stimulants like Ritalin and Adderall are meant to treat disorders like ADHD or shift-work sleep disorder and require a prescription for legal use (Greely, Campbell, Sahakian, & Kessler, 2008). On the other hand, caffeine is largely unregulated and, although caffeine is contained in a variety of medications like analgesics and diet pills, it is typically used by healthy individuals (Hodge et al., 2011). While existing research has contributed greatly to the understanding of caffeine as a psychoactive and bioactive substance, *caffeine use* as a widespread voluntary behavior is less understood. Large-scale caffeine consumption surveys have provided insight into the prevalence and mean levels of caffeine use in the general population and in various demographic subgroups. Some cross-sectional research has also focused on explaining individual differences in caffeine use, examining traits like extraversion, impulsivity, and chronotype as explanatory factors. However, if one were to ask someone in line at a coffee shop why they were there, he/she probably would not point to his/her impulsive personality. One might be more likely to hear complaints about insufficient sleep, inability to concentrate, poor mood, or a heavy workload (Graham, 1988; Irons et al., 2014). These intuitive reasons for using caffeine are transient, describing features of one's situation or psychological state that can change daily or even hourly. It is therefore surprising that little research attention has been given to within-person variability in caffeine use and the psychological and situational determinants of caffeine consumption in daily life.

The purpose of this study was to examine how psychological states, including mood and stress, and situational characteristics like workload and sleep deprivation impact within-person variability in caffeine consumptions. Additionally, individual differences in caffeine expectancies and personality characteristics, including impulsivity and facets of Behavioral Activation System (BAS) were examined as potential moderators of these within-person relationships. Data for this study were collected using an experience sampling method (ESM), whereby participants were surveyed four times per day for a period of fourteen days. Due to the nested structure of the data, hierarchical linear modeling (HLM) was used for hypothesis testing.

To provide an appropriate context for this study, the first section of this paper is a brief review of the literatures on caffeine's effects, caffeine expectancies, and what is currently known about individual patterns of caffeine use. The second section introduces the current investigation, including hypotheses. The third section covers the methods used in this investigation, including participants, materials, and procedures. The fourth section describes the analysis strategy and the results for this study. Finally, the fifth section discusses the implications of study findings along with limitations and suggestions for future research.

CHAPTER 2: Caffeine and Mood

2.1 Effects of caffeine on mood

The effects of caffeine on mood have been the subject of dozens of studies, and though the topic has not been addressed through meta-analysis, several reviews have summarized the results of the many individual studies on the caffeine-mood relationship. Ruxton (2008) reviewed 20 placebo-control studies performed between 1992 and 2007. Caffeine doses used in these studies ranged from 37.5 to 450 mg typically administered in a single dose prior to testing. Sixteen of these studies were performed on well-rested subjects, while the remaining four studies examined the effects of caffeine on mood in sleep restricted individuals. There was consistent support for mood improvements following caffeine use. In 15 of 20 studies, positive effects were seen on mood dimensions related to energy, alertness, or arousal. Three studies also reported positive effects of caffeine on more global mood dimensions like hedonic tone or overall mood. In a few cases, increases in anxiety or tension were also reported. Haskell, Kennedy, Wesnes, & Scholey (2005) provided sufficient information to calculate effect sizes for low and moderate doses of caffeine and various mood dimensions. Using a within-person design to study the effects of caffeine on mood in 48 healthy volunteers (mean age = 23.4 years), they found significant mean differences from baseline measures in subjective alertness (d = .44 for 75 mg; d = .47 for 150mg), subjective tiredness (d = .45 for 75 mg; d = .56 for 150mg), mental fatigue (d = .53 for 75 mg; d = .49 for 150 mg) and jitteriness (d = .91 for 150 mg). Smith (2002) echoed these findings in his review of the effects of caffeine on human behavior. He specifically highlighted the stability of the caffeine-alertness relationship, citing findings of increased alertness with both large (e.g., 250 mg and above) and more realistic (e.g., 100mg) doses of caffeine. Smith's (2002) review concluded that the positive effect of caffeine on alertness persists whether participants are relatively alert pre-treatment or are subjected to low-alertness situations (e.g., sleep deprived, on sedative drugs, early in the morning). Smith (2002) found that the available literature generally supported Lieberman’s (1992) position that caffeine may cause increased anxiety when consumed in large doses, but otherwise has little effect on this mood dimension. For example, Brice & Smith (2002) examined the effects of a single large dose and four smaller doses on mood. They found a significant overall effect of caffeine on anxiety, showing greater anxiety in participants consuming a single caffeinated cup of coffee (200 mg) than those consuming a single cup of decaffeinated coffee (d = .52). Those consuming four cups of caffeinated coffee (65 mg each) across a four hour period also reported higher anxiety than those consuming four cups of decaffeinated coffee during the same period (d = .22).

2.2 Mood-related caffeine expectancies

In this section, I examine what effects caffeine users expect following consumption vis-á-vis mood. These expectations may be developed through previous experience with caffeine or through suggestion from acquaintances or media (Bandura, 1977, 1986; as cited in Huntley & Juliano, 2012). While experimental research has shown generally positive effects of caffeine on a variety of mood outcomes, the degree to which caffeine is used in order to achieve such effects may depend on users’ anticipation of these effects following consumption.

Two measurement development/validation studies suggested that mood improvement is one of the expected effects of caffeine among many caffeine users, and that mood-related caffeine expectancies predict caffeine consumption patterns (Heinz, Kassel, & Smith, 2009; Huntley & Juliano, 2012). Heinz et al. (2009), using their Caffeine Expectancy Questionnaire (CEQ), found that expectations of mood effects (e.g., "caffeine helps calm me down", "drinking caffeine is good for dealing with boredom") among a sample of N = 418 undergraduate students were positively correlated with past week caffeine consumption, r = .27, symptoms of caffeine dependence, r = .42, and perceived difficulty in stopping caffeine use, r = .41. Similarly, Huntley and Juliano (2012), administering their measure, also called the Caffeine Expectancy Questionnaire (CaffEQ), to a sample of United States residents (N = 665; M age = 30.4; 81% female), found that individuals who endorsed more expectations of social/mood enhancement from caffeine use (e.g., "caffeine makes me feel happy", "I feel more sociable after having caffeine") consumed more caffeine, r = .32, had more difficulty stopping consumption, r = .35, and consumed caffeine sooner after waking, r = -.24 (with latency of caffeine after waking). The latter two relationships remained significant after controlling for average daily caffeine use.

2.3 Daily mood and caffeine consumption

Four studies have evaluated the relationship between daily mood and daily caffeine consumption using daily diary methods. These studies assess average mood and total caffeinated beverage consumption once per day across a period ranging from 1 to 8 weeks, allowing researchers to examine within-person changes in day to day mood in relation to changes in daily caffeine consumption. Findings from daily diary studies on the mood-caffeine relationship are mixed. Dekker, Paley, Popkin, & Tepas (1993) observed large average within-person correlations between coffee consumption and positive and negative mood on workdays (r = -.51 and .53, respectively) and non-workdays (r = -.48 and .49, respectively) among a sample of 27 locomotive engineers. This suggests that individuals may consume caffeine in order to maintain an agreeable mood state throughout the day. However, other daily diary studies have found no such relationship. Steptoe & Wardle (1999) found nonsignificant average within-person correlations between caffeinated beverage consumption and positive and anxious mood among a sample of 29 nurses and 40 teachers who reported on these variables daily for 8 weeks. Interestingly, they also observed substantial between-person variability in within-person positive mood-beverage correlations (positive mood-coffee range: r= -.66 - .33; positive mood-tea range: r = -.33 - .375) and within-person anxious mood-beverage correlations (anxious mood-coffee range: r = -.38 - .41; anxious mood-tea range: r = -.59 - .32). Nonsignificant relationships between mood and caffeine use have also been observed in samples of government employees (Jones, O'Connor, Conner, McMillan, & Ferguson, 2007) and university faculty and staff (Bryan et al., 2012).

Existing research has demonstrated reliable improvements in mood following caffeine consumption and suggests that mood improvement is one of the primary effects of caffeine consumption expected by caffeine users. Given the effects of caffeine on mood observed in laboratory settings and users' knowledge of these effects demonstrated through caffeine expectancies research, one would expect caffeine users to consume caffeine when experiencing negative mood states. However, evidence for this pattern caffeine use is mixed. It appears that there may be substantial between-person variability in caffeine consumption patterns related to mood, but there have been no attempts to account for this variability. The current study employed multilevel analyses, introducing caffeine expectancies as a person-level variable that may account for between-person differences in the within-person relationship between mood and caffeine use. A second issue is that extant longitudinal studies have measured both mood and caffeine consumption at the day-level. This precludes researchers from drawing conclusions about the temporal relationship between caffeine consumption and mood. In other words, it is not clear whether observed relationships are the result of changes in caffeine consumption following changes in mood or vice versa. Another possibility is that both phenomena are occurring to some degree. This could have the effect of obscuring the relationship between caffeine use and mood when measured at the day level and may explain non-significant relationships observed in some within-person studies. Users may be consuming caffeine in response to poor mood, resulting in subsequent mood improvement and diminishing the observed relationship between mood and caffeine use. Therefore, the current study attempted to clarify the nature of the mood-caffeine relationship by using an experience sampling methodology that allows for the examination of temporal precedence and eliminates the potential for obscured effects.

CHAPTER 3. Caffeine, Performance, and Work

3.1 Effects of caffeine on performance

Probably owing to its stimulant effects, caffeine has frequently been studied with respect to its effects on various aspects of performance. These studies have typically been performed in lab settings with placebo-control designs in which participants perform various cognitive tasks after caffeine administration. Smith (2002) summarized the findings of these studies as showing support for salutary effects of moderate amounts of caffeine on performance of vigilance tasks and other simple tasks requiring high alertness. For example, Haskell et al. (2005) found significant improvements from baseline measures of simple reaction time (d = .53 for 75mg), digit vigilance reaction time (d = .43 for 75mg; d = .55 for 150mg), numeric working memory reaction time (d = .58 for 150mg), sentence verification accuracy (d = .45 for 75mg; d = .70 for 150mg), and rapid visual information processing accuracy (d = .81 for 150mg for habitual caffeine users only). Caffeine has also been shown to improve performance on a four-choice reaction time task (Lieberman, Wurtman, Emde, Roberts, & Coviella, 1987), and a categoric search task (Christopher, Sutherland, & Smith, 2005) at doses ranging from 32 to 450mg. While the cognitive effects of caffeine can be observed in both fatigued and well-rested individuals, the effects tend to be larger for the former group (Nehlig, 2010). For example, Lorist, Snel, and Kok (1994) used a mixed design to study the effects of caffeine on information processing and mood in fatigued and well-rested individuals (N = 30 undergraduate students). Subjects in the sleep-deprived condition were kept awake all night and tested between 4:00 and 6:30 AM, while subjects in the rested condition were tested after a regular night of sleep. They found that the effect of caffeine relative to placebo on choice reaction time was nearly twice as large in the fatigued condition (d = .60) than in the rested condition (d = .33). Finally, although positive performance effects of caffeine are often reported for simple psychomotor tasks, it is not clear that caffeine has any appreciable effect on the performance of more complex tasks. In a review paper, Nehlig (2010) concluded that effects on learning and memory tasks are rarely reported and typically involve interactions with dosage or person-level variables.

3.2 Performance-related caffeine expectancies

Research from the caffeine consumption and caffeine expectancies literatures suggests that many people believe caffeine enhances performance, and that these beliefs are related to consumption behavior. For example, the "acute positive effects" subscale of the CEQ (Heinz, Kassel, & Smith, 2009) contains three items related to cognitive/performance enhancement: "I pay attention more efficiently," "I think more clearly," "Caffeine helps sharpen my memory." Scores on this subscale were correlated with average daily caffeine consumption (r = .26) in a sample of 418 undergraduate students. Similarly, the "energy/work enhancement scale" of the CaffEQ (Huntley & Juliano, 2012) contains various items related to performance enhancement, including "Caffeine helps me work over long periods of time," and "Caffeine increases my motivation to work." Scores on this subscale were correlated with average daily caffeine consumption (r = .27), difficulty stopping caffeine use (r = .37), and latency of caffeine use after waking (r = -.20). Bradley & Petree (1990) assessed expectancies for caffeine-enhanced performance among 270 college students (178 female) and their relation to caffeine consumption and caffeinism. Participants endorsed reasons for consuming caffeine like “Help with study or work,” “Improve performance,” “Improve concentration.” Expectancies of improved performance with caffeine were positively related to average daily caffeine consumption (*r* = .38) and symptoms of caffeinism (*r* = .47).

3.3 Caffeine consumption and workload

The research discussed above establishes that caffeine consumption may benefit performance on certain types of tasks, and that users’ recognition of these effects is positively related to their caffeine consumption. Studies have sought to extend knowledge in this area by assessing whether between-person and within-person differences in workload are associated with caffeine consumption. Cross-sectional studies have produced mixed results. Rios et al. (2013) found no differences in typical caffeine consumption, among students reporting high, moderate, and low levels of academic load, while Ratlifff-Crain and Kane (1995) reporting a positive correlation (*r* = .31) between typical hours worked and typical caffeine consumption among 288 participants recruited outside of a campus café. Within person analyses have generally shown support for a positive relationship between workload and caffeine consumption (Dekker, Paley, Popkin, & Tepas, 1993). Conway, Vickers, Ward, and Rahe (1981), using a daily diary method, found that, on average, workload was positively related to the amount of coffee consumed (*r* = .28) among a sample of 34 military officers. Zunhammer, Eichhammer, and Busch (2014) studied 150 college students to examine changes in caffeine consumption related to exam preparation. They found that average caffeine consumption during periods of exam preparation (M = 7.1 servings/week) was significantly greater than during the pre (M = 4.76) and post-exam (M = 4.56) periods. However, Jones et al. (2007) found no significant relationship between daily caffeinated beverage consumption and hours worked per day.

Laboratory experiments have reliably demonstrated improved performance on relatively simple psychomotor and vigilance tasks, though the effects of caffeine on the performance of more complex tasks are not as clear. Nonetheless, users' expectations of generalized performance enhancement resulting from caffeine use have been demonstrated by studies on caffeine expectancies. While there seems to be a disconnect between the narrow range of tasks on which caffeine has been shown to improve performance and users' more global expectations of improved performance, both types of evidence suggest that caffeine consumption may increase in response to a heavier workload. Evidence for this pattern of caffeine consumption from between-person and within-person studies is mixed. Importantly, workload-caffeine relationship among college students has not been studied using conventional longitudinal methods like daily diaries or experience sampling methods (ESM). The current study makes a unique contribution to this area of study by conducting the first ESM investigation of the workload-caffeine relationship among college students, and examining whether this relationship is dependent on factors like caffeine expectancies and personality.

CHAPTER 4. Caffeine and Stress

4.1 Effects of caffeine on stress

Experimental evidence regarding the effects of caffeine on stress is relatively limited compared to the other psychological variables to be considered in the proposed study. Some of the physiological effects of caffeine consumption, such as increased blood pressure and cortisol synthesis, mimic the physiological stress response (Al'Absi & Lovallo, 2004). This has led researchers to examine whether caffeine exacerbates physiological responses to environmental stressors. Some studies on male medical students have demonstrated increased reactivity to stress under the influence of caffeine (e.g., Lane & Williams, 1985), while others have shown only additive effects on physiological measures (e.g., Pincomb, Lovallo, Passey, Brackett, & Wilson, 1987). However, it does not appear that caffeine, either alone or in combination with environmental stress, leads to increased subjective stress (St. Claire et al., 2010). Perhaps somewhat relevant to this question is the fact that caffeine has been found to increase anxiety at very high doses, with no significant effect on anxiety at normal levels of consumption (Nehlig et al., 1992).

4.2 Stress related caffeine expectancies

Evidence from the literature related to caffeine expectancies suggests that some caffeine users perceive caffeine as instrumental in dealing with stress. Rios et al. (2013) surveyed a sample of college students, finding that 49% considered caffeine useful for coping with stress, and 42% planned to use caffeine as a stress coping tool in the future.

Stress relief motives are represented in two of the four subscales of the validated Caffeine Motives Questionnaire (Irons et al., 2014). Items “to help deal with stress in my daily life” and “to help deal with anxiety” are the highest loading items in the negative affect relief subscale which correlated (*r* = .20) with caffeine consumption. Item “to help relax or calm down” is part of the reinforcing effects subscale which correlated (*r* = .37) with caffeine consumption. The mood effects subscale of the CEQ also contains three items related to the calming or relaxing effects of caffeine (Heinz et al., 2009).

4.3 Stress as a predictor of caffeine consumption

Several cross-sectional and longitudinal studies have examined the link between stress and caffeine consumption in daily life. The cross-sectional studies examined the relationship between typical stress levels and habitual caffeine consumption and have produced mixed results. Jones and Fernyhough (2009) found a small but significant correlation (*r* = .17) between caffeine consumption and perceived stress measured retrospectively across the past year among 219 university students in the United Kingdom. In a study on stress and energy drink consumption among college students, perceived stress during the past month was positively related to several energy drink consumption parameters, including the number of days on which at least one energy drink was consumed during the past month (*r* = .24) and the maximum number of energy drinks consumed during a single day (*r* = .24) (Pettit & DeBarr, 2011). Rios et al. (2013) found no significant relationship between caffeine use and stress during the past semester. Two longitudinal studies have examined how within-person changes in perceived stress relate to caffeine consumption. Conway et al. (1981) monitored coffee consumption among military officers across training days known to vary in stressful demands. In their all-male sample, daily coffee consumption was positively related to six of the eight stress indicators measured (r = .22 - .54), and coffee consumption was greater on high stress days was significantly greater than on the other study days. In a daily diary study of 422 British government employees, daily hassles significantly predicted caffeine consumption (O'Connor, Conner, Jones, McMillan, & Ferguson, 2009). Two studies have taken a different approach, simply asking participants about changes in their typical caffeine consumption during stress, with just over half reporting increased consumption during stress in both studies (Ratlifff-Crain & Kane, 1995; Rios et al., 2013).

While laboratory studies have shown little evidence that caffeine has any appreciable effect on perceived stress, research on caffeine expectancies shows that some individuals expect a calming effect from caffeine consumption. Longitudinal and cross-sectional research on voluntary caffeine consumption have also demonstrated positive relationships between perceived stress and caffeine use. However, there are limitations to both types of study. While cross-sectional studies can adequately describe the relationship between typical stress levels and typical caffeine use, they fail to address the question of whether a given individual tends to consume more caffeine when feeling stressed. Existing longitudinal studies have measured stress and caffeine use at the day level, which precludes the examination of temporal precedence in the stress-caffeine relationship. In order to advance research on this topic, the current study employed several within-day measurements of stress and caffeine use, and examined whether individual differences in the stress-caffeine relationship are a function of caffeine expectancies.

CHAPTER 5. Caffeine and Sleep

5.1 Performance effects of caffeine after sleep deprivation

There are many laboratory studies on the effects of caffeine on subsequent sleep. In these studies, caffeine is typically administered relatively close to bedtime. Complete coverage of these findings is beyond the scope of this study. For a comprehensive review, see Roehrs & Roth (2008), who observed that caffeine, even in small doses, increases sleep latency and decreases total sleep duration. The effects of caffeine on performance following sleep deprivation are more relevant to this investigation as they represent a potential motive for increasing caffeine consumption after insufficient sleep. Generally, the effects of caffeine on performance in sleep deprived individuals are qualitatively similar to those observed in rested samples; however, sleep deprived subjects have often shown greater increases in performance following caffeine administration (Nehlig, 2010; Smith, 2002). This is of particular interest to workers who are often required to operate on restricted sleep. Researchers have attempted to demonstrate the effects of caffeine in a variety of such situations using high fidelity simulations. In a sample of 18 acutely sleep-deprived medical students, 150 mg of caffeine restored completion time and economy of motion to baseline levels in a simulated laparoscopic surgery task (Aggarwal, Mishra, Crochet, Sirimanna, & Darzi, 2011). Muehlbach and Walsh (1995) simulated 5 nights of night shift work in a sample of young adults, demonstrating fewer errors, and fewer attempts to correct non-faulty items during a simulated assembly line task with 2 mg/kg of caffeine relative to placebo, though they did not provide sufficient information to calculate an effect size. In a sample of 20 special forces personnel, 200 mg of caffeine improved performance relative to placebo on a field vigilance task, but not on a live-fire marksmanship task, during 3 consecutive days of restricted sleep (4 hrs/day) (Kamimori et al., 2015).

5.2 Sleep-related caffeine expectancies

Survey research on perceptions of caffeine's effects related to sleep and sleep deprivation suggests that many individuals recognize the potential of caffeine to both disrupt sleep and restore performance under conditions of sleep deprivation. McIlvain, Noland, Melody, and Bickel (2011) asked a sample of 300 college students about their beliefs regarding the effects of caffeine. Seventy-six percent of participants surveyed believed that caffeine would help them to stay awake and 59.3% believed that caffeine would help wake them up in the morning. Bradley and Petree (1990) found that expectancies of improved performance with caffeine, including items related to combatting sleepiness ("Wake up in the morning" and "Wake up or stay awake later in the day or evening"), were positively related to typical caffeine consumption ($r = .38$). Huntley and Juliano's (2012) CaffEQ contains a 4-item subscale related to sleep disruption, and their energy/work enhancement subscale ($r = .26$ with caffeine consumption) contains two high loading items (.93 and .87) related to combatting sleepiness. The cognitive enhancement ($r = .29$ with caffeine consumption) subscale of the Caffeine Motives Questionnaire developed and validated by Irons et al. (2014) contains two items related to staying awake or combatting drowsiness.

5.3 Sleep and caffeine consumption in daily life

The relationship between naturalistic sleep duration/quality and caffeine consumption has only been examined in the context of cross-sectional, between-subjects studies. These studies suggest that even relatively low levels of habitual caffeine consumption are associated with sleep disturbances and daytime sleepiness (Roehrs & Roth, 2008). Sanchez et al. (2013) found that undergraduate students who consumed more than three caffeinated beverages per week were almost twice as likely to be classified as poor sleepers compared to non-consumers (OR = 1.88; 95% CI 1.42 - 2.50). Hicks, Hicks, Reyes, and Cheers (1983) found that sleep duration, measured in hours and split into 5 categories (>8, 8, 7, 6, <6), had a significant effect on the number of caffeinated beverages consumed daily in a sample of undergraduate students (est. η^2 = .14). In another study, frequency of energy drink consumption was positively related to sleep disturbance (r = .44) in a sample of 107 college students (Stasio, Curry, Wagener, & Glassman, 2011). In an interesting departure from typical findings, Sanchez-Ortuno et al. (2005) found no significant relationship between coffee consumption and sleep duration in a sample of French workers when consumption was less than 8 cups per day. However, they found that excluding these extremely high users, coffee consumption was still negatively related to time in bed and suggested that this may reflect a tendency to use caffeine in order to extend active hours later into the evening without detrimental effects on sleep duration.

The lack of longitudinal studies on the relationship between sleep duration and caffeine makes the results of existing research difficult to interpret. Negative correlations between sleep duration and caffeine consumption might reflect the sleep-disrupting effects of caffeine, or the use of caffeine to combat sleepiness following a poor night's sleep. The current study helps to clarify the nature of this relationship by taking a longitudinal, multilevel approach which will allow for the examination of temporal precedence in the sleep-caffeine relationship and the modeling of individual differences in this relationship as a function of caffeine expectancies.

CHAPTER 6. Limitations of previous research

One common problem in the existing literature related to predictors of caffeine consumption is the use of cross-sectional, between-subjects methods to examine relationships that are conceptually consistent with a within-person approach. The inappropriate use of between-subjects designs to examine within-person phenomena can result in misleading findings and even result in relationships that differ in direction from the true relationship (Hamaker, 2012). Curran & Bauer (2012) offered an illustrative example of this problem from the medical literature, citing the fact that although a person is more likely to experience a heart attack while exercising (within-person level), there is a lower prevalence of heart attacks among those who exercise more. This problem might explain different findings from cross-sectional and longitudinal studies regarding the caffeine-stress relationship. Cross-sectional designs also fail to appropriately model the temporal relationship between two variables. While cross-sectional research has reliably demonstrated a relationship between habitual caffeine consumption and sleep duration, it is not clear if this reflects inhibition of sleep by caffeine, or the use of caffeine to counteract daytime sleepiness after insufficient sleep. Even longitudinal methods, such as daily diaries, have the potential to obscure relationships, particularly when there may be a bidirectional relationship between the variables considered. This problem is particularly relevant to the caffeine-mood relationship. Finally, there has been little attention to individual differences in the relationship between psychological and behavioral predictors and caffeine consumption. In light of these issues, a longitudinal, multilevel investigation of caffeine use with appropriate intervals between measurements, as was employed in this study, has the potential to contribute greatly to knowledge about the predictors of caffeine consumption in daily life.

CHAPTER 7. Hypotheses

While there is ample evidence that caffeine consumption positively impacts mood and that caffeine users, to differing degrees, expect these mood effects following consumption, existing research has failed to establish a clear relationship between mood and caffeine consumption in daily life. It is possible that measurement of caffeine use and mood at the day-level has obscured this relationship in previous studies. This study sought to overcome this limitation by measuring these variables several times per day and it was expected that there would be a negative relationship between mood and subsequent caffeine consumption and that caffeine expectancies would account for some of the between-person variability in within-person mood-caffeine relationships. Furthermore, based relatively larger effects observed on arousal-related dimensions of mood over pleasantness dimensions, it was expected that there would be a larger relationship between arousal and subsequent caffeine consumption than between pleasantness and subsequent caffeine consumption.

Hypothesis 1: Pleasantness on a given observation will negatively predict caffeine consumption during the interval leading up to the next observation (r^2 = .10 - .15).

1a. There will be a significant cross-level interaction between pleasantness and mood-related caffeine expectancies. Specifically, within-person pleasantness-caffeine relationships (slopes) will become greater as mood-related caffeine expectancies increase (Δr^2 = .10).

Hypothesis 2: Arousal on a given observation will negatively predict caffeine consumption during the interval leading up to the next observation ($r^2 = .15$)

2a. There will be a significant cross-level interaction between arousal and energy-related caffeine expectancies such that the strength of the arousal-caffeine relationship will increase as energy-related caffeine expectancies increase ($\Delta r^2 = .10$)

While there is no experimental evidence that caffeine affects perceived stress levels, it appears that a substantial proportion of caffeine users perceive caffeine to be useful for dealing with stress and report increased consumption during times of stress. Thus, it is expected that caffeine use will be positively related to feelings of stress as they fluctuate throughout the day.

Hypothesis 3: Stress measured on a given occasion will positively predict caffeine consumption during the period leading up to the next measurement occasion ($r^2 = .12$).

3a. There will be a significant cross-level interaction such that the stress-caffeine relationship will increase in strength as expectancies of caffeine-induced stress relief increase ($\Delta r^2 = .10$)

Experimental research has established that caffeine positively affects performance on a variety of simple psychomotor tasks. However, it appears that individuals' expectations of positive performance effects are more global, applying to work in general, rather than a limited range of tasks. Thus, it is expected that study participants will exceed their typical caffeine use on days when their workload is greater than normal, and that caffeine expectancies related to work performance will explain some of the between-person variability in this relationship.

Hypothesis 4: Daily work hours will be positively related to caffeine consumption for that day (r^2 = .10).

4a. There will be a significant cross-level interaction such that the strength of the daily work hours-caffeine relationship will increase with higher expectancies of caffeine-enabled work-enhancement/extension (Δr^2 = .12)

As a stimulant, caffeine increases feelings of alertness and mitigates performance decrements associated with low arousal for certain types of tasks. Furthermore, these effects seem to be integrated into users' perceptions of caffeine as measured by caffeine expectancies. While negative correlations between sleep duration and caffeine consumption observed in cross-sectional research are subject to multiple interpretations, it was expected that when sleep duration and caffeine use are measured at appropriate intervals, that sleep duration will negatively predict caffeine use. Additionally, the strength of this within-person relationship should be positively related to an individual's perception that caffeine helps combat sleepiness.

Hypothesis 5: Sleep duration for a given night will positively predict caffeine consumption on the following day (r^2 = .15).

5a. There will be a significant cross-level interaction such that the strength of the sleep duration-caffeine relationship will increase with greater expectancies that caffeine helps combat sleepiness (Δr^2 = .10).

In addition to this set of primary hypotheses, several exploratory hypotheses are considered. Stress is unique among the predictors to be included in the proposed study in that experimental research has not demonstrated reliable effects of caffeine on stress. However, expectations of stress relief among caffeine users are reflected in the caffeine expectancies literature, and many individuals report increasing caffeine consumption during times of stress. It seems reasonable that, rather than using caffeine to alleviate stress directly, individuals may use caffeine to facilitate the completion of work or school assignments that act as a source of stress. Therefore, it was expected that workload and stress will interact to predict caffeine consumption.

Hypothesis 6: There will be a significant interaction between stress and workload such that the strength of the stress-caffeine relationship will increase as workload increases.

Beginning with Yerkes and Dodson (1908), many researchers have noted the curvilinear (inverted "U" shaped) relationship between arousal state and performance (e.g., Easterbrook, 1959; Kahneman, 1973) and have even explored caffeine as a means of manipulating arousal to affect task performance (Revelle et al., 1980). Given the relationship between arousal and performance, and the ability of caffeine to restore arousal to normal levels following insufficient sleep, it is expected that the relationship between workload and arousal will be particularly strong when participants are operating on less than their normal amount of sleep.

Hypothesis 7: There will be a significant interaction between sleep duration and workload such that the strength of the workload-caffeine relationship will increase as sleep duration decreases.

Previous research supports a positive relationship between impulsivity and typical caffeine consumption (Penolazzi, Natale, Leone, & Russo, 2012). This personality dimension is thought to assess differential levels of basal arousal, with high impulsives having low levels of arousal (Eysenck, 1967, as cited in Matthews & Gilliland, 1999; Revelle et al., 1980). Following the logic presented in relation to the previous hypothesis, it may be particularly important to maintain optimal levels of arousal when one is engaged in work. Thus, it was expected that impulsiveness will moderate the workload-caffeine relationship, with high impulsives demonstrating stronger relationships between workload and caffeine use.

Hypothesis 8: There will be a significant cross-level interaction such that the strength of the workload-caffeine relationship will increase as impulsiveness increases.

Previous research has demonstrated a relationship between the Behavioral Approach System (BAS) subscales and typical caffeine use (Penolazzi, Natale, Leone, & Russo, 2012). However, there has been no investigation of how these personality factors might impact within-person patterns of caffeine use in relation to psychological states. One possibility is that the previously observed relationships between BAS and caffeine use reflect a tendency to use caffeine to seek out pleasant mood states. It is expected that BAS-Reward Responsiveness will moderate the pleasantness-caffeine relationship, with those scoring high on this subscale demonstrating a stronger negative relationship between pleasant mood and subsequent caffeine use.

Hypothesis 9: There will be a significant cross-level interaction such that the strength of the negative relationship between pleasantness and caffeine consumption will increase as a function of reward responsiveness.

CHAPTER 8. Method

This study employed an experience sampling method (ESM) with interval contingent sampling. ESM is an intensive longitudinal method which typically requires participants to respond to several brief surveys each day for a period of one week or more. This method is more appropriate for assessing change over time than are cross-sectional survey methods or daily diaries, particularly when the variables of interest are likely to vary within a day. Interval contingent sampling, wherein surveys are administered at a fixed time throughout the day, was chosen as the primary sampling method, though one exception will be discussed later. This decision was made based on the relative advantage of interval-contingent over event-contingent sampling in relation to compliance verification (i.e., one cannot verify that participants report immediately following the behavior in question. Interval-contingent sampling also places less burden on participants relative to signal-contingent (random time) sampling by allowing them to plan and allot time for survey completion in the midst of their daily obligations (Conner & Lehman, 2012).

8.1 Participants

One hundred and forty nine undergraduate students at a large public university were recruited for this study using an online experiment scheduling system. In order to be eligible for the study, participants had to be between18 and 30 years old, be a full-time student, possess as smart-phone running an Android or IOS operating system, and consume caffeine three or more times per week. The sample size for this study was determined based on rules of thumb commonly used to ensure sufficient power in multilevel studies. Researchers tend to rely on these rules of thumb because power analysis for multilevel studies is extremely complex due to difficulty estimating all of the variance components necessary for power calculations (Scherbaum & Ferreter, 2008). Recommendations for sample size in multilevel designs are the product of simulation studies on the effects of intraclass correlation (ICC) and Level 1 and Level 2 sample sizes. With level 2 sample sizes larger than 30, ICC no longer appears to affect parameter or variance component estimation (Maas & Hox, 2005). Increasing sample size at Level 2 has a greater effect on power than increasing Level 1 sample size, and Level 2 sample sizes of 100 or more allow for accurate estimation of both fixed parameters and variance components, however some degree of over-sampling is appropriate for ESM studies, given the prevalence of missing data (Maas & Hox, 2004). After data collection, 19 participants who reported zero milligrams of caffeine consumption for 85% or more of the surveys were excluded from the primary analyses, resulting in a final sample of 130 participants (83 Females, Mean age = 20.16 years). The logic for excluding these participants with very low rates of caffeine use was that they would not have met the eligibility requirement for the study, had they accurately reported on their typical caffeine consumption during the eligibility screening.

8.2 Measures

8.2.1 Initial Questionnaire

Caffeine expectancies were measured using items from both available measures, the CEQ (Heinz et al., 2009) and CaffEQ (Huntley & Juliano, 2012). Custom subscales assessing expectancies of mood improvement, energy enhancement, stress reduction, work enhancement/extension, and withdrawal symptoms were created by pulling items from both extant measures with identical or excessively similar items removed. A 6-point response scale (1 = Strongly Disagree; 6 = Strongly Agree) was used for all caffeine expectancy items. The ten item Mood Expectancies Subscale (α = .85) assessed the degree to which participants expected that caffeine consumption would improve their mood and contained items like "Drinking caffeine improves my mood" and "I feel more content when I consume caffeine." The five item Energy Expectancies subscale (α = .74) measured to what degree participants expected caffeine use to make them feel more energized or less sleepy and contained items like "Caffeine picks me up when I am feeling tired" and "Caffeine makes me feel more alert." The four item Stress Expectancies subscale (α = .77) assessed the degree to which participants expected stress-relieving effects after caffeine use (e.g., "Caffeine helps me relax"; "Caffeine helps calm me down"). The six item Work Expectancies subscale (α = .86) assessed participant's expectations of enhanced or extended working capabilities following caffeine use (e.g., "Caffeine improves my concentration"; "Caffeine helps me work over long periods of time"). The fourteen item Withdrawal Expectancies subscale (α = .95) measured to what degree participants expected negative effects or cravings when abstaining from their normal amount of caffeine (e.g., "I need to have caffeine every day"; "I feel miserable when I do not have my usual caffeine").

Caffeine expectancies were the only Level 2 variables explicitly hypothesized to moderate Level 1 relationships. However, several personality factors have been found to be related to individual differences in caffeine consumption (Penolazzi et al., 2012) and were measured for use in exploratory analyses. These include Behavioral Approach System (BAS) subscales (Carver & White, 1994) and the Barratt Impulsiveness Scale (BIS-11: Patton, Stanford, & Barratt, 1995). The BAS measurement is composed of three subscales representing Drive, a tendency to pursue desired goals; Fun Seeking, a tendency to engage in potentially rewarding activities; and Reward Responsiveness, assessing positive reactions to achieved or anticipated rewards. The authors reported Cronbach's alpha for these scales as .76, .66, and .73, respectively. For the current investigation, Cronbach's alpha was .80 for Drive, .73 for Fun-seeking, and .69 for Reward Responsiveness. Validation information presented with the scales indicate that BAS-Drive was moderately related to Extraversion (r = .41) and to positive temperament as measured by the General Temporal Survey (GTS: Watson & Clark, 1993). BAS-Fun was strongly related to Extraversion (r = .59) and moderately related to the GTS disinhibition subscale (r = .39). The BAS-reward subscale was moderately related to positive affectivity (r = .39) and to the GTS positive temperament subscale (r = .35).

The Barratt Impulsiveness Scale (BIS-11:Patton et al., 1995) is composed of six subscales, attention, motor, self-control, cognitive complexity, perseverance, and cognitive instability, although many researchers only report the total scores for the scale (Stanford et al., 2009). In a recent validation study assessing 1,577 adults (mean age = 21.6), Stanford et al. (2009) reported good internal consistency for the total scale (α = .83) and demonstrated test-retest reliability (*spearman's rho* = .83) with an inter-test interval of one month. Chronbach's alpha for the BIS-11 in this investigation was .84. To establish convergent validity, the authors compared BIS-11 scores with scores on related measures. BIS-11 scores were positively related to the experience seeking (r = .24), disinhibition (r = .39), and boredom susceptibility (r = .36) subscales of the Zuckerman Sensation Seeking Scale (Zuckerman, Eysenck, & Eysenck, 1978) among a sample of 336 college students. The BIS-11 was also strongly related (r = .63) to an alternative measure of impulsiveness from the Eysenck Impulsiveness Scale (Eysenck, Pearson, Easting, & Allsopp, 1985) among a sample of 712 college students and volunteers from two separate communities (Stanford et al., 2009).

8.2.2 Daily Measures

Mood was measured using the Brief Mood Introspection Scale (BMIS) (Mayer & Gaschke, 1988). It consists of 16 adjectives, typically endorsed on a 4-point Likert-type scale, that assess two dimensions of mood (Pleasantness and Arousal). This measure was chosen because it was short enough to be deployed in an ESM study and because these two dimensions were of particular interest in relation to caffeine consumption. However, in its 4-point response format as reported by the authors, only the Pleasantness scale had acceptable internal consistency (α = .83) while the Arousal scale had relatively poor internal consistency (α = .58). In an effort to increase internal consistency for the Arousal subscale, a 5-point (not at all; a little; moderately; quite a bit; extremely) response scale was used for this study; however, the observed Cronbach's alpha (.56) was actually slightly lower than that reported by the authors. Investigation of item-total correlations revealed that two reverse scored items (calm and tired) were negatively correlated with the remainder of the scale. Removing these two items improved internal consistency for the scale. (α = .67). The pleasantness subscale demonstrated strong internal consistency for this study (α = .87). The authors of the BMIS demonstrated good convergent validity for their scales with correlations ranging from .83 to .96 with corresponding subscales from the long-form Mood Introspection Scale (MIS) (Mayer, Mamberg & Volanth, 1988) and the Russel Adjective Scale (RAS) (Russell, 1979).

Stress was measured using two adjectives (preoccupied and distressed) which participants endorsed on the same 5-point scale employed for the BMIS. The two items were highly correlated ($r = .67$) in the present study.

Daily workload was assessed using a single item which asks participants to report the number of minutes they spent on work related to school or employment throughout the entire day. To increase the accuracy of recall, participants were instructed to engage in a work-specific version of the day reconstruction method. This is a versatile method for capturing rich data on daily life while using a single daily report, rather than several reports throughout the day (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004). Participants are asked to think of the previous day as a series of scenes or episodes, providing a name for each episode, and recording the approximate time at which each began and ended (Kahneman et al., 2004). For the current study, participants were asked to perform this exercise with reference to working episodes, and to add up the amount of time spent working throughout the day. For ease of interpretation, reported daily workload was converted into hours before analyses were conducted.

Sleep duration was measured with select items from the Pittsburgh Sleep Diary (PghSD) (Monk et al., 1994). The PghSD consists of two forms, one to be completed at bedtime and one upon waking. For the current study, participants completed items from the morning form which requires them to record bedtime, sleep latency, wake time, and the total duration of awakenings after initially falling asleep. Sleep duration was calculated by subtracting sleep latency and the total duration of awakenings from the time between bedtime and wake time (see Sanchez-Ortuno et al. (2005)). The PghSD has been validated against objective measures of sleep duration/quality (i.e., wrist actigraphy), and related personality and demographic variables. In a study of 96 healthy volunteers (48 males and 48 females, aged 20-40), morningness was related to the timing of sleep episodes such that those higher in this trait went to sleep and woke earlier (*rho* > .6) (Monk et al., 1994). In a subset of 39 participants from the above study, there was good agreement between sleep and wake times measured via wrist actigraphy and the PghSD: the distribution of subjective minus objective sleep times was roughly normal and centered near zero (*M* = -1 min; *s.d.* = 26.75) while subjectively reported wake times were slightly earlier than objective wake times (M = -8.6 min; *s.d.* = 27.44). Total time asleep as measured by the PghSD and wrist actigraphy were positively correlated (*r* = .430). The same 39 participants were used to establish test-retest reliability of the PghSD. There were strong positive correlations between the number of awakenings (*r* = .66), minutes awake after falling asleep (*r* = .56), perceived sleep quality (*r* = .59) from the two PghSD administrations (mean inter-test interval: 22 months; min: 12, max: 30) (Monk et al., 1994).

Caffeine consumption was measured using the type-frequency method whereby individuals indicate the number of ounces of different types of caffeinated beverages (e.g., coffee, tea, energy drink, etc.) consumed during a given time period. This information was converted into the standard metric of milligrams of caffeine using standard caffeine content values offered by (Mandel, 2002).

8.3 Procedure

Participants were recruited via an online experiment scheduling system and in-class announcements both of which provided a brief description of the study. Those who were interested in the study completed a brief online eligibility screening. Ineligible participants were thanked for their interest in the study, while eligible participants were directed to an online orientation video that provided a detailed description of the study procedure and instructions for participating. At the end of the orientation video, participants were instructed on how to download the ESM application, MetricWire, on their smartphone and create an account. They were then required to email a dedicated study email address with their account information so they could be enrolled in the study. Once enrolled, participants were sent a link to the initial questionnaire which consisted of demographic items, caffeine expectancies measures, and measures of impulsivity and BAS subscales. Participants were required to complete the initial questionnaire prior to the 14 day daily reporting period.

The daily reporting period began on a Monday and continued for 14 consecutive days, ending on Sunday evening. The first day of reporting proceeded as follows: The first survey of the day was completed by participants upon waking and assessed participants' current mood and stress levels. The second survey was completed at 12:00 PM and assessed participants' current mood and stress, along with their caffeine consumption since the morning survey. The third survey occurred at 4:00 PM and was the same as the noon survey, though it referenced caffeine consumption use since the noon survey. The fourth and final survey of the day occurred at 8:00 PM and assessed current mood and stress, caffeine consumption since the 4:00 PM survey, and participants' workload across the entire day. Additionally, the final survey of the day included two items assessing perceived complexity of and interest in the day's work. With the exception of the morning survey, participants were required to complete each daily survey within 30 minutes of the scheduled signal, after which the survey was no longer available within the MetricWire App.

The procedure for the other 13 days of the daily reporting period was nearly identical to that for the first day, with one exception. After the first day, each morning survey included assessments of caffeine use and workload that referred back to the previous evening during the time period between the 8:00 PM report and when the participant went to sleep. The inclusion of these items reflected a concern that, particularly in a sample of college students, work and caffeine use may well continue into later hours. Rather than expanding the survey window beyond normal waking hours, which would be overly burdensome to participants and potentially lead to missing data, it was decided that capturing late evening activity in the following morning's survey was the best solution.

It is also noteworthy that the timing of the morning survey varied depending both within and between participants, depending on the wake time of each participant on a given day. This is an exception to the interval-contingent sampling strategy which guided the timing of the other daily surveys. Similar to the problem with surveying participants late into the evening, selecting a single fixed time for the morning survey would be likely to either wake participants or lead to missing data. Thus participants were asked to initiate the morning survey each day upon waking, rather than being signaled to begin the survey at a particular time. Subjects were compensated for their participation with course credit or extra credit for various psychology courses in which they were enrolled. Their compensation was pro-rated based on their completion rate across the surveys administered during the study.

8.4 Data Preparation

Before testing study hypotheses the, data were prepared for analysis. Because ESM data collection is carried out in the field with relatively less oversight from investigators than would be possible in a laboratory study, certain measures should be taken to ensure data quality. For the current study, one concern was whether or not missing data were distributed randomly across all reports. Under the daily reporting protocol described above, it was possible for each of the 130 study participants to complete 56 surveys, leading to a total of 7,280 possible records. Across the entire dataset, there were 1,618 missing records, indicating a total completion rate of 78%. Of these missing records, 314 were morning surveys, 438 were noon surveys, 426 were afternoon surveys, and 440 were evening surveys. Thus, the completion rate for the morning survey was substantially better than for the remaining three daily surveys. However, due to the unique protocol for the morning surveys, further analysis was required to ensure the validity of morning records. The most pressing concern was whether or not participants complied with the instructions to complete the morning survey upon waking each day. Providing some leniency, all morning surveys that were completed within an hour of self-reported wake time were retained for analysis while those completed more than one hour after waking were removed from the dataset. This led to the exclusion of 566 morning records from further analysis. Additionally, 161 surveys that were completed too quickly to contain valid responses were removed from further analysis. Finally, 4 surveys that were begun on one day and completed the next were also removed from the data. These steps led to a final figure of 2,349 missing records, a 68% completion rate. Of the final missing records, 911 were morning surveys, 488 were noon surveys, 486 were afternoon surveys, and 464 were evening surveys.

For all models discussed in the following sections, the dependent variable was participants' caffeine consumption. Despite caffeine use being among the most common consumption behaviors among adults, measuring caffeine use with the frequency employed in this study makes it a relatively rare event. As a consequence, reported caffeine consumption at the lowest measurement level (the individual time point) was very frequently zero milligrams. This posed a somewhat unique challenge to the assumptions of traditional regression techniques, including HLM. In this case, one might consider caffeine consumption as a binary variable, coding whether or not the subject consumed caffeine. On the other hand, there are vast and meaningful differences in the caffeine content of the caffeine sources typically consumed by users. For this reason, caffeine consumption was measured as a continuous variable in this study, and HLM, as opposed to logistic HLM, was chosen as the primary method of analysis. Because of the high frequency of zeros in the dependent variable, both DV distribution and the residuals from the primary models demonstrated significant departures from normality. While this violates one of the important assumptions required for HLM, simulation studies (e.g., Maas and Hox, 2004) have shown that a large sample of Level 2 units (i.e, over 100) protects against bias in both the parameter estimates and standard errors for HLM analyses. Because of the unique issues associated with the DV distribution for this study, the primary hypotheses were tested with a log-transformed DV as an additional check. As there were no differences in the significant effects identified in the raw score and log-transformed models, it was deemed appropriate to proceed using the raw scores for ease of interpretation.

8.5 Analysis Strategy

All hypotheses were tested using HLM. Two sets of models were tested in accordance with the structure of the original hypotheses. The first set of models was used to predict within-day variance in caffeine consumption, and the second to predict between-day variance in caffeine consumption. The outcome variable for these two sets of models was caffeine consumption, in milligrams, reported at each time point and aggregated to the day level, respectively. All level 1 (within-person) predictors were centered around the participant's mean, while all Level 2 (between-person) predictors were centered around the grand mean. Prior to hypothesis testing, preliminary analyses were conducted to examine within-person and between-person variance components for both the within-day and between-day models and Intraclass Correlations were calculated to assess the need for hierarchical linear modeling. As an additional preliminary step, between-person variance in fixed effects for each Level 1 predictor was tested for significance. To do this, each Level 1 predictor was added to the model alone as a unique fixed effect with a random intercept term for subject. The fixed-effect model for each predictor was then compared to a model that included a random slope term for that predictor. Model comparison was performed via ANOVAs with Chi Squared significance tests. This additional preliminary step was performed so that non-significant random slope terms could be excluded from models during hypothesis testing in order to preserve degrees of freedom. However, for the sake of adhering to the original hypotheses, all random slope terms are retained in later tables displaying the results of hypothesis testing. Following the preliminary analyses, hypothesis testing proceeded as follows. For both the within-day and between-day models, fixed effects were tested first, followed by the introduction of level 2 moderator variables. Each fixed effect was tested in isolation to determine its contribution in the absence of other variables, then all fixed effects were included in the final model. Cross-level interaction hypotheses were similarly tested by beginning with the final fixed effect model, and adding each level 2 moderator in isolation before finally including all fixed effects and level 2 moderators in the final model.

CHAPTER 9. Results

Descriptive statistics and correlations among the Level 1 measures are presented in Table 1. Mean caffeine consumption across all participants and surveys was 53.84 mg and mean daily consumption was 174.95 mg. Across all participants and days, average sleep duration was 6.86 hours and participants worked an average of about 4 hours per day. At the within-day level, it is noteworthy that stress was significantly negatively correlated with pleasantness and positively correlated with arousal. At the between-day level, a small but significant negative correlation between work hours and sleep duration was observed. While several other significant correlations were observed (e.g., caffeine consumption and stress), they were very small in magnitude and likely reached significance primarily due to the large number of observations in this study.

Table 1: Level 1 Measures Descriptive Statistics and Correlations

Level 1 Measures Descriptive Statistics and Correlations

Time Point Measures	M	SD	1	2	3	4
1. Pleasantness	3.47	0.56	-			
2. Arousal	2.17	0.48	.034**	-		
3. Stress	2.05	1.01	-.563**	.378**	-	
4. Caffeine Consumption (mg)	53.84	100.19	-.015	.066**	.041**	-
Daily Measures	**M**	**SD**	**1**	**2**	**3**	
1. Sleep Hours	6.86	2.17	-			
2. Work Hours	4.02	3.70	-.130**	-		
3. Daily Caffeine Consumption (mg)	174.95	200.48	-.030	.096**	-	

Table 2 displays the descriptive statistics and correlation matrix for the Level 2 measures. The correlations among all of the positively valence expectancy scales were quite large but not so much as to indicate an isomorphic construct. The BAS-Drive subscale was positively related with withdrawal, mood, energy and work expectancies, and the BAS-Fun subscale was positively related to all but work expectancies subscale. Interestingly, the BAS-Reward subscale was unrelated to any of the expectancy measures. Impulsiveness was positively related to the withdrawal, mood, and negative expectancies subscales, along with the BAS-Fun subscale.

9.1 Preliminary analyses

In order to assess the need for hierarchical linear modeling, empty within and between-day models were run with random intercept terms for subject. Dividing the between-subject variance by the total variance yields an ICC of .167 for the within-day model and .437 for the between-day model. This justifies proceeding with HLM, as there is sufficient variance between participants at both the within and between-day level that standard regression will not lead to optimal prediction. Next, each Level 1 predictor was entered into the model as a fixed effect one at a time, first with only the random intercept term for subject and then with a random slope term for each predictor. ANOVA was used to test for improvement of model fit with the addition of each random slope term. At the within-day level, these tests supported the inclusion of random a random slope term for arousal, but not for pleasantness or stress. At the between day level, the inclusion of random slope terms for both work hours and sleep duration was supported.

Table 2: Level 2 Measures Descriptive Statistics and Correlations

Level 2 Measures Descriptive Statistics and Correlations

	M	SD	1	2	3	4	5	6	7	8	9	10
1. Withdrawal Expectancies	2.95	1.06	-									
2. Mood Expectancies	3.76	0.79	.557**	-								
3. Stress Expectancies	3.22	0.88	.488**	.647**	-							
4. Energy Expectancies	4.14	0.74	.579**	.632**	.454**	-						
5. Work Expectancies	4.08	0.88	.515**	.618**	.577**	.704**	-					
6. Negative Expectancies	2.84	0.77	.305**	.299**	.016	.363**	.077	-				
7. BAS-Reward	3.42	0.37	.046	.148	.059	.107	.064	.023	-			
8. BAS-Drive	2.78	0.54	.245**	.175*	.129	.194*	.193*	-.008	.465**	-		
9. BAS-Fun	2.92	0.54	.218**	.278**	.221**	.187*	.135	.165*	.252**	.342**	-	
10. Impulsiveness	2.09	0.34	.169*	.221**	.118	.034	-.033	.306**	.084	.032	.476**	-

9.2 Hypothesis Testing

Hypotheses 1, 2, and 3 dealt with the within-day fixed effects of mood and stress. In other words, the associated models tested whether there was an average within-person effect of these variables on subsequent caffeine consumption. The results for these tests are displayed in Table 3. In the final model, the fixed effect of pleasantness (β = -10.665) was significant, supporting Hypothesis 1. Hypotheses 2 and 3 were not supported, as the fixed effects of stress and arousal were not significant. Hypotheses 1a, 2a, and 3a dealt with the moderating effect of caffeine expectancies on within-person relationships between mood, stress and caffeine consumption. Table 4 shows the results of adding the level 2 moderators to the within-day model. In the final model, only the fixed effect of the level 2 variable stress expectancies (β =16.687) was significant, while all cross-level moderation effects were non-significant. Thus, hypotheses 1a, 2a, and 3a were not supported.

Table 3: Within-day fixed effects models

Caffeine Consumption (mg)

	Model 1		*Model 2*		*Model 3*		*Model 4*	
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Fixed Parts								
(Intercept)	51.20	3.83	51.14	3.83	50.91	3.82	51.14	3.83
Pleasantness	-6.79*	3.35					-10.19*	4.08
Arousal			-6.06	4.91			-0.75	5.39
Stress					-1.48	2.02	-4.35	2.48
Random Parts								
σ^2	7691.299		7696.975		7696.282		7685.118	
$\tau_{00, Sub}$	1581.884		1576.540		1570.834		1576.126	
ICC_{Sub}	0.171		0.170		0.170		0.170	
R^2_{within} / $R^2_{between}$	.09 / .05		.09/.05		.09 / .05		.09 / .05	

Table 4: Within-day cross-level moderation models

	Caffeine Consumption (mg)							
	Model 5		*Model 6*		*Model 7*		*Model 8*	
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
(Intercept)	50.77	3.75	50.99	3.76	50.74	3.62	50.72	3.62
Pleasantness	-10.16*	4.16	-10.32*	4.14	-10.25*	4.14	-10.03*	4.29
Mood Expectancies	14.73*	4.87					-1.52	6.83
Arousal	-0.29	5.42	1.20	6.22	0.66	6.22	0.67	6.61
Stress	-4.43	2.49	-4.28	2.49	-4.22	2.49	-3.80	2.66
Pleasantness*Mood Expectancies	-4.88	4.14					-2.37	4.50
Energy Expectancies			13.81*	5.00			8.31	6.00
Arousal*Energy Expectancies			-7.45	7.82			-6.50	7.96
Stress Expectancies					17.67*	4.04	15.51*	5.20
Stress*Stress Expectancies					0.95	2.21	-0.54	2.47
Random Parts								
σ^2	7701.870		7640.074		7636.879		7607.292	
$\tau_{00, Sub}$	1481.255		1494.590		1367.618		1360.074	
ICC_{Sub}	0.161		0.164		0.152		0.152	
R^2_{within} / $R^2_{between}$	.09 / .10		.10 / .10		.10 / .17		.10 / .18	

Hypotheses 4 and 5 dealt with the between-day fixed effects of workload and sleep duration on daily caffeine consumption. The associated models tested whether there was an average within-person effect of these variables on daily caffeine use. The between-day fixed effects results are shown in Table 5. In the final model, the fixed effect of work hours (β = 8.551) was significant, supporting Hypothesis 4. The fixed effect of sleep duration was not significant, so Hypothesis 5 was not supported. Hypotheses 4a and 5a were concerned with moderating effects of caffeine expectancies on the within-person effects of workload and sleep duration on caffeine use. Table 6 displays the results of adding caffeine expectancies to the between-day fixed effects model. In the final model, both the fixed effect of work expectancies (β =38.354) and the cross-level interaction between work hours and work expectancies (β = 5.280) were significant, supporting Hypothesis 4a. Hypothesis 5a was not supported, as neither the fixed effect of energy expectancies, nor its interaction with sleep duration were significant.

9.3 Exploratory Analyses

Exploratory Hypothesis 6 proposed that the within person effect of stress on daily caffeine use would be dependent upon a participant's workload. This hypothesis was not supported. Hypotheses 7 and 8 proposed that the within person effect of workload on daily caffeine use would be dependent upon sleep duration and impulsiveness, respectively. Neither of these hypotheses were supported. Finally, hypothesis 9 posited a stronger relationship between pleasant mood and subsequent caffeine use among participant scoring high on the BAS-Reward Responsiveness subscale. No significant interaction effect was found, so hypothesis 9 was not supported.

Table 5: Day-level fixed effects models

	Daily Caffeine Consumption (mg)					
	Model 5		*Model 6*		*Model 7*	
	B	*SE*	*B*	*SE*	*B*	*SE*
Fixed Parts						
(Intercept)	179.51	11.97	176.98	12.02	181.29	12.24
Workload	6.66**	2.15			8.55***	2.48
Sleep Duration			-2.46	2.29	-2.06	2.36
Random Parts						
σ^2	23949.054		23976.321		23688.166	
$\tau_{00, Sub}$	16539.819		16207.029		16749.453	
N_{Sub}	130		130		130	
ICC_{Sub}	0.409		0.403		0.414	
Observations	1658		1419		1369	
R^2_{within} / $R^2_{between}$	.00/ .00		.00/.00		.01/.00	

Table 6: Day-level cross-level moderation models

	Daily Caffeine Consumption (mg)					
	Model 8		*Model 9*		*Model 10*	
	B	*SE*	*B*	*SE*	*B*	*SE*
Fixed Parts						
(Intercept)	180.31	11.75	179.98	11.88	180.08	11.74
Workload	9.00***	2.49	8.73***	2.50	8.95***	2.50
Work Expectancies	52.26***	13.16			38.35*	18.41
Sleep Duration	-1.74	2.37	-1.95	2.38	-1.81	2.38
Workload* Work Expectancies	5.30*	2.59			5.28*	2.60
Energy Expectancies			55.64***	15.88	23.71	21.96
Sleep Duration*Energy Expectancies			-1.27	2.91	-0.98	2.91
Random Parts						
σ^2	23659.733		23744.752		23677.365	
$\tau_{00, Sub}$	15025.014		15413.755		14996.728	
ICC_{Sub}	0.388		0.394		0.388	
R^2_{within} / $R^2_{between}$	.01 / .07		.01 / .05		.01 / .07	

9.3.1 Time of Day and Weekend Effects

Mean caffeine consumption between waking and the noon survey was 73.22 mg and decreased throughout the day. Mean caffeine use and mean scores for the mood and stress scales by time of day are displayed in Table 7. Note that mood and stress were measured at the beginning of the time period referenced in the table heading, while caffeine consumption was measured at the end of the time period, except for caffeine use after 8:00 PM which was measured the following morning.

Table 7: Caffeine consumption, mood, and stress by time of day

Caffeine Consumption (mg), Mood, and Stress by Time of Day

		Wake – 12PM	*12PM – 4PM*	*4PM – 8PM*	*After 8 PM*
Caffeine (mg)	M	73.22	65.66	48.65	34.29
	SD	106.71	111.69	97.89	79.85
Pleasantness	M	3.32	3.52	3.53	3.54
	SD	0.57	0.55	0.54	0.55
Arousal	M	2.23	2.39	2.38	2.39
	SD	0.41	0.39	0.39	0.38
Stress	M	2.04	2.04	2.06	2.07
	SD	1.01	1.00	1.00	1.04

One question this study sought to address was whether caffeine consumption was driven primarily by habit or if caffeine users are responsive to psychological states when deciding when to consume caffeine. To address this issue, two models were run, the first to assess the effect of time of day on caffeine use and the second to determine whether the transient psychological states measured throughout the study contributed unique prediction value over the effect of time. These models are displayed in Table 8. Time of day significantly predicted caffeine consumption which tends to decrease throughout the day, and its introduction into the full within-day prediction model nullified the previously significant effect of pleasantness on subsequent caffeine use.

Table 8: Time of day models

	Caffeine Consumption (mg)			
	Model 11		*Model 12*	
	B	*SE*	*B*	*SE*
Fixed Parts				
(Intercept)	78.86	4.31	75.46	4.19
Time of Day	-14.15***	1.20	-15.17***	1.31
Pleasantness			-3.09	4.55
Mood Expectancies			-1.27	6.74
Arousal			8.14	6.81
Energy Expectancies			8.60	5.93
Stress			-0.99	2.69
Stress Expectancies			15.02**	5.16
Pleasantness*Mood Expectancies			-3.78	4.68
Arousal*Energy Expectancies			-7.93	7.99
Stress*Stress Expectancies			-1.06	2.51
Random Parts				
σ^2	8225.710		7335.628	
$\tau_{00, Sub}$	1670.566		1351.191	
ICC_{Sub}	0.169		0.156	
R^2_{within} / $R^2_{between}$	.03 / .00		.13 / .19	

Similar questions were addressed with regards to caffeine consumption on weekdays versus weekends and the relative contributions of sleep and workload versus day of the week. Means for daily caffeine consumption, workload, and sleep duration on weekdays and weekends are shown in Table 9.

Table 9: Caffeine consumption, workload, and sleep on weekdays and weekends

Daily Caffeine Consumption, Workload, and Sleep Duration on Weekdays and Weekends

		Weekdays	Weekends
Caffeine Consumption (mg)	M	183.73	152.38
	SD	205.36	185.65
Workload (hours)	M	4.47	2.83
	SD	3.81	3.07
Sleep Duration (hours)	M	6.58	7.69
	SD	2.11	2.15

Weekends were associated with a significant decrease in caffeine consumption (β = -32.64) when considered in isolation, however when the weekend variable was introduced into the full between-day model, the impact of day of the week was reduced to non-significance. However, the fixed effects of workload and work expectancies along with the interaction between the two remained significant. These results are displayed in Table 10.

Table 10: Weekday vs weekend models

Daily Caffeine Consumption (mg)

	Model 13		*Model 14*	
	B	*SE*	*B*	*SE*
Fixed Parts				
(Intercept)	183.26	12.00	184.59	12.01
Weekend	-32.64***	8.21	-18.70	10.25
Workload			8.23**	2.53
Work Expectancies			38.35*	18.42
Sleep Duration			-0.71	2.45
Energy Expectancies			23.38	21.98
Workload*Work Expectancies			5.37*	2.59
Sleep Duration*Energy Expectancies			-1.04	2.90
Random Parts				
σ^2	23730.146		23630.067	
$\tau_{00, Sub}$	16192.659		15019.952	
ICC_{Sub}	0.406		0.389	
R^2_{within} / $R^2_{between}$	.01 / .00		.01 / .07	

9.3.2 Expectancy Effects

While caffeine expectancies were conceptualized as moderators of the within-person relationships between psychological states and situations and caffeine use for the primary hypotheses, their independent effects on between-person typical caffeine use were also assessed. Significant and positive effects were observed for all but the negative expectancies subscale. Withdrawal expectancies was the strongest predictor, accounting for 23% of the variance in between-person caffeine use. The results of these analyses are displayed in Table 11.

9.3.3 Effect of Typical Caffeine Consumption

The distribution of caffeine consumption as measured at each time point in this study was highly positively skewed. One contributing factor to this departure from normality is the high number of zeros observed at a given time point, likely due to the frequency with which caffeine consumption was measured. However, another possibility is that there are distinct groups of caffeine users who display different patterns of caffeine use in daily life. In order to assess this possibility, reported caffeine consumption across all time points was averaged for each participant and participants were split into high, moderate, and low consumptions groups. This was accomplished by observing the cumulative percentage of participants reporting a particular level of typical caffeine consumption and splitting the groups at the 33^{rd} and 66^{th} percentiles, the results of which are displayed in Table 12. User group was then examined as a moderator of the within-person relationships hypothesized at both the within and between-day levels. At the within-day level, the results showed that user group significantly moderated the relationship between pleasant mood and subsequent caffeine consumption such that participants with higher typical caffeine consumption demonstrated a stronger negative relationship between pleasant mood and subsequent caffeine consumption (β = -10.34, $p < .05$).

Table 11: Direct expectancy effects

	Model 15		*Model 16*		*Model 17*		*Model 18*		*Model 19*		*Model 20*	
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Fixed Parts												
(Intercept)	54.81	3.72	55.15	3.75	54.82	3.56	55.18	3.67	55.49	3.88	53.78	3.45
Mood Expectancies	16.95***	4.84										
Energy Expectancies			15.58**	5.02								
Stress Expectancies					19.80***	3.97						
Work Expectancies							16.28***	4.12				
Negative Expectancies									3.30	5.10		
Withdrawal Expectancies											19.03***	3.21
Random Parts												
σ^2	8476.767		8477.101		8475.321		8476.202		8477.305		8476.920	
$\tau_{00, Sub}$	1525.787		1557.677		1387.672		1488.118		1686.767		1274.685	
ICC_{Sub}	0.153		0.155		0.141		0.149		0.166		0.131	
R^2_{Within} / $R^2_{Between}$	.00 / .08		.00 / .06		.00 / .16		.00 / .10		.00 / .00		.00 / .23	

Table 12: Mean caffeine consumption by user group

Mean Caffeine Consumption by User Group

		Low	Moderate	High
Caffeine Consumption (mg)	M	16.36	48.65	103.02
	SD	8.61	10.53	42.93
	N	43	44	43

CHAPTER 10: Discussion

This study examined caffeine use in the daily lives of college students, using intensive longitudinal methods to assess factors that contribute to within and between-person variability in caffeine use. One of the overarching questions driving this investigation was whether or not individuals use caffeine strategically in response to psychological and situational characteristics that may impact their ability to perform daily tasks. The results of this study provide some support for this hypothesis by showing a pattern of consumption that would be consistent with the strategic use of caffeine for mood repair during the day. It was also observed that participants in this study tended to consume more caffeine on days when they had a higher workload. This suggests that students may use caffeine as a tool to help them complete their work on days when they have a greater than typical workload.

Previous research on the relationship between caffeine use and mood has demonstrated that caffeine in doses that would be realistic for the average consumer reliably improves mood, especially on dimensions related to alertness. Given these findings, it seems reasonable that a strategic caffeine user might choose to seek out caffeine when experiencing an unpleasant mood. However, extant daily diary studies have failed to produce reliable findings on the existence of this caffeine use pattern. This study corrected for some of the methodological issues of previous studies in order to conduct a more appropriate test of this phenomenon. The results showed that, on average, individuals consumed more caffeine during the few hours following an unpleasant mood than following a relatively pleasant mood (10 mg for each unit increase in pleasant mood). Surprisingly, no such effect was found for the arousal dimension of mood. This runs counter to what was expected given the relatively larger impact of caffeine on arousal over its effect on more global measures of mood. One possible explanation for the failure to observe an effect of arousal on subsequent caffeine use could be that low arousal does not create as strong a desire for mood change as an unpleasant mood. In this case individuals might be less likely to seek out caffeine when experiencing low arousal than when their mood is actually experienced as unpleasant. It is also noteworthy that despite the measures taken to improve the internal consistency of the arousal subscale, it remained relatively low and this measurement issue could have played a role. Another possible explanation could be the measurement protocol for this study's morning surveys. Unlike the other surveys which were required participants to respond within 30 minutes of a scheduled alert, morning surveys were to be initiated by the participants upon waking. While only morning surveys completed within one hour of self-reported wake time were retained for analysis, those participants who did not report immediately after waking could have experienced substantial shifts in arousal or even consumed their first caffeine of the day before completing their first survey, leading to an underestimation of the effect of arousal on subsequent caffeine consumption. Momentary stress was also not found to be significant predictor of subsequent caffeine use. This is less surprising as caffeine has been found in several studies to mimic the physiological stress response. Thus, it may not generally be helpful to increase caffeine consumption during times of elevated stress. This finding does run counter to previous research which suggests that many caffeine users find caffeine useful for dealing with stress. It seems plausible, however, that this sentiment may relate more directly to workload as a source of stress rather than to the psychological symptoms of stress. Exploratory analysis of the interactive effect of workload and stress on daily caffeine use revealed a trend in the expected direction, but the effect did not reach significance.

The results of this study support the findings of extant research demonstrating a within-person relationship between workload and caffeine use. For each additional hour of work performed per day, participants consumed an average of 9mg more caffeine. This finding supports a pattern of caffeine use wherein participants use caffeine to facilitate work performance on days when they have a greater than normal workload. Additionally, it was found that the strength of this relationship was stronger for participants who had greater expectancies of enhanced/extended work abilities after caffeine use. In this case, situation-dependent use of caffeine was dependent upon participants' pre-existing attitudes about caffeine. Surprisingly, daily caffeine use was unrelated to particpants' sleep duration on the previous night. This runs counter to previous findings which have demonstrated a reliable relationship between sleep duration and caffeine use. One possible explanation for this finding was that sleep-duration, per se, was not the important factor but the combination of poor sleep and heavy workload, however this interaction was found to be non-significant. Previous findings of a relationship between sleep duration and caffeine use have relied on cross-sectional studies, limiting the researchers' ability to interpret the relationship. This study specifically tested whether the previous night's sleep duration affected caffeine use on the following day. Given the n findings here, future research should explore whether the relationship demonstrated in cross-sectional research is primarily driven by sleep disturbance following heavy caffeine consumption or caffeine use late in the day.

Caffeine expectancies reflect participant's pre-existing attitudes regarding the effects and utility of caffeine use. In this study, they were tested as moderators of the within-person relationships of primary interest. While only the effect of workload was shown to be moderate by caffeine expectancies, the relationships between caffeine expectancies and typical caffeine use explained one quarter of the between-person variance. All but the negative expectancies scale significantly and positively predicted typical caffeine consumption, with the withdrawal expectancies scale accounting for nearly all of the unique variance (23%). These results suggest although caffeine use does vary within-persons depending upon psychological states and situational characteristics, caffeine use may be largely driven by habit and physiological dependence. Furthermore, the significant effect of energy expectancies and stress expectancies on typical caffeine use, despite the lack of significant within-person prediction by stress, arousal or sleep duration suggest that positive attitudes regarding the utility of caffeine may drive caffeine use regardless of their relevance to an individual's current psychological state or situation.

Participants in this study were found to consume more caffeine earlier in the day and on weekdays as opposed to weekends. It is noteworthy that mood did not account for significant within-person variance in caffeine consumption when time of day was accounted for. Interpreting this finding is not entirely straight-forward. On one hand, it might be seen as diminishing the importance of mood as a factor that drives caffeine consumption in daily life. However, it should be noted that time, per se, is not typically a driving factor for psychological or behavioral phenomena. Rather, the more important question is what changes with time. To the degree that both mood and caffeine use tend to covary with time, it seems reasonable to suggest that variability in mood is more likely the driving factor behind caffeine use. The results of this study simply suggest that this variability is somewhat predictable across individuals.

This study also demonstrated a stronger negative relationship between pleasant mood and subsequent caffeine use among participants with higher typical caffeine use. Although no explicit hypotheses were proposed regarding this moderation effect, the direction of this effect was somewhat surprising. It was initially expected that high caffeine consumers, whose caffeine use might be more habit driven, would be less likely to demonstrate a strategic pattern of caffeine use for the purposes of mood repair. However, there is an alternative explanation which retains the proposition that caffeine consumption among high caffeine users is more compulsive than strategic, but still accounts for this result. A decline in the subjective sense of well-being and contentedness, and in overall mood are all commonly observed symptoms of acute caffeine withdrawal and that these symptoms are more severe when a person's typical caffeine use is higher (Juliano & Griffiths, 2004). In this sense, the tendency of those with higher typical levels of caffeine consumption to use caffeine for mood repair more frequently than others can be seen as rational or strategic, given their greater likelihood to experience mood-related withdrawal symptoms. However, in this case the effectiveness of this strategy would be contingent upon their pre-existing caffeine dependence and one could question whether their caffeine use is primarily a cause or a cure of depressed mood.

By examining the psychological and situational predictors of caffeine consumption, this study employed a rational framework for understanding the phenomenon of caffeine use as it relates to daily experience. Taken together, the findings suggest that caffeine users do, to some degree, use caffeine as a tool to modulate mood and performance in response to transient events in their daily lives. However, habit strength and pre-existing expectations about the utility of caffeine also explained substantial variability in caffeine use, regardless of situation. This suggests that caffeine users' implicit or explicit policies around caffeine use are only partly aligned with scientific evidence on the effects and utility of caffeine. Although caffeine users may view caffeine as a tool for managing psychological states and performance, its habit forming properties along with individuals' habituation to caffeine's effects have the potential to reduce the utility of caffeine use and drive users to habitual, rather than strategic, consumption.

Individuals seeking to maximize the utility of caffeine might seek to limit their use to situations when it is likely to be of help, like when increased alertness is required. By revealing some of the situations in which individuals are likely to seek out caffeine, this study provides researchers a basis for exploring and suggesting alternatives to caffeine use (e.g., naps, exercise, meditation) that can achieve similar results. Finally, the results of this study may also provide some useful insights related to cognitive enhancement. The non-medical use of powerful prescription stimulants like Ritalin and Adderall for the purpose of increasing one's capacity to learn or work over extended periods of time is a growing trend, particularly among college students (Mccabe, Knight, Teter, & Wechsler, 2005). This raises important questions for academic institutions and policy makers around issues of fairness and innovation in education. Currently, there are harsh legal penalties for the non-sanctioned use of these drugs (Greely et al., 2008);

however, as the availability of and demand for cognitive enhancement drugs increases academic officials and legislators will need to articulate clear and reasonable justifications for policies related to their use. As a relatively mild and unregulated stimulant that is used widely in academic and employment settings, caffeine provides a useful standard against which the ethics surrounding cognitive enhancement might be measured. This study revealed that university students may use caffeine as a tool to facilitate their academic performance. In this regard, the introduction of more powerful stimulants that enable enhanced or extended performance capabilities is a difference of degree rather than a qualitative change to the ethical landscape of academic performance. However, the tendency of caffeine users towards habitual consumption behavior may have different implications for the future of cognitive enhancement.

Notwithstanding new developments, regular caffeine use seems to have few adverse effects on physical or psychological health. This may not be true for the more powerful stimulants which are increasingly used in high pressure performance environments. This study's findings suggest that caffeine users are only moderately capable of limiting their consumption to situations where it has demonstrated utility. If the same is true of these more powerful drugs, the development of habitual use patterns may not be so benign.

While this study makes substantial contributions to the understanding of caffeine use as a behavior in the context of daily life, it has several limitations inherent to its design. First, inferences about the caffeine content of beverages based on their category (e.g., brewed coffee, espresso, black tea) are imprecise. Whether prepared at home or purchased from popular chain stores, caffeinated beverages vary substantially in caffeine content even when prepared using the same methods (Bracken et al., 2016; McCusker, Goldberger, & Cone, 2003). This study also did not control for participants' body weight in measuring their caffeine consumption, unlike many experimental studies which do so in order to obtain a standardized estimate of the effective dose. Difficulties in the measurement of caffeine consumption limit both the ability of researchers to accurately measure caffeine use from self-reports and the ability of caffeine users to modulate their caffeine use with precision. Though it is currently difficult to imagine a feasible procedure for measuring caffeine via assays while retaining the advantages of the ESM method, if future technology were to enable easily administered and transmittable mobile assays, it would be a significant development in caffeine research. Several limitations also arise from the measurement protocol employed for the morning surveys in this study. Because participants determined the timing of the morning survey, it was not possible to positively verify their compliance with the instructions to begin the survey upon waking. This also meant that the timing of the morning survey varied both within and between subjects, meaning the interval for which caffeine consumption was measured during the noon survey was not constant, as it was for the other daily surveys. The morning survey was also not signaled and this likely led to substantially more missing data than was present for the remaining daily surveys. Future ESM studies regarding caffeine use behavior would benefit greatly from developing some method of promptly signaling participants to complete their first survey after waking. One possibility is the use of activity monitors to trigger a survey when the participant awakes.

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