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The effects of food deprivation on caffeine and food reinforcement in females

Lauren Baillie
Louisiana State University and Agricultural and Mechanical College

THE EFFECTS OF FOOD DEPRIVATION ON CAFFEINE AND FOOD REINFORCEMENT IN FEMALES

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Lauren Baillie
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Abstract

This study examined the reinforcing value of caffeine and food in a sample of 14 normal-weight females who indicated some degree of dietary restraint, and consumed caffeine daily. Eligible individuals participated in two sessions, one of which required a 24-hour fast. During both sessions, participants completed measures assessing caffeine withdrawal symptoms, urge to drink caffeine, hunger, and a multiple-choice questionnaire (MCQ) requiring them to earn points towards either snack foods or caffeinated beverages. There were no significant differences between the fasting and non-fasting conditions on MCQ scores, though the means were in the predicted direction (i.e., participants appeared to work harder for caffeine in the fasting session than in the non-fasting one). Between group differences were analyzed to determine if smokers worked harder for caffeine than non-smokers on the MCQ. Again, no significant differences were found, but means were in the predicted direction (i.e., smokers worked harder than non-smokers in both conditions). Predicted correlations were not found (a) between withdrawal symptoms and urge to consume caffeine; (b) between dietary restraint and MCQ scores; or (c) between dietary restraint and amount of daily caffeine consumption. Results were likely affected by limited power from the small sample size.

Introduction

Food deprivation has widely documented effects on both animal and human behavior regarding efforts to obtain and consume food or other substances. In general, animal research has consistently found that animals will work harder to obtain substances after having abstained from food for prolonged periods of time. Carroll and Meisch (1978) found that etonitazene intake in food-deprived rats increased by over 100%, and increased as the food-deprivation period continued over the next two weeks. Similarly, food deprivation has been shown to make oral phencyclidine (Carroll, 1982; Rodefer, DeRoche, Lynch, & Carroll, 1996) and ethanol intake more reinforcing (Rodefer et al.) and increase cocaine self-administration (Comer, Turner & Carroll, 1995) in rhesus monkeys.

Despite such strong evidence of the food deprivation effect in animals, studies on human food deprivation have been fewer in number and their findings have been inconsistent. In one study on fasting and cigarette smoking, it was hypothesized that participants would smoke more cigarettes during a 24 hour food deprivation period than they would when allowed to eat normally (Zacny & De Wit, 1990). This hypothesis was based on the robust findings that animals more readily self-administer substances when food-deprived than when sated, and that smoking may alleviate the stress caused by food deprivation and suppress hunger urges. Surprisingly, though carbon monoxide levels were higher among participants in the fasting condition, the study revealed no effect of fasting on the number of cigarettes smoked.

In another study that investigated the relationship between food deprivation and the reinforcing properties of cigarette smoking, as well as food, Bulik and Brinded (1993) compared women diagnosed with bulimia nervosa to women without an eating disorder. Like Zacny and De Wit (1990), they hypothesized that participants would work harder for both food and cigarettes when fasting than when allowed to eat normally, and that this food-deprivation effect would be stronger in the women with Bulimia Nervosa (BN). However, results showed no difference between groups or feeding condition in regards to points earned for food, attempts made for food, and percentage of time working for food. There were also no effects of feeding condition on points earned for cigarettes, attempts made for cigarettes, and percentage of time working for cigarettes. In contrast to the original hypothesis, bulimic women spent significantly more time working for cigarettes in the non-deprived condition than in the fasting condition (Bulick & Brinded, 1993).

The studies described above demonstrate the lack of cohesion among human food-deprivation studies, as well as the discrepancies with the animal deprivation literature. On some levels, it is not surprising that there are differences between substance intake in humans and animals during fasting periods, since the nature of substance use is different between humans and animals (Lawson, Bulik, Rodefer, Scanlon & Borger, 1995). Psychosocial factors influence human drug use in any given circumstance, while this is not the case for animals. Additionally, studies on human food-deprivation usually involve acute fasting periods as opposed to chronic fasting periods, which are much easier to implement in animals. It is quite possible that the acute food-deprivation conditions used in human studies are not readily comparable to the chronic food-deprivation conditions frequently utilized in animal research (Lawson et al., 1995).

Though the findings in human deprivation studies have not mirrored those of animal studies, it does not mean that effects of food-deprivation are unimportant. Individuals with eating disorders or who diet are accustomed to chronic deprivation, which has permanent physical consequences that affect the reinforcing value of food and drugs. Dopamine is believed to mediate the reinforcing values of food and drugs (Pothos, Hernandez, & Hoebel, 1995) and is responsible for providing motivation to find food and eat it (Epstein, & Leddy, 2006). Weight loss that results from these states of chronic food deprivation leads to a decrease in basal extracellular dopamine levels in the nucleus accumbens, and these levels do not return to normal even after weight is regained. Pothos et al. (1995) suggest that individuals who are underweight may increase their intake of reinforcing substances in an attempt to increase dopamine to normal levels, or because their dopamine receptors are more sensitive, enhancing the reinforcing effects of substances. Therefore, it is important to gain greater insight into the relationship between food-deprivation and commonly used substances that have been shown to be highly reinforcing.

Reinforcing Value of Food

Motivation to eat may be objectively measured by assessing how reinforcing certain foods are to an individual, and can be measured by using food as the only option, or by providing different alternatives in a concurrent schedule of reinforcement (Epstein, & Leddy, 2006). Generally speaking, individuals find food more reinforcing during periods of food-deprivation and when they experience the food as tasting good. Additionally, food reinforcement value decreases as the amount of work required to obtain food increases, or other reinforcing choices are made available (Epstein, & Leddy, 2006).

It is important to consider another factor that interacts on some level with food reinforcement to influence eating. Hedonics, which refers to liking a food, is a more subjective way to predict food intake (Epstein, & Leddy, 2006; Epstein, Truesdale, Wojick, Paluch, & Raynor, 2003). Hedonics and the motivation to eat may work together initially, as eating behaviors develop, since an individual will be motivated to eat something that is palatable, but that relationship eventually disintegrates with repeated experiences consuming the food. Epstein et al. (2003) found no correlation between the reinforcing effects of food and hedonic ratings. Additionally, research has shown that measures of food reinforcement (how hard an individual will work to obtain food in certain conditions) are better predictors of snack food consumption

(Epstein, & Leddy, 2006) and of food consumption in smokers (Epstein et al., 2004) than hedonic ratings.

Other factors, such as obesity, affect the reinforcing value of food in individuals. Saelens and Epstein (1996) demonstrated that obese participants found eating snack food more reinforcing than other activities, such as playing computer games. This was evident both in regards to attempts made to obtain food and actual calories consumed. These results indicate that if alternative activities are available that are more reinforcing than eating, caloric consumption may be reduced (Saelens, & Epstein, 1996). This implication is significant, since obese people tend to find food more reinforcing than non-obese individuals (Epstein, & Leddy, 2006).

Reinforcing Value of Caffeine

Caffeine is the most commonly used psychoactive stimulant drug (Nehlig, Daval & Debry, 1992). It is an adensonine antagonist that enhances the brain's energy metabolism while diminishing blood flow in the brain (Nehlig, Daval, & Debry, 1992). The adensonine receptors on which caffeine acts, such as A_1 and A_{2A} receptors, counteract the effects of nearby dopamine receptors. Therefore, caffeine's action on the adensonine receptors results in an increase of dopamine release (National Institute of Neurological Disorders and Stroke, 2005). As Epstein et al. (2003) explains, food reinforcement is related to the dopaminergic system. When dopamine release is blocked, the reinforcing value of food is decreased. Based on this information, it seems likely that caffeine ingestion has direct effects on how much an individual will work to obtain food.

There is strong evidence to suggest that caffeine withdrawal, or a caffeine abstinence syndrome, occurs when regular consumers are deprived. Commonly reported symptoms include headaches, fatigue, decreased alertness, and sluggishness (Comer, Haney, Foltin, & Fischman, 1997; Mitchell, De Wit, & Zacny, 1994). A questionnaire survey of women revealed that moderate and heavy caffeine users experienced a variety of negative symptoms, such as headache, irritability, nervousness, restlessness, lethargy and decreased ability to work effectively, if they did not drink their morning coffee (Goldstein & Kaizer, 1969). In a comprehensive review of the literature on caffeine abstinence and withdrawal, Juliano and Griffiths (2004) identify ten symptoms that can serve as valid criteria for indicating caffeine withdrawal: headache, tiredness/fatigue, decreased energy/activeness, decreased alertness/attentiveness, drowsiness/sleepiness, decreased contentedness/well-being, depressed mood, difficulty concentrating, irritability, and muzzy/foggy/not clearheaded. There are additional symptoms that have been documented, but not as consistently as those mentioned above. These may be potential indicators of withdrawal and include flu-like symptoms, nausea/vomiting, and muscle pain/stiffness (Juliano & Griffiths, 2004).

Caffeine withdrawal symptoms usually appear 12 to 24 hours after abstinence has begun. Withdrawal can last anywhere from two to nine days, and symptom intensity is related to the size of the dose that is chronically ingested (Juliano & Griffiths, 2004). Caffeine consumption over a limited period of time (three to seven days) and at minimal doses can still lead to withdrawal symptoms (Juliano & Griffiths, 2004). Consuming caffeine can reverse the unpleasant withdrawal symptoms (Juliano & Griffiths, 2004). This is supported by the findings of Mitchell, De Wit, and Zacny (1994), which show that scores of subjective withdrawal measures among participants that were partially deprived of caffeine and those that were not deprived were not significantly different. These results suggest that doses of caffeine that are smaller than the normal amount consumed can be sufficient enough to eliminate withdrawal.

<u>Negative Reinforcement</u>. The fact that caffeine consumption reverses the effects of withdrawal suggest that a large aspect of caffeine's reinforcing value is prevention of these negative symptoms (Juliano & Griffiths, 2004). In a study with groups of caffeine

tolerant/dependent and nontolerant/nondependent individuals, those that were not caffeine-dependent did not prefer caffeinated beverages, but in some cases preferred decaffeinated ones, or reported unpleasant symptoms when they consumed caffeinated drinks. Additionally, those who were caffeine-dependent showed decrease in liking for decaffeinated coffee during the first two days of withdrawal, and then gradually increased to pre-withdrawal levels (Griffiths, Bieglow, & Liebson, 1986). This suggests that caffeine is reinforcing simply by alleviating the unpleasant symptoms associated with withdrawal. Further support of this comes from a study by Tinley, Yeomans, and Durlach (2003), which found that individuals acutely deprived of caffeine only increased pleasure ratings for the taste of caffeinated tea, whereas participants who had been chronically withdrawn eventually found caffeinated tea increasingly unpleasant. This extends the findings of Griffiths et al. (1986) to suggest that caffeine does not have as many positively reinforcing components as it does negatively reinforcing aspects.

One way of experimentally differentiating the positively reinforcing components from the negatively reinforcing components is to use a multiple-choice procedure, in which participants choose between receiving a drug and receiving different amounts of money. Using this technique to determine how much money moderate caffeine users would sacrifice for caffeine, researchers found caffeine was not worth an amount that was significantly different from $0.00, but that participants would forfeit an amount significantly different from $0.00 in order not to receive the placebo (and instead receive caffeine). Those who received the placebo reported unpleasant symptoms, such as headaches and feeling worn out, and those who had more headaches and felt less alert were willing to sacrifice more money in order to avoid the placebo (Schuh, & Griffiths, 1997). Based on these results, the authors conclude that caffeine consumption is motivated more by desire to avoid negative effects of withdrawal than by the positive effects of caffeine.

Positive Reinforcement. Still, a significant amount of evidence suggests that caffeine does have acute positive effects that encourage intake. As a questionnaire study revealed, both heavy and light coffee drinkers reported having coffee in the morning because of its pleasant taste and its stimulating effects. Heavy drinkers, however, were more likely to report these reasons than were light coffee drinkers (Goldstein & Kaizer, 1969). Furthermore, more heavy coffee drinkers emphasized the increased sense of well-being associated with coffee drinking, and more frequently acknowledged that coffee drinking in the morning is a habit (Goldstein & Kaizer, 1969). While both heavy and light coffee drinkers cited that coffee increased alertness and activity, the heavy drinkers reported this more frequently (Goldstein & Kaizer, 1969). Given that users can identify several positive effects associated with coffee drinking, it appears that relief of withdrawal symptoms is not the only factor which influences caffeine use.

Further evidence to support these findings comes from a double- blind study by Griffiths & Woodson (1988) that used caffeine capsules, as opposed to coffee, to differentiate the effects of caffeine from coffee among caffeine users. After taking capsules with 100 mg and 200 mg of caffeine, participants indicated that they preferred caffeine capsules when given a choice between caffeine capsules and placebo capsules. These results are of particular significance since the participants were not experiencing withdrawal, indicating that they experienced positive effects when they took the caffeine pill. Similarly, another study found that caffeine deprived and non-deprived individuals picked caffeine over a placebo in 80% of choice trials (Evans, Critchfield, & Griffiths, 1994). The latter study involved caffeine-dependent participants and did not assess for withdrawal, so it is not clear if those that received the placebo chose caffeine to alleviate withdrawal symptoms. However, the authors point to an experiment by Silverman, Mumford, and Griffiths (1994), in which participants were not caffeine-dependent and still picked caffeine instead of a placebo when completing a vigilance task. Results from these studies suggest that on some level, caffeine does positively reinforce users, but it seems that caffeine may be more reinforcing to individuals who are caffeine-dependent and are experiencing a period of caffeine abstinence (Evans et al., 1994).

In addition to looking at the effects of caffeine as found in beverages and capsules, other research has examined the reinforcing value of caffeine as found in other dietary sources, such as chocolate. Caffeine and theobromine are methylxanthines that are found in chocolate (Smit & Blackburn, 2005). When these compounds were paired in quantities normally found in a chocolate bar with a non-caffeinated beverage, participants liking of the drink increased. Though the effects of theobromine and caffeine were not studied separately, the authors explain that the reinforcing effects of caffeine have been established at much lower doses than used in this case, and that the reinforcing value of theobromine is very low. Therefore, these results suggest that methylxanthines, such as caffeine, affect liking for chocolate beyond chocolate's innate appeal (Smit & Blackburn, 2005).

Though there is evidence that indicates caffeine is positively reinforcing, this effect has not been shown as clearly as the negatively reinforcing effects. This is possibly because traditional mood surveys and performance evaluations do not capture specific pleasant physiological or psychological effects associated with caffeine use (Smit et al., 2006). A plausible explanation is continued consumption of a caffeine product eventually results in more rapid onset and lasting duration of mood effects, which would increase caffeine's reinforcing value (Smit et al., 2006). Given the lack of clarity on the different aspects of caffeine reinforcement in humans, more research in this area is needed.

Caffeine and Eating Disorders

The relationship between food and caffeine is a topic of research. After a period of caffeine withdrawal, upon re-administration, participants have been reported to consume fewer calories than when they were not drinking caffeine, with caloric intake decreasing from 2,558 kcal to 2,253 kcal (Comer et al., 1997).

There is an important relationship between caffeine use and disordered eating habits. In a sample of inpatient eating disordered patients, Haug, Heinberg and Guarda (2001) found that 85% reported having used caffeine at some point in the last month. Additionally, 35% described consuming four or more caffeinated beverages or drugs daily for the past six months. Patients who smoked consumed significantly more caffeine than non-smokers (Haug, Heinberg & Guarda, 2001). Reports indicate that women diagnosed with Anorexia Nervosa (AN) increase caffeine intake from soda throughout the course of their disorder. Before the onset of their disorder, approximately 25% of consumed caffeine came from soda. This percentage increased to 54% at the onset to 65% following the onset year. Caffeine intake from chocolate reportedly decreases drastically (Striegel-Moore et al., 2006). The same study also found that females with Bulimia Nervosa also increase their consumption of caffeine throughout the course of their eating disorder, though effects for specific time intervals were not significant (Striegel-Moore et al., 2006). This is consistent with clinical accounts of bulimics who purposely increased caffeine consumption, ranging from 910 mg to 2320 mg a day (Fahy & Treasure, 1991), compared with 1200 mg per day in individuals treated for caffeine dependency (Foxx & Rubinoff, 1979).

Bulik et al. (1992) surveyed inpatient anorexic and bulimic women regarding eating habits, and found that coffee and tea consumption was similar, but that bulimic women drank more caffeinated soda and spent more money per week on caffeinated drinks. Of eating disordered adolescents surveyed, 35% of those with purging habits consumed more than five caffeinated drinks a day. Those with restrictive eating behaviors also consumed a high number of caffeinated drinks (Sock, Goldberg, Corbett, & Katzman, 2002). Similarly, Haug, Heinberg and

Guarda (2000) found that anorexic patients falling under the purge subtype drank more caffeinated drinks daily than restrictive anorexics.

Caffeine and Food Deprivation

As is true of the general literature on substance administration during food deprivation periods in humans, the studies that focus specifically on caffeine reinforcement during periods of food deprivation have not yielded consistent results. Bulik, Brinded, and Lawson (1995) examined bulimic and healthy control women under food deprivation conditions. Results indicated that participants in both groups worked harder to obtain coffee during acute food deprivation periods than during non-deprived periods. The only significant difference between the bulimic and control participants was that bulimic women consumed twice as much coffee as control women. Another study using similar methodology found no significant differences in the amount of coffee consumed among women who ate normally, ate three half meals in a day, and those who ate only one meal a day (Lawson et al, 1995). Given the relationship between caffeine use and eating disorders, which are often characterized by acute and/or chronic periods of food deprivation, it is necessary to further explore caffeine use in these situations.

Caffeine and Smoking

It is fairly well established that individuals who smoke consume more caffeine than non-smokers. One review of epidemiological studies found that coffee consumption in smokers and non-smokers was significantly different, with 86.4% of smokers consuming coffee compared to 77.2% of non-smokers reporting coffee consumption (Swanson, Lee & Hopp, 1994). Additionally, increases in coffee consumption were associated with smoking increases, a pattern which applied to both males and females (Swanson et al., 1994). In a study comparing ever-smoking (current smokers or ex-smokers) and never-smoking same-sex sibling pairs, researchers found that ever-smokers consumed 357.8 mg/day, compared to their never-smoking counterparts who ingested 172.6 mg/day (Pomerleau, Pomerleau, Snecdecor, Gaulrapp, & Kardia, 2004), a statistically significant difference. Epidemiology estimates of simultaneous use of caffeine and cigarettes, however, may be low, as many studies do not examine caffeine intake from dietary sources other than coffee (Klesges, Ray, & Klesges, 1994).

In an effort to examine the potential differences in smoking and caffeine intake from different sources, Klesges et al. (1994) compared smokers who primarily consumed caffeine from tea to smokers who mainly consumed coffee. Results indicated that smokers were more likely to consume caffeine from coffee as opposed to tea. Among smokers in both groups, it was found that caffeine intake was highest among heavy smokers and lowest among never-smokers, and that heavy caffeine consumers smoked more than moderate or light smokers, recent ex-smokers, long term ex-smokers, and never-smokers. Within the group of coffee drinkers, a dose-response relationship was observed, with heavy smokers drinking double the amount of coffee as never-smokers, and recent ex-smokers drinking less coffee than heavy smokers, but more than non-smokers. These results suggest that the source of caffeine moderates the relationship between caffeine intake and smoking, as smokers are no more likely to drink tea than non-smokers, but are more likely to drink coffee. Coffee-drinking, in turn, has a consistent relationship with smoking status. Though this study was based on data gathered between 1976 and 1980, when caffeine consumption in the United States tended to be higher, and caffeinated soda was not as popular as it currently is, the results still emphasize the consistent relationship between caffeine consumption and smoking, as well as the need to consider multiple sources of caffeine when considering this relationship (Klesges et al., 1994).

<u>Pharmacological Effects</u>. It has been consistently found that nicotine increases the metabolism of caffeine, thereby decreasing its half-life (Swanson, Lee & Hopp, 1994). Since the property of cigarettes results in caffeine being metabolized more quickly, it is plausible that

smokers must consume more caffeine than non-smokers in order to get the same effects for the same amount of time (Klesges et al., 1994). In a study of caffeine plasma levels in a sample of smokers and non-smokers, since the property of smoking seems to produce a caffeine-metabolizing enzyme, it was expected that non-smokers would have higher plasma levels than smokers (de Leon et al., 2003). Though smokers did consume more coffee than non-smokers, when amount of caffeine consumption was controlled, non-smokers did have significantly higher caffeine plasma levels (de Leon et al, 2003). This evidence serves as additional support for the hypothesis that the components of cigarettes result in the quicker metabolism of caffeine.

Caffeine and Subjective Effects of Nicotine. The literature on the relationship between smoking and caffeine suggests that sensitivity to the subjective effects of nicotine is associated with sensitivity to caffeine, and that sensitivity to one may possibly predict sensitivity to the other (Perkins, Fonte, Ashcom, Broge & Wilson, 2001). Furthermore, there is also evidence that caffeine may enhance the subjective ratings of the effects of nicotine. Jones and Griffiths (2003) found that smokers (who also used cocaine regularly) who were maintained on oral doses of caffeine for twelve days and then intravenously administered nicotine were more likely to report enhanced positive effects and decreased negative effects of nicotine, than during a period of caffeine abstinence. In addition, when participants were caffeine-maintained they indicated that they were willing to pay significantly more money to receive a high dose of nicotine than when they were not caffeine-maintained. These effects, however, were not observed when participants were administered a lower or higher dose of nicotine. Another study failed to find any significant interactions of caffeine and nicotine on subjective effects ratings of nicotine (Perkins, Fonte, Stolinski, Blakesley-Ball, & Wilson, 2005).

Caffeine and Behavioral Effects of Nicotine. It has been suggested that, for individuals who smoke and consume caffeine regularly, one behavior may serve as a cue for the other behavior (Swanson et al., 1994). Another possibility is that external events, such as breaks during the workday, connect the self-administration habits of these substances (Tanda & Goldberg, 2000). However, at this point, the research has provided little, if any, support for either theory. Lane and Rose (1995) found no difference in the number of cigarettes smoked, expired carbon monoxide, or cotinine concentration in smokers maintained at caffeine doses of 100 mg and 500 mg. Another study found that rats that were chronically maintained on caffeine did not demonstrate nicotine self-administration habits different from rats that were not caffeine maintained (Jaszyna et al., 1998). While it seems that caffeine does have some influence on nicotine subjective effects rating, there does not seem to be much indication that caffeine alters the behavioral effects of nicotine in either animals or humans.

Hypotheses

The purpose of this study is to determine the effect of feeding conditions on the reinforcing value of caffeinated beverages compared to food among weight-concerned females. It is expected that: (1) participants will work harder to earn points towards caffeinated beverages on a multiple choice task during a fasting period than a non-fasting period. During the fasting session, they will be caffeine-withdrawn, and the negatively reinforcing properties of caffeine are expected to be greater than the reinforcing properties of snack foods; (2) smokers will work harder than non-smokers to obtain caffeinated beverages on a multiple choice task, since smokers tend to drink more caffeine than non-smokers (e.g., Pomerleau et al., 2004) and may require greater amounts of caffeine to experience the same effects as non-smokers (Klesges et al., 1994); (3) the degree to which participants experience caffeine withdrawal symptoms will positively correlate with ratings of urges to drink a caffeinated beverage at various points throughout the day; (4) subjective ratings of withdrawal symptoms will be positively correlated with efforts made to earn caffeinated drinks on a multiple choice task; (5) dietary restraint scores will be positively correlated with overall caffeine intake, since eating disordered individuals tend to consume larger quantities of caffeine than non-disordered individuals (e.g., Fahy & Treasure, 1991); and (6) dietary restraint scores will be positively correlated with efforts made to earn caffeinated drinks on a multiple choice task.

Methods

Participants

Participants were recruited through fliers posted on the campus of Louisiana State University, newspaper ads, and the undergraduate participant pool. Eligible participants fell within the normal to overweight range on Body Mass Index (BMI; between 18.5 and 29.9), indicated a degree of cognitive restraint of eating, consumed caffeine daily, and indicated moderate liking of one of several snack food options. Individuals were excluded if they were underweight (BMI<18.5), obese (BMI>29.9), reported high levels of eating disinhibition, scored within the clinical range on measures of eating disorder symptoms, or had a medical condition, such as hypoglycemia or diabetes, with symptoms that would be exacerbated by an acute fast. Participants enrolled through the student participant pool were awarded research credits for their participation, and those who enrolled through ads received monetary compensation.

Measures

Demographics & Health Questionnaire. This questionnaire consists of 11 items which assess age, sex, race, cigarette use and preferred brand, caffeine use, health problems and dieting behavior. Anthropomorphics, such as height and weight, and the biochemical measure of carbon monoxide (CO) were measured and recorded on this form.

Eating Attitudes Test (EAT-26; Garner et al., 1982). The EAT-26 is a self-report measure that was used to assess the presence of eating disorder symptoms. Questions on this 26-item questionnaire assess three factors: dieting, bulimia and food preoccupation, and oral control. The EAT-26 has been shown to be reliable and valid. Scores of 20 and greater have been associated with diagnoses of Anorexia Nervosa, as well the presence of other eating disorders (Garner et al., 1982). Individuals who scored in this range were excluded from participation and referred for further assessment.

Bulimia Test- Revised (BULIT-R; Thelen et al., 1991). This is a 36-item self report questionnaire intended to asses for symptoms of Bulimia Nervosa. It is a reliable measure, and has been validated on samples of bulimic women, as well as non-clinical college female controls (Thelen et al., 1991). It assesses symptoms using five scales: bingeing and control, radical weight loss and body image, laxative and diuretic use, vomiting, and exercise. Individuals who score above 104 on the BULIT-R are likely to meet clinical criteria for bulimia (Thelen et al., 1991). Participants who scored 104 or higher on the BULIT-R were excluded from the study and referred for further assessment.

Eating Inventory (EI; Stunkard & Messick, 1988). The EI is a 51-item self report measure designed to assess three aspects of eating: cognitive restraint of eating, disinhibition, and hunger. It has been shown to be a reliable and valid measure (Stunkard & Messick, 1988). In order to insure that participants demonstrated restraint, only those who scored above 4 on the Cognitive Restraint scale (CR) were included. Additionally, those who scored above 8 on the disinhibition scale were excluded from participation.

Caffeine Consumption Questionnaire (CCQ; Landrum, 1992). The CCQ is a standardized measure for evaluating weekly caffeine intake from several dietary sources including coffee, tea, cocoa, chocolate, soda, and over-the-counter drugs at different times of the day. The questionnaire breaks down several of these sources into subcategories, asking participants to indicate the way their coffee is prepared, and which specific brands of soda and drugs they use. It has been shown to be an appropriate measure of caffeine intake among college students (Shohet & Landrum, 2001). For this study, this measure was used to assess the number of weekly and daily servings of caffeine consumed. Based on this information, estimates of daily milligrams of consumed caffeine were calculated from reported caffeine concentrations in specific products (The Really Big Caffeine Database, 2007; Caffeine in Food, 2007).

Expired Carbon Monoxide (CO). At screening, expired CO was measured for all participants, as a biological indicator of smoking status. In general, 8-10 parts per million is the cutoff point that distinguishes smokers from non-smokers (SRNT Subcommittee on Biochemical Verification, 2002). A variety of factors influence expired CO levels, such as degree of physical exertion and sleeping. Additionally, environmental pollutants can increase CO to 2-6 ppm, regardless of smoking status (SRNT Subcommittee on Biochemical Verification, 2002). Since many participants were screened in the morning, which could result in a lower expired CO reading, no cutoff was utilized among reported smokers.

Geiselman Menstrual Cycle Interview (GMCI). For participants who were not using oral or transdermal contraceptives, items from the GMCI were used to determine length of menses, length of menstrual cycle, current cycle day, and the anticipated date of next menses. This was done in an effort to schedule participants during the luteal phase of their menstrual cycle, defined as the 11 days prior to the onset of menses.

Visual Analogue Scales (VAS). These are self-report measures used to assess participants' urges to consume caffeinated beverages and food. Additionally, this form of questionnaire was used in order to rate their liking of four snack foods for which they had the opportunity to earn points towards at the end of each session. Participants drew a vertical line through a 100 mm line, indicating the strength of their urge or liking. During a screening session, participants used the VAS to indicate how much they like each of the following snack foods: sugar cookies, Twinkies, Pringles potato chips, and Doritos. At three set points during the fasting and non-fasting sessions, participants received a questionnaire asking, "How strong is your urge to drink a caffeinated beverage right now?" and, "How hungry are you right now?"

The responses on the VAS questionnaires provide subjective measures of hunger, urges to drink coffee or soda.

Caffeine Withdrawal Symptoms Questionnaire (CWSQ). This is a 10 item questionnaire that asks participants to rate the degree to which they are experiencing symptoms shown to be valid indicators of caffeine withdrawal by Juliano & Griffiths (2004). The CWSQ is adapted from a questionnaire used in previous research studies (Goldstein, Kaizer, & Whitby, 1969; Griffiths, Bigelow, & Liebson, 1986), and was used to determine the degree to which an individual is experiencing caffeine withdrawal.

Multiple-Choice Questionnaire (MCQ). This is a 22 item questionnaire designed to assess the reinforcing value of a preferred snack food in relation to a caffeinated beverage. For each item, participants indicated their preferred caffeinated beverage (coffee, tea, soda, or diet soda) and their preferred snack (sugar cookies, Twinkies, Pringles potato chips, or Doritos). This selection of snack items was chosen based on a previous study by Goldfield, Epstein, Davidson and Saad (2005), which offered four similar snack foods to participants. For each item, participants chose between earning points towards their preferred drink or their preferred snack. The questionnaire is designed so that it becomes increasingly difficult to earn points for the caffeinated beverage, but earning points towards the snack does not become any more difficult. Participants were instructed to complete each item in order by choosing one or the other at each point. The point at which an individual switches from the caffeinated beverage to the snack food is referred to as the crossover point, with later crossover points indicating a greater reinforcing value of the preferred caffeinated drink. This method has been shown to be valid in determining drug reinforcement (Griffiths, Troisi, Silverman, & Mumford, 1993; Griffiths, Rush, & Puhala, 1996) as well as food reinforcement (Goldfield et al., 2005). Multiple-choice procedures are better at assessing the reinforcing value of substances than single choice measures (such as recording self-administration of a substance after a period of abstinence) because they are more externally valid, given that outside of the experimental session people are not limited to just one substance. Further, the reinforcing value of a particular substance may depend on the reinforcing value of other available substances, with some things being less reinforcing when more reinforcing things are available (Epstein & Leddy, 2006). In this study, the multiple-choice questionnaire was used to evaluate how reinforcing a caffeinated drink is in relation to a snack.

Hypoglycemic Symptoms Checklist (HSC). This is a 12 item questionnaire designed to assess the presence of common symptoms of hypoglycemia, including sweating, trembling, and irritability (NIH, 2003). The HSC was administered at several points throughout the fasting and non-fasting sessions.

ReliOn Ketone Test Strips (Bayer HealthCare LLC, Mishawaka, IN, USA). Ketone strips were used to determine the presence of ketone bodies in participants' urine at the end of both experimental sessions. In response to reduced glucose levels during periods of prolonged food deprivation, the liver produces ketones, which are sources of fuel for the brain (Emery, 2005). Ketones have been shown to be present in urine samples after overnight fasts in small quantities (Balasse & Fery, 1989), so presence of ketones after fasting in some participants would provide evidence of overall compliance with the fast.

Procedure

Screening. Individuals who called in response to ads or enrolled through the student subject pool system attended a screening session, in which informed consent was obtained. Information regarding age, daily cigarette use and daily caffeine consumption, use of oral contraceptives, medical conditions and eating habits was collected. Exhaled carbon monoxide, weight, and height were measured. Individuals also rated their liking of several snack foods. Those who were eligible and willing to participate were administered GMCI to attempt to schedule participants during the luteal phase of their menstrual cycle. Eligible participants scheduled for two additional six hour sessions, one of which required a 24-hour fast. The order in which participants completed sessions was counterbalanced, with 5 completing the fasting session first, and 7 completing the non-fasting session first.

Fasting Condition. Participants were instructed to not consume any food or caloric beverage 18 hours prior to their scheduled session. At 9:00, 12:00 and 3:00 participants completed a hunger rating VAS, caffeine urge VAS, CWSQ, and HSC. At 3:00 participants completed the multiple-choice questionnaire. They were told that they would receive their preferred caffeinated beverage or snack based on the question number that was randomly selected. They were immediately given what they had earned for the selected question. At the end of the day, a urine sample was collected in order to ensure compliance with the fast. Before leaving, participants were given as many nutritional bars as they requested. Water was available to them throughout the day. Smokers were provided with one pack of their preferred brand of cigarettes, which they were allowed to take with them at the end of the session.

Non-fasting Condition. Participants were instructed to eat and drink normally prior to their scheduled session. To insure that participants were not hungry, breakfast and lunch were provided to them at 9:00 and 12:00, respectively. For breakfast, participants were given yogurt, a cereal bar, a banana, and orange juice (approximately 535 total calories). For lunch, participants chose from a variety of frozen meals (ranging from 600 to 680 calories), and a non-caloric beverage. They completed the hunger rating VAS, caffeine urge VAS, CWSQ, and HGC at 9:00, 12:00, and 3:00. At 3:00, participants completed the multiple choice questionnaire. Participants were given the rewards earned for the selected question. Urine samples were collected, and before leaving, they were given as many nutritional bars as they requested. Water was available throughout the day. Smokers were provided with one pack of their preferred brand of cigarettes, which they were allowed to take with them at the end of the session. After completing both experimental sessions, participants were either given research credits or a $130 payment.

Results

Participant Characteristics

One hundred fifty six individuals participated in the initial screening, 46 of whom were eligible to participate in the experimental sessions. Of these eligible participants, 32 did not wish to participate, resulting in 14 participants who completed both the fasting and non-fasting sessions. 85.7% of those who completed the experiment were Caucasian (n=10), 7.1% African American (n=1) and 7.1% Asian (n=1), had a mean age of 20.43 (±2.06), and an average BMI of 21.99 (±2.58). They consumed an average of 3.07 (±1.77) caffeinated beverages daily, for a mean intake of 165.29 mg (±107.54) of caffeine each day. Eligible individuals who did not participate in the study had higher CR scores (10.13 v. 7.14), t (41)= -2.33, p=.03, somewhat higher EI- Disinhibition scores (5.44 v. 4.14), t (44)= -1.99, p=.053 and somewhat higher EAT total scores (8.52 v. 4.57), t (44)= -1.96, p=.056, compared to eligible participants who completed the study. There were no other differences between these groups on demographic factors or eating measures. Individual participant scores on screening measures are shown in Table 1.

Of the eligible individuals who participated, six were smokers and eight were non-smokers. Smokers smoked an average of 12 cigarettes (±5.97) daily and had a mean CO reading of 18 ppm (±16.40) at screening. CO readings were higher for smokers than for non-smokers (1.29 ±.49), t (5)=2.50, p=.055. Compared to non-smokers, smokers consumed more milligrams of caffeine daily (239.79 v. 109.41), t (12)= 2.76, p=.02. There were no differences on any demographic characteristics or eating measures between smoking and non-smoking participants.

Fasting Compliance

Hunger Ratings. To verify that participants adhered to the fast, hunger ratings were collected at three points throughout the day, and the average rating was calculated. A repeated

Table 1.

Individual Participant Characteristics at Screening

	Smoker	Age	Race	BMI	CR	Disinhib.	EAT	BULIT-R	CO	Daily Mg/ Caffeine
1	Y	20	AA	21.43	5	4	1	52	15	259
2	Y	21	C	19.26	8	7	1	58	48	405
3	N	22	C	20.70	10	5	17	44		194
4	Y	22	C	24.63	4	3	2	35	17	259
5	N	20	C	25.00	5	5	0	37	1	153
6	N	25	A	19.50	4	7	1	51	1	83
7	N	18	C	26.92	4	5	1	35	1	151
8	N	20	C	23.40	11	4	10	52	2	130
9	Y	23	C	21.05	12	2	6	38	21	152
10	N	21	C	23.00	9	3	2	33	2	40
11	N	19	C	19.81	6	2	3	37	1	52
12	Y	18	C	18.60	4	2	3	34	2	299
13	Y	19	C	24.60	6	5	4	47	5	63.14
14	N	18	C	20.10	2	4	13	48	1	71.25

C= Caucasian, AA= African American, A= Asian measures analysis of variance (ANOVA) was run to determine if average VAS hunger ratings were different between conditions. Results indicated that hunger ratings were significantly higher in the fasting condition (m=70.86 mm) than in the non-fasting condition (m=38.90 mm), F (1,13) = 16.51, p=.00, partial eta^2=.56. This is an indicator that participants complied with the fasting instructions.

Caffeine Withdrawal Symptoms. As with the hunger ratings, participants rated the degree to which they were experiencing symptoms associated with caffeine withdrawal at three points throughout the day. The CWSQ scores were averaged across these time points, and a repeated measures ANOVA was conducted to determine if averages differed within conditions. Average CWSQ scores were significantly higher in the fasting condition (m=9.61) than in the non-fasting condition (m= 5.74), F (1, 12)= 7.03, p=.02, partial eta^2= .37. This within-condition discrepancy provides further evidence that participants adhered to the fast, by abstaining from caffeinated products.

Urinary Ketone Concentrations. In an effort to obtain a biological verification of fasting adherence, urine samples were collected and tested for the presence of ketones at the end of both fasting and non-fasting sessions. At the end of the fasting condition, participants tested positive for ketones 50% of the time, compared to only 8.3% after the non-fasting session. Combined with the differences found between conditions regarding hunger ratings and caffeine withdrawal symptoms, the more frequent presence of ketones lends additional support to the belief that participants adhered to the fasting instructions.

Within Group Differences in Caffeine Reinforcement

Of the 14 participants, only nine completed valid MCQs during both conditions. Several MCQ responses were invalid due to multiple crossover points, and were excluded from analysis. A repeated measures ANOVA was conducted to determine if participants worked harder to obtain caffeinated beverages in the fasting condition than in the non-fasting condition, as indicated by the MCQ crossover points (later crossover points indicating greater reinforcement). Though the mean crossover point was higher during the fasting condition (*m*=10. 11) than during the non-fasting condition (*m*=7.56), the difference did not reach statistical significance, F (1,7)= .04, p=.85, partial eta^2= .01.

Between Group Differences in Caffeine Reinforcement

As explained above, several MCQs were excluded from analysis, resulting in two smokers and seven non-smokers who completed valid MCQs in both experimental sessions. A repeated measures ANOVA was performed, and unexpectedly revealed no differences between smokers and non-smokers efforts to obtain caffeine, F (1,7)= .04, p=.85, partial eta^2= .01, though the mean crossover point was higher for smokers than non-smokers on both fasting and non-fasting days (11.5 v. 9.71, and 11.5 v. 6.43, respectively).

Correlations

Caffeine Urge and Withdrawal Symptoms. Because caffeine is negatively reinforcing, it was expected that VAS caffeine urge ratings would be positively correlated with CWSQ ratings at all three time points. However, the only significant Pearson correlation found was between VAS urge and CWSQ ratings at the third time point of the fasting condition r(12)= .56, p=.04. That significant correlation alone does not seem to indicate that the urge to drink a caffeinated beverage is associated with the severity of withdrawal symptoms.

Caffeine Reinforcement and Withdrawal Symptoms. To test the hypothesis that withdrawal symptom severity would be associated with greater effort to obtain caffeine, Pearson correlations were calculated using the MCQ crossover point and afternoon CWSQ score for each condition. Results yielded no significant relationships for either the fasting, r(9)= .18, p=.59 or non-fasting, r(7)= -.47, p= .20 sessions.

Dietary Restraint and Caffeine Intake. Pearson correlation coefficients were computed to determine the relationship between EI- CR scores and daily caffeine consumption, in daily beverages and milligrams consumed. There were no significant relationships between restraint scores and quantity of caffeinated beverages, $r(12)=.12$, $p=.69$, or between restraint scores and milligrams of caffeine consumed daily, $r(12)=-.22$, $p=.46$.

Dietary Restraint and Caffeine Reinforcement. Results yielded no significant Pearson correlation coefficients for either CR scores and MCQ crossover points in the non-fasting, $r(7)=.63$, $p=.07$, or the fasting $r(9)=-.01$, $p=.98$ conditions.

Discussion

The results of this study did not lend statistically significant support to the hypotheses that food-deprived individuals would work harder for caffeine than non-deprived individuals, or that smokers would work harder to obtain caffeine than non-smokers would. These findings are contrary to those of Bulick, Brinded, and Lawson (1995), in which bulimic patients and healthy controls worked harder to obtain coffee in a fasting state than in a non-fasting state. Results of this study are also discrepant from other research that indicates smokers require greater quantities of caffeine than non-smokers to experience the same effects (Klesges et al., 1994). There are a number of methodological issues that may contribute to the lack of significant findings in the current design, such as the small sample size (though somewhat larger than that of similar studies), and the exclusion of several MCQs due to invalid responses, most of which occurred in smokers, therefore decreasing the number of smokers included in the analysis to only two. Characteristics of the sample may also play a role. In particular, smokers tended to report relatively light smoking behaviors, on average 12 a day, and their CO readings were only marginally greater than those of non-smokers. It is possible that the baseline differences in these groups were not large enough to be affected by the experimental manipulation. It is noteworthy, however, that despite the limited sample size, smokers in this study consumed significantly more milligrams of caffeine daily than non-smokers, which is consistent with previous findings (e.g., Pomerleau et al., 2004). Additionally, the mean crossover points for both within and between group analyses were in the expected direction. It is possible that if the aforementioned methodological issues are rectified, that analyses may yield statistically significant results.

Despite the absence of significant findings, these results are not wholly different from that of the available literature. Rather, inconsistent support of the food deprivation effect has been a hallmark of the research in this area. Zacny and DeWitt (1990) found no effect of fasting on the number of cigarettes smoked, while Bulick and Brinded (1993) failed to find an effect of feeding condition or group (bulimic patients compared to healthy controls) on efforts to obtain cigarettes. Other research has found no difference in the amount of coffee consumed among women in different feeding conditions (Lawson et al., 1995). Such seeming lack of support for the food deprivation effect in humans does not necessarily mean that it is nonexistent, but brings to light methodological difficulties in capturing its complexity.

It is surprising that analyses did not reveal significant correlations between caffeine urge VAS ratings and CWSQ scores. Given the extensive literature on the negatively reinforcing properties of caffeine, it would be expected that more severe withdrawal symptoms would be associated with a greater desire to consume caffeine. There are several possible explanations for the lack of support these results lend to that theory. First, the CWSQ may not be sensitive to caffeine withdrawal. While it does consist of items identified as being valid symptoms of withdrawal (Juliano & Griffiths, 2004), they are not necessarily unique to caffeine withdrawal, raising questions about alternative ways of identifying withdrawal symptoms. Researchers have consistently found cognitive and behavioral impairments to be associated with caffeine withdrawal, but many different measures have been used to measure these effects, and there has not been enough research done on any particular measure to meet validity criteria specified by Juliano and Griffiths (2004) for a withdrawal symptom. While it would be advantageous to assess for withdrawal based on more objective physiological symptoms, such as increased cerebral blood flow, electroencephalography (EEG) changes, decreased motor activity, skin conductance, and urinary epinephrine and norepinephrine levels, not enough research has been done to consider any of these reliable indicators of caffeine withdrawal (Juliano & Griffiths, 2004). At this point, therefore, it appears that measures such as the one used in this study are the most appropriate, though further research on the CWSQ is needed to establish its reliability and validity at measuring caffeine withdrawal severity. It is possible that, given the restricted sample size, there was not enough variance in scores to result in significant differences, or that the relationship is nonlinear.

Second, it is possible that the VAS is not an appropriate method to asses desire to drink a caffeinated drink. The urge VAS and CWSQ may also be measuring different constructs, since related concepts such as craving and urge have been distinguished in some contemporary models of addiction (e.g., Marlatt & Gordon, 1985), though it is possible that they are mediated by the same processes.

Finally, the lack of significant correlations between the CWSQ and VAS urge ratings could indicate that the desire to consume caffeine may not have to do with avoidance/alleviation of withdrawal symptoms, but instead may be influenced by positively reinforcing properties of caffeine, such as its taste or stimulating effects, as participants have reported in prior studies (Goldstein & Kaizer, 1969). These drawbacks of the CWSQ, as well as the number of invalid MCQs, in addition to the limited sample size could also contribute to the insignificant correlation between CWSQ scores and crossover points.

While significant relationships between dietary restraint and daily caffeine intake, and between dietary restraint and caffeine reinforcement were expected, the lack of variance in EI-CR scores could easily have contributed to the statistically non-significant results. It is also possible that this scale, as it was used in this research design, does not accurately measure dietary restraint. As part of the original version of the EI, the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), the CR scale initially “reflected conscious mechanisms for restraining food intake” (Stunkard & Messick, 1985, p. 77). Individuals who scored on the CR scale were believed to be more receptive to nutritional information and learning behavioral strategies aimed at weight control (Stunkard & Messick, 1985). In accordance with this belief, research has shown that women who had high CR scores reported lower total caloric consumption, calories from sweet foods, and a lower frequency of sweet food intake compared to those who had low CR scores (French, Jeffery & Wing, 1994), leading the authors to conclude that such measures of current and chronic dieting do not measure weight loss behaviors, but a more general restraint. High CR scorers have also reported greater consumption of fruits and vegetables than low CR scorers, leading some to conclude that those with high scores are more interested in controlling fat as opposed to overall weight, and tend to do so through the practice of healthful eating instead of general restrictive eating habits (Beiseigel & Nickols-Richardson, 2004).

While such evidence would seem to indicate that the CR scale is an acceptable measure to assess dietary restraint, its appropriateness is questionable when caloric intake is objectively measured (instead of relying on self-reports of caloric intake). Stice, Fisher and Lowe (2004) examined the CR, as well as several other dietary restraint scales, in a variety of laboratory and naturalistic settings, and found that none of the measures correlated with caloric restriction, regardless of factors such as weight status, presence of an eating disorder, or variety of available foods. Since the dieting measures correlated with each other, the results prompted the authors to assert that none of the measures are appropriate indicators of short-term food restriction, and to suggest that results from previous studies utilizing these measures be reinterpreted, given the substantial implications they would have on the diagnostic conceptualization of eating disorders, such as BN (Stice, Fisher & Lowe, 2004).

Stice, Presnell, Lowe and Burton (2006) cite research that indicates dieters are not actually achieving the negative energy balance necessary to lose weight, but are simply controlling an inclination to overeat (Presnell, Stice & Tristan, 2006). Given the seeming inaccuracy of self-reports of caloric intake, it is plausible that traditional measures of dietary restraint, such as the CR scale, identify individuals on perceived weight-loss diets, as opposed to actual weight-loss diets, in which a negative energy balance exists (Stice, Presnell, Lowe & Burton, 2006). Additional research indicates that CR scores are not related to current energy balance and do not predict future energy balance, but that changes in weight-loss program participants' CR scores over a period of time were correlated with a negative energy balance during that time (Williamson et al., 2007). Given the limited sample size and range of CR scores in the current study, the lack of objective measurement of food intake, and the one-time administration of the scale, it is highly possible that participants' reported cognitive restraint of eating is not indicative of actual dietary restraint, but rather a general effort towards maintaining healthful eating habits.

In addition to the previously mentioned methodological drawbacks of this study, there are a number of strengths. Though the sample size was small, it is comparable to or larger than those of similar studies. Several measures indicated that participants did comply with the fast, and the fact that they were present in the lab for both conditions afforded additional control over their eating during both experimental conditions. The use of a forced-choice MCQ with two reinforcing options (instead of caffeine v. money or food v. money) is advantageous, since it allows for a direct comparison of the reinforcing value of food and caffeine in food-deprived and non-food deprived states, which is an advantage over some of the existing literature.

In summary, though there were no significant differences between groups (smokers and non-smokers) or feeding conditions (fasting and non-fasting), it is possible that a larger sample size might yield different results. Further research is needed to determine the nature of the effects of food deprivation on caffeine reinforcement, particularly in eating disordered individuals, since this population may have a propensity to overuse caffeine throughout the onset and course of the disorders. Researchers would benefit from further exploration of the psychometric properties of the CWSQ in assessing the presence of caffeine withdrawal, given the unimpressive reliability of objective physiological measures. Continued use of the type of forced-choice MCQ used in this study would be beneficial, since it would allow for greater insight into nature of reinforcement among different populations in different conditions.

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Vita

Lauren Elizabeth Baillie was born in Boston, Massachusetts, in 1983. She received her Bachelor of Arts in psychology from the Catholic University of America in 2005, and began graduate work in clinical psychology at Louisiana State University in August of 2005. Her clinical and research interests focus on various aspects of health psychology, with an emphasis on weight, body image and eating pathology.