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Food cravings and food cue responding across the menstrual cycle

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FOOD CRAVINGS AND FOOD CUE RESPONDING ACROSS THE MENSTRUAL CYCLE

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

In

The Department of Psychology

by

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TABLE OF CONTENTS

ABSTRACT.....	iii
INTRODUCTION.....	1
METHODS.....	21
RESULTS.....	33
DISCUSSION.....	42
REFERENCES.....	55
VITA.....	65

ABSTRACT

Food cravings have been linked to obesity and eating disorders. Women report craving food more than men, and women experience greater rates of obesity and eating disorders.

Retrospective and quasi-prospective studies have suggested that food cravings may be more common during the luteal phase of the menstrual cycle. Unfortunately, these studies have been limited by the use of poorly defined menstrual cycle phases, disregard for individual differences in menstrual cycle length, and absence of validated measures of cravings. The current study examined the effects of menstrual cycle phase on 1) cravings in response to a high fat/high sugar chocolate candy cue, 2) amount of chocolate candy eaten in an *ad libitum* intake session following chocolate candy cueing, and 3) desire to eat foods of differing macronutrient content.

Thirty-five college females attended a laboratory session in the late follicular and late luteal phases of their menstrual cycle. In each session they completed a measure of state food craving prior to and following exposure to a bowl of preferred, high fat/high sugar chocolate candy.

Consumption of candy following cue exposure was measured during an *ad libitum* taste test.

Additionally, participants completed a measure assessing their desire to eat foods of differing macronutrient content. A urinary luteinizing hormone detection kit was utilized to confirm ovulation.

Results show that 1) craving for a preferred chocolate candy prior to or following the candy cue did not differ between the late follicular and late luteal phase, 2) the amount of

chocolate candy eaten did not differ between cycle phases, and 3) the macronutrient content of

foods desired did not differ significantly between cycle phase. A non-significant trend suggested that high fat/high complex carbohydrate and low fat/high protein foods were more strongly

desired in the late luteal phase. Regardless of cycle phase, participants reported greater craving

for chocolate candy following the cue. These results suggest that cravings for high fat/high sugar foods do not differ across cycle phases in women. Additional research is needed to determine if cycle phase effects desire to eat foods of differing macronutrient content, as suggested in the current study.

INTRODUCTION

Food Cravings, Control of Food Intake, and Eating Pathology

Obesity and overweight are recognized as leading public health problems in the United States. Obesity and overweight are substantial contributors to disease burden and mortality (Flegal, Graubard, Williamson, & Gail, 2007; Guh et al., 2009) and are highly prevalent, with recent data indicating that 33.8% of Americans are obese and an additional 34.2% are overweight (Flegal, Carroll, Ogden, & Curtin, 2010). Obesity is also expensive due to increased medical expenditures and losses in worker productivity associated with obesity and its comorbidities (Finkelstein, DiBonaventura, Burgess, & Hale, 2010; Finkelstein et al., 2008).

Along with low physical activity levels, increased food intake is the most significant proximal cause of the high rates of overweight and obesity. However, researchers have increasingly recognized that overweight and obesity are not simply due to malfunctions of the homeostatic or metabolic control of food intake (Berthoud, 2004). Rather, reward-related, “non-homeostatic,” mechanisms have the ability to override metabolic, homeostatic control of food intake, thereby contributing to increased food intake and obesity (Berthoud, 2004; Mela, 2006). In this context, food cravings have received increasing attention. In the past, researchers have defined food cravings as “intense desire[s] to eat a specific food or food type,” (Hill, 2007; Weingarten & Elston, 1990) with particular emphasis on the specificity and the intensity of the desire (Hill, 2007). The focus on the former helps differentiate food cravings from general hunger, and the latter differentiates food cravings from normal food selection (Hill, 2007).

Food cravings are commonly reported. Several studies conducted in America, Canada, and Spain show that a majority of individuals have experienced food cravings at some point in

their lives (Osman & Sobal, 2006; Pelchat, 1997; Weingarten & Elston, 1990; Zellner, Garriga-Trillo, Rohm, Centeno, & Parker, 1999). For example, Osman and Sobal (2006) found that greater than 94% of American and Spanish college students reported experiencing a food craving. A study in France found that over one-quarter of women surveyed reported weekly food cravings (Lafay et al., 2001).

For some individuals, food cravings may contribute to difficulty controlling food intake and body weight. Evidence suggests that food cravings often lead to the consumption of the craved food (Hill & Heaton-Brown, 1994; Weingarten & Elston, 1991), and individuals who experience frequent food cravings tend to consume more kilocalories per day than those who do not regularly crave foods (Lafay et al., 2001). The frequency with which an individual experiences food cravings correlates with their Body Mass Index (BMI; Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002; Pepino, Finkbeiner, & Mennella, 2009; White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). Additionally, obese individuals report greater cravings for high fat foods than normal weight individuals (White et al., 2002).

An individual's success on a weight loss regimen may also be impacted by the frequency with which they experience food cravings. Sitton et al. (1991) found that individuals who reported frequent food cravings were more likely to drop out of a medically supervised fasting program than individuals who had fewer cravings. In another study, a decrease in cravings for foods that are commonly purchased at fast food restaurants was correlated with weight loss during a very low calorie diet (Martin, O'Neil, & Pawlow, 2006). The consuming of a craved food while on a diet program has also been associated with lesser weight loss (Gilhooly et al., 2007).

In addition to their relationship with obesity and poor weight loss outcomes, food cravings have been associated with eating disorders. In particular, individuals with binge eating disorder (Mussell et al., 1996) and bulimia nervosa (Cepeda-Benito, Fernandez, & Moreno, 2003) report stronger or more frequent food cravings. Furthermore, food cravings may serve as proximal triggers for binge episodes (Waters, Hill, & Waller, 2001). In a study of obese females with binge eating disorder, craving for sweet foods commonly preceded binge episodes (Greeno, Wing, & Shiffman, 2000).

Taken together, these studies indicate that the frequency, persistence, and tendency to eat in response to food cravings may differentiate those individuals who are able to maintain a healthy body weight from individuals who are overweight, obese, or susceptible to eating disorders. This suggests that a better understanding of food cravings is an important step towards improving weight control and reducing eating disorder vulnerability.

Food Cravings, Gender and the Menstrual Cycle

Food cravings are more common in women than men (Lafay et al., 2001; Weingarten & Elston, 1990; Zellner et al., 1999). Among young adults surveyed at university campuses, 70% of men and 100% of women reported experiencing at least one food cravings over the previous year (Pelchat, 1997). Lafay et al. (2001) noted that 28% of women reported experiencing food cravings at least once per week, whereas only 13% of men reported this level of food craving.

Notably, women also have greater rates of obesity than men (Flegal, Carroll, Ogden, & Johnson, 2002; Hedley et al., 2004). This is despite the fact that women diet more often than men (Keel, Baxter, Heatherton, & Joiner, 2007; Williamson, Serdula, Anda, Levy, & Byers, 1992). Geary and Lovejoy (2008) have presented data demonstrating that rates of obesity are

higher in women than men in many countries throughout the world. In the United States, women appear to be particularly overrepresented in rates of morbid obesity, defined as BMI \geq 40 (Flegal et al., 2010). Women are also more likely to be diagnosed with eating disorders, including those characterized by binge eating episodes, i.e., bulimia nervosa and binge eating disorder (Hudson, Hiripi, Pope, & Kessler, 2007). The relationship between food cravings and these syndromes on the one hand, and food cravings and gender on the other hand, suggests that women's experience of food cravings may be relevant in the etiology, maintenance and treatment of obesity and eating disorders.

A discussion of food cravings in women often contains references to menstrual cycle-related fluctuations in cravings. Though the research in regards to food cravings across the menstrual cycle is limited and plagued by methodological problems (detailed below), there is a substantial body of well-designed research demonstrating cyclical variations in the amount of food women eat. Specifically, women consume fewer kilocalories during the late follicular and periovulatory phases of the menstrual cycle compared to the luteal phase (Bryant, Truesdale, & Dye, 2006; Johnson, Corrigan, Lemmon, Bergeron, & Crusco, 1994; Lyons, Truswell, Mira, Vizzard, & Abraham, 1989; Pelkman, Chow, Heinbach, & Rolls, 2001). In a review of the literature, Buffenstein et al. (1995) estimated that daily energy intake increases by greater than 10% during the luteal phase; however, some researchers have reported luteal phase increases in food consumption of as great as 500 kilocalories per day (Dalvit, 1981).

Fluctuations in the female sex hormones estrogen and progesterone appear to account for these cyclical variations in food intake. In women, estrogen levels are elevated and progesterone levels are low during the late follicular and peri-ovulatory phases of the menstrual cycle, phases

in which food intake is at its nadir (see Figure 1). Similarly, food intake is lower during days when estrogen levels are high and progesterone levels are attenuated across a variety of vertebrate animal species, including rats, guinea pigs, and monkeys, (Czaja & Goy, 1975; Drewett, 1974; Eckel, Houpt, & Geary, 2000). Experimental studies in animals have provided additional support to the role of female sex hormones in effecting food intake. When estrogen levels are substantially decreased via the surgical removal of the ovaries, i.e., ovariectomy, animals become hyperphagic, whereas the administration of exogenous estrogen normalizes food intake in ovariectomized animals (Asarian & Geary, 2002; Bartness & Waldbillig, 1984; Morin & Fleming, 1978; Wade, 1975). Further, progesterone has been shown to oppose the effects of estrogen on food intake in rodents (Wade, 1975). Additional data indicate that female sex hormones may have a specific effect on fat intake. Lower levels of fat intake during the late follicular and the periovulatory phases of the menstrual cycle have been observed in cycling women (Barr et al., 1995; Reimer, Debert, House, & Poulin, 2005; Tarasuk & Beaton, 1991).

Food Cravings across the Menstrual Cycle Early studies examining changes in food cravings primarily utilized retrospective reports to learn about women's experience of food cravings across the menstrual cycle (Hargrove & Abraham, 1982; Rozin, Levine, & Stoess, 1991). In these surveys, women commonly endorsed an increase in the frequency or intensity of food cravings during the days prior to menses, with some studies also indicating elevations in food cravings during menses (Dye et al., 1995; Pelchat, 1997; Rozin et al., 1991). For example, Pelchat (1997) found that 45% of women reported that at least one of their food cravings was associated with their menstrual cycle phase. In another study, 74% of women reported

experiencing food cravings during the week prior to menses, whereas 27% reported having food cravings during the week after menses (Dye, Warner, & Bancroft, 1995).

Thus, women have consistently reported menstrual cycle-related fluctuations in food cravings on retrospective surveys. However, there is evidence that retrospective ratings of menstrual cycle symptoms result in greater symptom reporting than daily ratings (Marván & Cortés-Iniestra, 2001; Parlee, 1982). For example, Marvan and Cortes-Iniestra (2001) reported that women rated premenstrual somatic and behavioral/mood symptoms higher when making retrospective ratings compared to when they made daily ratings. Though no known studies have compared retrospective and prospective ratings across the menstrual cycle specifically for food cravings, it is feasible that previous reports of increased food cravings during the luteal phase were inflated due to retrospective bias.

This potential for bias in retrospective reporting makes other data collection methods important to consider. A few studies have examined food cravings across the menstrual cycle utilizing a data collection approach that reduces reliance on retrospective accounts (Bancroft, Cook, & Williamson, 1988; Cohen, Sherwin, & Fleming, 1987; Gallant, Hamilton, Popiel, & Morokoff, & Chakraborty, 1991; Hill & Heaton-Brown, 1994). Typically, these studies have required participants to report their food cravings either at the end of the day, or less commonly, at the time that they experienced the craving. Thus, these studies utilize either a prospective design, or what Hill (2007) has called a “quasi-prospective” study design, thereby minimizing retrospective biases.

Unfortunately, other methodological problems have plagued these prospective and quasi-prospective studies of food cravings across the menstrual cycle. The use of imprecise definitions

of menstrual cycle phases has been a significant limitation in many studies examining food cravings across the menstrual cycle. A well-accepted approach to studying the menstrual cycle is to delineate four phases in relation to menses and ovulation: the menses phase, which is characterized by the presence of menstrual flow; the late follicular phase, which includes the day after the cessation of menses through the day prior to the peri-ovulatory phase; the peri-ovulatory phase, which includes the two days before through the two days after ovulation; and the luteal phase, which includes the day after the peri-ovulatory phase through the day prior to menses (Davidsen, Vistisen, & Astrup, 2007). Other researchers find it useful to further delineate between the early luteal phase and late luteal phase, also called the premenstrual phase (Lyons et al., 1989; Stern & McClintock, 1996). Female sex hormone levels fluctuate across menstrual cycle phases, and each of these phases is characterized by differing titres of estrogen, progesterone, and other female sex hormones (See Figure 1). Unfortunately, some studies examining food cravings across the menstrual cycle have grouped data into overly broad phases that do not correspond to the physiologically-based phases described above. In a study by Cohen et al. (1987) the researchers compared cravings during the ten days after menses onset with cravings during the ten days prior to the first day of menses. Thus, menses and the late follicular phase were combined, potentially obscuring any differences in food cravings between these two phases. Similarly, Hill and Heaton-Brown (1994) grouped the seven days following the onset of menses into one phase, despite the likelihood that many women's menses lasted fewer than seven days.

A related problem in past studies examining food cravings across the menstrual cycle is inattention to individual variability in menstrual cycle length. The length of the menstrual cycle, as well as the length of individual phases of the menstrual cycle, can vary dramatically from one

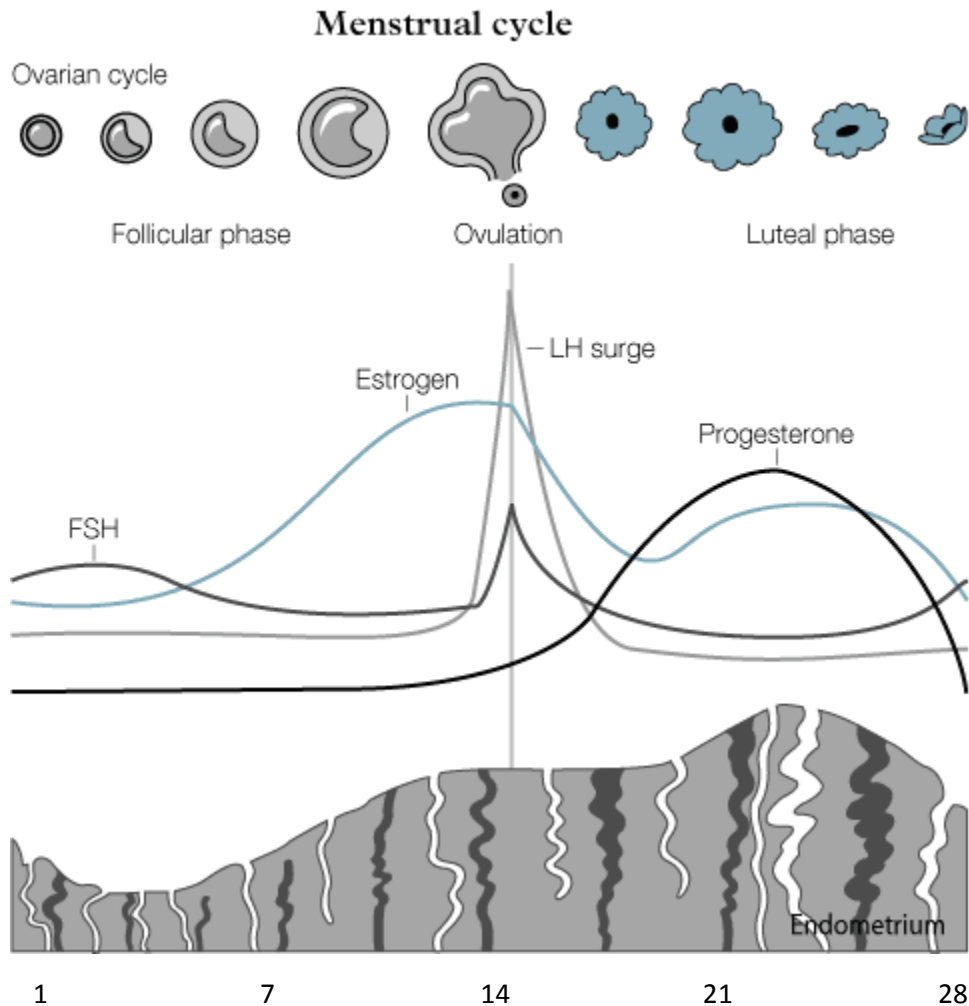


Figure 1. Schematic representation of a 28 day menstrual cycle. FSH = Follicle Stimulating Hormone. LH = Luteinizing Hormone.

woman to another. Stern and McClintock (1996) note that normal menstrual cycle lengths vary from 24 - 35 days, with the most variation being present in the length of the follicular phase, which can last from 4 - 19 days. Past studies examining food cravings across the menstrual cycle have often failed to take into account individual differences in menstrual cycle length and have

instead assumed a 28-day cycle. In one study, 13 women recorded each food craving they experienced across a five-week period (Hill & Heaton-Brown, 1994). Based on participants' self report date of menses onset, each day's data was assigned to one of the following time periods: the week occurring three weeks prior to menses, the week occurring two weeks prior to menses, the week prior to menses, or the week beginning on the first day of menses. Individual differences in cycle length were not taken into account when grouping data into phases. For some women, the week occurring three weeks prior to menses may have included days from the menses phase, whereas for other women this week may have overlapped primarily with the peri-ovulatory phase. This highlights the importance of an approach in which phases are defined by their underlying physiological features, particularly ovulation and menses, and in which ovulation and menses dates are utilized to verify cycle phase classification.

In addition to aiding in the identification of cycle phase, it is important to verify ovulation because anovulatory phases are common and may impact the effects of the menstrual cycle on changes in appetite. Anovulation is particularly common in young women; in a study examining 20 - 24 year old women, only 62% of women ovulated over all three menstrual cycles examined (Metcalf & Mackenzie, 1980). The potential impact of anovulation on appetite-related variables was presented by Barr and colleagues (1995). They showed that luteal phase increases in food intake were attenuated during cycle phases in which ovulation was absent. Unfortunately, most studies that have examined cyclical variations in food cravings have not confirmed the presence of ovulation.

Past investigations of food cravings across the menstrual cycle have also been limited by weaknesses in the instruments that have been used to measure cravings. In one study, the

researchers reported that there were greater food cravings during the four days prior to menses compared to the peri-ovulatory and follicular phase; however, their measure of food craving was a single item, and this food craving item was combined with an item assessing perceived weight gain (Gallant, Hamilton, Popiel, Morokoff, & Chakraborty, 1991). This combining of food craving and weight gain make it impossible to determine whether it is food cravings or weight changes that are contributing to the menstrual phase effects found in this study. Cohen et al. (1987) had thirty-four undergraduate women record all foods craved on a given day as well as the intensity of the cravings. The authors then created a craving rating score by adding intensity ratings for each craving on each day. This combining of craving frequency and intensity ratings impedes the determination of the potentially independent effects of the menstrual cycle on either of these dimensions of food craving. In general, the use of measures without evidence of adequate psychometric properties is an ubiquitous problem in the food craving literature that had been facilitated by the absence of available psychometrically sound measures of state food cravings during much of the early research on food cravings (Cepeda-Benito, Gleaves, Williams, & Erath, 2001). Fortunately, a multi-item, multi-dimensional measure of state food cravings has been developed (Cepeda-Benito et al., 2001).

An additional limitation of past prospective and “quasi-prospective” examinations of food craving across the menstrual cycle is that participants’ recordings have not been verified to have occurred on the date that participants reported them. Because these studies have typically collected paper-and-pen data recordings at the end of the experiment, it is impossible to verify the accuracy of the reported date of data collection. Indeed, past research indicates that participants in daily diary or momentary assessment studies often misrepresent the timeframe

during which they complete their data entry (Stone, Shiffman, Schwartz, Broderick, & Hufford, 2002).

In summary, numerous limitations have been present in past studies, including the absence of carefully defined and verified cycle phases; failure to verify ovulation; the use of assessment instruments without proven validity or reliability; and reliance on ratings forms that have not been verified to have been completed on the intended dates. Limitations notwithstanding, studies examining food cravings utilizing prospective or quasi-prospective methods have been consistent with self-report measures in showing increased cravings during the late luteal phase. For example, Hill and Heaton-Brown (1994) reported that craving level was 66% higher during the seven days prior to the onset of menses compared to other other time periods examined.

Food Cues, Food Cravings, and Food Intake

Examination of food cravings in a laboratory setting would eliminate some of the problems present in the quasi-prospective studies described above. One way to measure food cravings in a controlled setting is to examine responses to food cues. Food cravings are commonly precipitated by exposure to food cues, such as the sight or smell of a specific food (Hill & Heaton-Brown, 1994). Examining individuals' responses to food cues can therefore provide a useful methodology for studying food cravings (Hill, 2007; Sobik, Hutchison, & Craighead, 2005). The study of cue responding, including the examination of cravings in response to cues, has been extensively developed in the field of addictions research. It has repeatedly been demonstrated that exposure to drug cues induces drug cravings as well as physiological responses such as increased heart rate, sweat gland activity, and skin temperature

(Carter & Tiffany, 1999; Tiffany, Carter, & Singleton, 2000). Furthermore, an association between intensity of drug cravings in response to cues and drug relapse has been reported (Cooney, Litt, Morse, Bauer, & Gaupp, 1997; Litt, Cooney, & Morse, 2000).

Unlike drug cues, food cues are ubiquitous in the environment of most individuals. Responses to food cues have received increasing attention in the empirical literature. Numerous studies have shown that exposure to food cues elicits food cravings (Cornell, Rodin, & Weingarten, 1989; Ferriday & Brunstrom, 2011; Nederkoorn, Smulders, & Jansen, 2000; Sobik, et al., 2005; Tetley, Brunstrom, & Griffiths, 2009), as well as physiological responses, such as increases in salivation, temperature, heart rate, and blood pressure (Nederkoorn et al., 2000). Additionally, individuals consume more food following a period of exposure to a food cue, compared to when food presentation does not follow a prolonged cue exposure (Fedoroff, Polivy, & Herman, 1997; Ferriday & Brunstrom, 2008). Also, reported cravings intensity in response to food cues has been shown to predict the amount of presented food that is consumed (Nederkoorn et al., 2000).

Food cue responding may be relevant to understanding eating pathology and obesity. In a recent study, BMI was positively associated with the desired portion size after exposure to a food cue (Tetley et al., 2009). Similarly, Ferriday and Brunstrom (2011) found a greater increase in desire to eat and greater salivary response following a food cue in overweight compared to normal weight individuals. Researchers working with children have reported similar findings. In one study, overweight children ate more than normal-weight children following exposure to sweet or salty snack foods (Jansen et al., 2003). Binge eating is also associated with craving in response to food cues (Sobik et al., 2005). These findings are consistent with studies showing a

relationship between BMI, binge eating, and food craving frequency (White et al., 2002) and suggest that the study of food cue responding is a useful paradigm for investigating eating behaviors in a laboratory setting (Sobik et al., 2005). No known studies have examined food cue responding across phases of the menstrual cycle, despite the growing evidence of the relevance of food cue responding for the understanding of pathological eating.

Macronutrient Content of Food Cravings

Limited attention has been given to the macronutrient content of craved foods as it relates to the menstrual cycle. This is unfortunate, as the macronutrient content of foods has a significant impact on appetite motivation and food intake, and thereby has important implications for weight control. Numerous studies have shown that individuals consume more total energy when provided with foods high in fat than when given lower fat foods (Blundell & Macdiarmid, 1997; Lissner, Levitsky, Strupp, Kalkwarf, & Roe, 1987; Stubbs, Harbron, Murgatroyd, & Prentice, 1995). In a study by Stubbs et al. (1995), participants were fed a low-fat, medium-fat, or high-fat diet. Participants consumed nearly 5,000 more calories across a seven day period when provided the high-fat diet compared to the low-fat diet. Epidemiological studies have shown that a diet high in fat is associated with obesity (Blundell & Macdiarmid, 1997; Bray & Popkin, 1998) and obese individuals tend to prefer high fat foods (Drewnowski & Almiron-Roig, 2009; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992).

Whereas foods high in fat tend to promote hyperphagia, foods high in protein are associated with greater satiation and satiety (Green, Burley, & Blundell, 1994; Lejeune, Westerterp, Adam, Luscombe-Marsh, & Westerterp-Plantenga, 2006; Rolls, Hetherington, & Burley, 1988). For example, Rolls et al. (1988) reported that individuals who received a protein

preload subsequently consumed fewer kilocalories and reported less hunger compared to individuals who had consumed a preload high in fat or sucrose.

Empirical investigation of the effects of carbohydrates in the control of hunger and food intake has been hampered by researchers' disinclination to distinguish between simple sugars and complex carbohydrates. Such a distinction is important, as evidence indicates that these macronutrients have differing effects on appetite motivation and food intake (Geiselman & Novin, 1982). In rodents, access to high sugar foods has been demonstrated to increase total energy intake (Kanarek & Marks-Kaufman, 1979). Studies in human subjects have also revealed that simple sugars contribute to hyperphagia. Compared to a diet high in complex carbohydrates, a diet high in simple sugar was associated with greater total energy intake during a 14 day study (Raben, Macdonald, & Astrup, 1997), and intake of a sucrose preload was less effective at suppressing later energy intake than a protein or complex carbohydrate preload (Rolls et al., 1988).

The combination of fat and sugar may be particularly conducive to hyperphagia. Individuals rate a high fat milk product as more hedonically pleasing when it also contains sugar (Drewnowski & Greenwood, 1983). In a laboratory-based study, women reported greater hunger and consumed more food following a high fat/high sugar preload compared to a high protein or high complex carbohydrate preload (Rolls et al., 1988). Further, obese women report that high fat/high sugar foods, such as cookies, cakes, and ice cream, are their favorite foods (Drewnowski et al., 1992) and intake of high fat/high sugar foods is associated with obesity in women (Macdiarmid, Vail, Cade, & Blundell, 1998).

Macronutrient Content of Craved Foods In the 1980s, a research team led by the Wurtmans hypothesized that carbohydrate cravings are an important factor in obesity (Wurtman Wurtman, Growdon, Henry, Lipscomb, & Zeisel, 1981; Wurtman, Wurtman, Mark, Tsay, Gilbert, & Growdon, 1985). However, it has since been noted that those foods labeled “high carbohydrate” in this line of research were typically foods high in both fat and simple sugar, such as cakes, ice cream, and pastries (Drewnowski et al., 1992). Indeed, more recent evidence indicates that commonly craved foods tend to be high in fat (Gilhooly et al., 2007; White et al., 2002). For example, Gilhooly et al. (2007) found that foods craved by their sample of female participants were 30% higher in fat content than foods that were part of participants’ normal diet.

Differences have been reported between women and men in the types of foods and the macronutrient content of foods craved (Christensen & Pettijohn, 2001; Pelchat, 1997; Zellner et al., 1999). The food most commonly craved by women is chocolate, and chocolate is less commonly craved by men than women (Hill & Heaton-Brown, 1994; Lim, Norman, Clifton, & Noakes, 2009; Rozin et al., 1991; Tiggemann & Kemps, 2005). When asked to describe their most recent food craving, 42% of women described a food containing chocolate, whereas only 11% of men described a chocolate food (Tiggemann & Kemps, 2005). Other studies have suggested that women may also crave high sugar foods more than men (Pelchat, 1997; Zellner et al., 1999). For example, Zellner et al. (1999) reported that both Spanish and American women were more likely to report craving sweet foods than salty foods, whereas American and Spanish men reported more frequent cravings for salty foods than sweet foods.

Macronutrient Content of Craved foods Across the Menstrual Cycle Little is known about the effects of the menstrual cycle on the macronutrient content of food cravings. In

retrospective self-report questionnaires, women have reported a specific increase in chocolate cravings in the days prior to menses (Rozin et al., 1991; Zellner, Garriga-Trillo, Centeno, & Wadsworth, 2004). While no known studies have specified the macronutrient content of the chocolate foods craved by participants, most commonly consumed chocolate foods are high in both fat and sugar. In one of the few studies to examine type of food craved across the menstrual cycle utilizing daily ratings of cravings, Hill and Heaton-Brown (1994) grouped craved foods into the categories of “chocolate-containing foods,” “sweet-tasting foods” or “savory foods.” They reported that cravings for each of these types of foods increased similarly during the days prior to menses, suggesting a lack of macronutrient specificity in menstrual cycle-related fluctuations in food cravings. Unfortunately, Hill and Heaton-Brown (1994) provided no description of the criteria or procedure they utilized in categorizing foods, leaving it unclear if the classification of foods as sweet or savory was guided by objective criteria. Without objective criteria based on the macronutrient content of foods, it is difficult to interpret the findings of Hill and Heaton-Brown (1994) and others with regards to macronutrient specificity of menstrual cycle changes in food cravings.

A recent study by Yen and colleagues (2010) appears to address some of the limitations of past studies by utilizing validated measures and a prospective approach to examining food cravings across the menstrual cycle. In this study, 59 women with clinically significant premenstrual symptomology (i.e., premenstrual dysphoric disorder [PMDD]) and 60 control women were tested at two points during their menstrual cycle: the luteal and follicular phases. During each testing, participants completed an adapted version of the Food Craving Inventory (FCI), a measure that evaluates cravings for many different types of foods over the past month

and includes the subscales of High Fat Foods, Sweets, Carbohydrates/Starches, and Fast Food Fats (White et al., 2002). The authors reported a luteal phase increase in cravings for the Sweets subscale of the FCI in women with PMDD, but not in control women. In women without PMDD, a luteal phase increase in ratings for foods in the Carbohydrate/Starches and Fast Food Fats subscales were found on the FCI. However, the use of the FCI to measure food craving in this study is problematic. First, the authors do not report if they modified the time frame specified in the original version of FCI, which asks about food cravings in the past month. Obviously, this would not be appropriate for assessing menstrual cycle-related changes in cravings. Additionally, though this scale provides useful information on empirically derived categories of food cravings, the FCI does not allow for a systematic examination of the macronutrient content of craved foods.

In the study by Yen et al. (2010), participants also completed the Food Craving Questionnaire-State (FCQ-S), a measure that assesses cravings during the present moment for a food specified by the researcher. Participants were asked to rate their craving for “high fat, high sugar foods” on the FCQ-S. Yen et al. reported that participants’ ratings on the FCQ-S were higher during the luteal phase, indicating an increase in cravings for high fat/high sugar foods. Though this finding is suggestive, limitations of this study should be noted. The researchers did not verify ovulatory status nor did they appear to verify that luteal phase data collection was accurately scheduled during the luteal phase. Another concern with Yen et al.’s study is that it is unclear if the researchers controlled for the participant’s nutritional status prior to the study. Particularly given known differences in food intake during the luteal phase and the effects of hunger on food cravings (Cepeda-Benito et al., 2001), it is important to control for participants’

level of food intake and type of food eaten prior to cravings ratings. Additionally, participants were asked to report on cravings for “high fat, high sugar foods.” As this term was not further defined, it isn’t clear if participants had an accurate understanding of what was meant by high fat/high sugar foods. Finally, the findings with regards to macronutrient content of craved foods are conflicting in this study; findings from the FCI, though a flawed measure of macronutrient content of cravings, suggested no change in cravings for high fat/high sugar foods, whereas the FCQ-S results suggested a luteal phase increase in cravings for these foods. Thus, though this study provides potential evidence of an increase in high fat/high sugar food cravings during the luteal phase, the limitations of this study significantly limit the strength of these findings. It is also relevant to note that this study appears to have been conducted on a population of Taiwanese students. It is unclear how these results might generalize to an American population, particularly given the differences in eating and weight pathology between these groups.

Though past studies have contributed to difficulty identifying the effects of the menstrual cycle on the macronutrient content of cravings, a specific increase in high fat/high sugar foods during the late luteal phase can be hypothesized based on the evidence reviewed thus far. Specifically, women have reported an increase in cravings for chocolate foods, which most typically are high in fat and sugar, during this menstrual cycle phase (Rozin et al., 1991; Zellner et al., 2004) and researchers have also revealed a specific increase in intake of dietary fats during the late luteal phase of the menstrual cycle (Johnson et al., 1994; Tarasuk & Beaton, 1991). Given that individuals typically consume the foods they crave (Hill & Heaton-Brown, 1994), studies reporting greater high fat food intake during the late luteal phase add to the evidence that cravings for high fat/high sugar foods may also be elevated during the late luteal phase.

Summary and Specific Aims

In sum, food cravings appear to be important factors in the development and treatment of obesity, and may be particularly important to understanding the greater experience of appetite control difficulties in women compared to men. Retrospective and quasi-prospective data has suggested that women experience late luteal phase increases in food cravings, however past studies have not examined cue reactivity with regards to the menstrual cycle, nor have they utilized well-validated measures of food cravings and of macronutrient content of cravings to study cravings across well-defined, physiologically-verified menstrual cycle phases. Answering questions about appetite variables across the menstrual cycle while overcoming past methodological limitations may be an important step towards improving weight control treatment and obesity prevention programs for women.

In the current study, a laboratory-based food cue exposure paradigm was utilized to measure food craving in response to a high fat/high sugar chocolate candy cue during two menstrual cycle phases: the late follicular phase and late luteal phase. In addition to assessing craving, amount of chocolate candy eaten during an *ad libitum* eating episode was measured. Additionally, participants rated their current level of desire to eat a variety of foods systematically and significantly varied in their content of fat, simple sugar, complex carbohydrate, and protein.

Specific Aim 1 Determine the effects of menstrual cycle phase (late follicular and late luteal) on craving for a preferred chocolate high fat/high sugar food prior to and following exposure to cue of that food.

Specific Aim 1 Hypothesis A Craving for preferred chocolate high fat/high sugar food will be greater during the late luteal phase of the menstrual cycle.

Specific Aim 1 Hypothesis B Food cue exposure will moderate the relationship between menstrual cycle phase and craving, such that menstrual cycle phase will account for more of the variance in food craving following exposure to the food cue than prior to food cue exposure.

Specific Aim 2 Determine the effects of menstrual cycle phase (late follicular and late luteal) on intake of a high fat/high sugar preferred chocolate candy following exposure to a cue of that food.

Specific Aim 2 Hypothesis Intake of the chocolate candy following cue exposure will be greater during the late luteal phase than the late follicular phase.

Specific Aim 3 Determine the effects of menstrual cycle phase (late follicular and late luteal) on participants' desire to eat foods' of differing macronutrient content.

Specific Aim 3 Hypothesis There will be a specific increase in the desire to eat high fat/high sugar foods during the late luteal phase.

METHODS

Participants

A recruitment goal of 34 participants was selected based on a power analysis for Hypothesis 1 and 3, utilizing a power level of .80, significance level of .05 and estimating a medium effect size (Cohen's $f = .25$). The final sample size in the current study was 35 participants.

Participants were females attending Louisiana State University (LSU) who were enrolled in psychology courses. They were recruited through the Psychology Department research participation system and provided with course credit for their participation. Women were invited to participate in screening for the study if they were not using exogenous sex hormones. The research participation system website specifically stated that participants should not attend screening if they were currently using oral contraceptives. All participants were required to be between ages 18 - 38. Participants were excluded if they reported any of the following: a) current use of exogenous hormones, including oral contraceptives (OCs), injectable hormonal contraceptive, or contraceptive implant device, b) use of any of these contraceptive methods in the previous six months, or plans to use them in the forthcoming three months, c) currently lactating, pregnancy in the previous six months, or plans to become pregnant in the next three months, d) menses do not regularly occur every 25-35 days, e) use of any medications that are known to have an effect on appetite, f) cigarette use in the past 6 months or greater than 20 cigarettes in their lifetime, g) current enrollment in a standardized weight reduction program or h) not liking at least one of the available candy bars or not having experienced a craving for chocolate at least once during the previous six months. In order to exclude women with eating

disorders or major depressive disorder, individuals were prohibited from participating if their score on the Bulimia Test- Revised (BULIT-R) was 104 or greater, if they scored 20 or greater on the Eating Attitudes Test-24 (EAT-24) or if they scored 19 or greater on the Beck Depression Inventory-II (BDI-II). Women with elevated scores on these measures were offered referrals for treatment in the community and at the LSU Psychological Services Center, where they were also offered free evaluations and low cost treatment.

One hundred and fourteen participants were screened for the current study and 59 (51.8%) were eligible for participation. Many participants met multiple exclusionary criteria. Reasons for ineligibility included current use of hormonal contraceptive ($n = 6$), use of hormonal contraceptives in previous 6 months or plan to use in the next 3 months ($n = 12$), planning to become pregnant in next three months ($n = 1$), significant variation in menstrual cycle length ($n = 12$), a reported tendency to have “skipped periods” ($n = 16$), menstrual cycle length shorter than 25 days or longer than 35 days ($n = 12$), current involvement in a diet program ($n = 1$), smoking of cigarettes in previous six months ($n = 15$), smoking of greater than 20 cigarettes in life ($n = 10$), absence of chocolate craving in previous 6 months ($n = 7$), and age older than 38 or younger than 18 ($n = 2$). Elevated scores on the BDI-II ($n = 13$) and the EAT-26 ($n = 9$) also led to exclusion of participants.

Of the 59 eligible participants, 45 completed only one laboratory session and 39 completed two laboratory sessions. Reasons for failing to complete laboratory sessions were participants’ failure to detect ovulation ($n = 9$), being unable to contact participant or participants’ deciding to withdrawal from the study ($n = 10$), and development of ovarian cysts after entering study ($n = 1$). Participants’ data were included in the current study if there were seven or fewer

days between their luteal phase laboratory session and the first day of their menses. This resulted in the exclusion of four additional participants. Thus, a total of 35 participants completed both late follicular and late luteal phase sessions and were therefore included in data analyses.

Measures

Food Craving Questionnaire-State (FCQ-S; Cepeda-Benito, et al., 2001). The FCQ-S assesses multiple dimensions of craving in the present moment for a specific food item. The FCQ-S was designed so that the specific food item for which craving is assessed can be chosen by the researcher. Subscales of the FCQ-S have evinced good structural validity as indicated by factor analytic methods, and have demonstrated strong internal consistency (Cepeda-Benito et al., 2001; Moreno, Rodríguez, Fernandez, Tamez, & Cepeda-Benito, 2008). Factors of the FCQ-S measure craving intensity (Intensity), anticipation of positive reinforcement from specified food (Positive Reinforcement), anticipation of negative reinforcement from specified food (Negative Reinforcement), anticipated lack of control over eating specified food (Lack of Control), and physiological aspects of craving (Physiological). In the validation study for the FCQ-S, food deprivation resulted in greater cravings scores, indicating that the scale is sensitive to change (Cepeda-Benito et al., 2001). In the current study, the FCQ-S Intensity was utilized to measure craving intensity prior to and following exposure to a preferred chocolate candy bar cue. The scale was adapted to ask specifically about cravings for chocolate candy.

Geiselman Food Preference Questionnaire-Crave. (FPQ-C). The FPQ-C was an adaptation of the Geiselman Food Preference Questionnaire (FPQ; Geiselman, Anderson, Dowdy, West, Redmann, & Smith, 1998), a measure designed to assess individuals' hedonic evaluations of foods with differing levels of fat and other specific macronutrients. The selection

of foods utilized in the FPQ was based on a 2 (Fat: High Fat and Low Fat) X 3 (Other Macronutrient: High Simple Sugar, High Complex CHO, and High Protein) design, yielding 6 design cells: High Fat/High Simple Sugar, High Fat/High Complex Carbohydrate, High Fat/High Protein/Low Carbohydrate, Low Fat/High Sugar, Low Fat/High Complex Carbohydrate, and Low Fat/High Protein. Twelve foods that are common in the US diet were chosen for each of the six cell. Foods were selected to significantly and systematically vary fat content with other macronutrient content. Thus, foods in high fat cells are > 45% fat (expressed as percentage of kilocalories from fat of total kilocalories in the food); foods in low fat cells are < 20% fat. Foods in the high sugar cells are > 30% sugar; high complex carbohydrate foods are > 30% complex carbohydrate; and high protein foods are > 13% protein, though most high protein foods had 20 - 35% protein. The test-retest reliability of the FPQ is strong (r 's = 0.82-0.99), and the FPQ has been shown to significantly correlate with macronutrient intake and total caloric intake, supporting the validity of the instrument (Geiselman et al., 1998). In the current study, the FPQ was adapted to measure participants' desire to eat foods of differing macronutrients by instructing participants to rate their desire to eat the specified food at that moment. Validation and reliability studies for the FPQ-C are currently in progress.

Visual Analog Scale (VAS) Appetite and Mood Questionnaires. VASs were utilized to assess appetite and hunger variables as well as mood states. VASs consisted of a 100 millimeter line with anchors at both ends. Participants were instructed to mark on the line to indicate their current state regarding the variable of interest. The following questions were asked to assess appetite-related variables and mood. 1) "How hungry do you feel at this moment?" (anchored by "not at all hungry" and "extremely hungry"); 2) "How strong is your desire to eat?" (anchored by

“very weak” and “very strong”); 3) “How full does your stomach feel at this moment?” (anchored by “not at all full” and “extremely full”); 4) “How stressed do you feel at this moment?” (anchored by “not at all stressed” and “extremely stressed”); 5) “How relaxed do you feel at this moment?” (anchored by “not at all relaxed” and “extremely relaxed”); 6) “How anxious do you feel at this moment?” (anchored by “not at all anxious” and “extremely anxious”); 7) “How content do you feel at this moment?” (anchored by “not at all content” and “extremely content”).

Eating Inventory. (EI; Stunkard & Messick, 1985). The EI is a widely utilized measure of eating behavior. The EI contains three subscales: dietary restraint, dietary disinhibition, and hunger. Dietary restraint refers to the conscious restricting of food intake; dietary disinhibition is the tendency to lose control of eating; and the hunger subscale has been described as susceptibility to hunger (Stunkard & Messick, 1985). The EI subscales have good internal consistency and have evinced test-retest reliability of greater than 0.90.

The Bulimia Test-Revised. (BULIT-R; Thelen, Farmer, Wonderlich, & Smith, 1991). The BULIT-R is a revised version of the BULIT. It is a 35-item scale that assesses symptoms of bulimia based on DSM-IV criteria. It has demonstrated good test-retest reliability, discriminative validity, and construct validity. In the current study, the BULIT-R was used to screen for eating disorders, and a score of 104 or greater will warrant exclusion from the current study.

Eating Attitudes Test-26. (EAT-26; Garner, Olmsted, Bohr, & Garfinkel, 1982). The EAT-26 is a 26 item questionnaire assessing common cognitive and behavioral components of anorexia nervosa and bulimia nervosa. The scale has strong internal consistency ($\alpha = .91$) and has been found to distinguish eating disorder cases from controls (Garner, et al., 1982).

Individuals scoring 20 or greater on the EAT-26 were excluded from the study and offered community referrals for eating disorder treatment.

Beck Depression Inventory-II. (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II will be used in the current as a measure of depressive symptomatology in order to exclude individuals with clinical levels of depression. The BDI-II has 21 items that assess common cognitive, physiological and behavioral symptoms of depression. A score of 19 or greater, indicative of moderate or severe depression, resulted in exclusion from the current study. Participants who scored in this range were referred to community treatment centers.

Chocolate Candy Bar Preference Questionnaire. Participants were asked to rate their hedonic evaluation of eight popular chocolate candy bars (Hershey's Milk Chocolate, Almond Joy, Reese's Peanut Butter Cups, Nestle Crunch, Snickers, Twix, Kit Kat, and Butterfingers) on a study specific questionnaire. They rated each candy bar on a 9-point Likert scale, with the following anchors: 1 = dislike extremely; 5 = neutral, neither like nor dislike; 9 = like extremely (Geiselman et al., 1998). In order to be included in the current study, participants were required to rate at least one chocolate candy on the list as a 6 or higher.

Medimpex Urinary Luteinizing Hormone (LH) Surge Detection Kit. Urinary LH surge detection kits were utilized to determine when an LH surge occurs. A surge in LH level indicates that ovulation is likely to occur within the following 48 hours. Urinary LH surge detection kit use has been found to be reliable and valid method of detecting ovulation during home-based use by women without medical training (Miller & Soules, 1996; Rudy & Estok, 1992). To use the LH kit, individuals urinate into a cup, briefly place a dipstick into the urine, and read the results of the test from the dipstick.

Geiselman Menstrual Cycle Interview. The Geiselman Menstrual Cycle Interview is a researcher-administered interview that assesses participants' recent and historic menstrual cycle characteristics, such as typical length of menses, typical length of menstrual cycle, and date of most recent menses. Information collected from this interview was utilized during screening to aid in the scheduling of late follicular and late luteal laboratory experimental session visits.

Daily Symptom Rating Scale (DSR; Freeman, DeRubeis, & Rickels, 1996). The DSR is a 17-item scale that assesses premenstrual symptoms. Ratings are made on a scale from 0 (not present at all) to 4 (severe, symptom is overwhelming and/or unable to carry out daily activity). Factor analysis yielded four factors: mood, behavioral, pain, and physical symptoms (Freeman et al., 1996). The subscales have demonstrated adequate internal consistency (from $\alpha = .92$ for mood to $\alpha = .63$ for pain). This measure has shown the ability to detect changes in premenstrual symptoms from medication use (Freeman, Rickels, Sondheimer, & Polansky, 1995)

Procedure

Screening and Laboratory Session Scheduling Screenings were conducted at the LSU Psychological Services Center. At screening, participants completed the EI, BULIT-R, EAT-26, BDI-II, Chocolate Candy Bar Preference Questionnaire, and additional screening questions. Their height and weight were also obtained. Eligible participants were provided with additional information about the study and were given the option to consent to participate in the remainder of the study for additional course credit. Those individuals who consented to participate were interviewed at the end of the screening session using the Geiselman Menstrual Cycle Interview in order to obtain the information needed to schedule their laboratory visits and/or LH testing. At this time, participants were provided with the LH surge detection kits for use in their own home

and given detailed instructions as to how to use the LH surge detection kit and informed of when to begin testing. Participants were instructed to use the kit daily until they observe a positive result, indicating an LH surge, which is anticipated to take between 1 - 9 days. The researcher contacted participants by email to obtain LH testing outcomes and to remind them to continue LH testing.

Participants were scheduled for their late follicular and late luteal phase laboratory sessions based on their typical menstrual cycle length, date of ovulation, and date of recent menses. Order of sessions was counterbalanced to control for order effects.

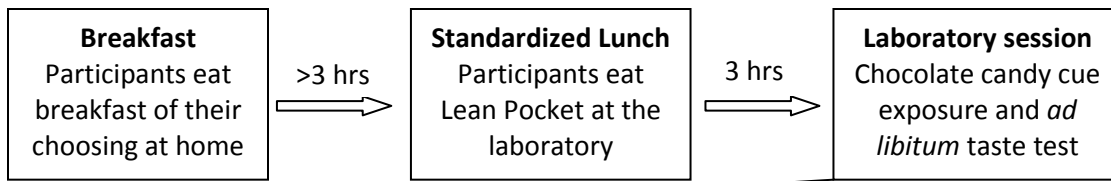
The late follicular phase visit was scheduled between the offset of menses and prior to the detection of ovulation, and the late luteal phase visit was scheduled after ovulation and prior to menses onset, with an effort made to schedule it as close to menses onset as possible. Participants' data was excluded from the study if more than seven days elapsed between their luteal phase laboratory session and the first day of their menses.

Laboratory Sessions Procedure for both the late follicular and late luteal laboratory sessions were identical. See Figure 2 for a schematic representation of the laboratory visit procedure. Participants were instructed to eat the same breakfast of their own choosing on both assessment days, and to refrain from consuming any foods or beverages other than water in the three hours prior to their laboratory session. Participants were scheduled to arrive at the clinic to receive a standardized lunch between 10:45 AM and 1:00 PM, depending on their availability. The timing of the sessions was held constant between both sessions. Before receiving their lunch, participants reported what they had eaten for breakfast and verified that they have not eaten during the past three hours. They also completed the DSR at this time. Participants were then

instructed to consume a Lean Pocket in its entirety. This was done to ensure that participants were at a similar nutritional status at the beginning of the experiment. The majority of participants were given a pepperoni pizza lean pocket (280 kilocalories), though a few participants were instead provided with a garlic chicken lean pocket (270 kilocalories) or a cheese pizza lean pocket (290 kilocalories) due to dietary restrictions. After eating the Lean Pocket, participants were dismissed from the laboratory and instructed to return in three hours and to refrain from consuming any food or any beverages other than water while they were away.

Cue Exposure Upon returning to the laboratory three hours after their initial visit, participants were escorted to a private room where they were instructed to complete the FCQ-S, FPQ-C, and VAS questionnaires. The FCQ-S, a measure designed to query about a specific food as designated by the researcher, was adapted in the current study so as to specifically measure cravings for chocolate candy.

Next, participants were provided with a large bowl full of miniature, unwrapped chocolate candy bars of the variety that they indicated having the greatest preference for on the Chocolate Candy Bar Preference Questionnaire. The bowl of candy bars contained between 19-22 unwrapped bars, equivalent to 800-1,000 total kilocalories (See Table 1 for additional nutritional information). One wrapped candy bar of the same variety was placed next to the bowl of candy bars to provide a more salient cue. To provide for a prolonged cue exposure, participants were instructed to complete questions about the appearance of the chocolate candy bars, and explicitly instructed not to eat the candy at that time. The researcher then left the



Task	Description	Time
Verification of Study Procedure	Participant verify that they haven't eaten anything since lunch	3 minutes
Questionnaire Set 1	<ul style="list-style-type: none"> ○ 1st Visual Analog Scales assessing mood and appetite ○ 1st Food Preference Questionnaire- Craving ○ 1st Food Craving Questionnaire-State 	10-15 minutes
Cue Exposure	<ul style="list-style-type: none"> ○ Bowl of chocolate candy brought into room and placed in front of participant. ○ Participant instructed to complete ratings of the appearance of the chocolate and instructed not to eat chocolate at that point. 	5 minutes (exact)
Questionnaire Set 2	<ul style="list-style-type: none"> ○ 2nd Visual Analog Scales assessing mood and appetite ○ 2nd Food Preference Questionnaire- Craving ○ 2nd Food Craving Questionnaire-State 	8-12 minutes
Ad lib chocolate eating episode	Participant instructed to complete sensory taste ratings of chocolate candy.	10 minutes (exact)
Questionnaire Set 3	<ul style="list-style-type: none"> ○ 3rd Visual Analog Scales assessing mood and appetite ○ 3rd Food Preference Questionnaire- Craving ○ 3rd Food Craving Questionnaire-State 	8-12 minutes

Figure 2. Representation of laboratory session procedures.

participant in the room with the candy bars for five minutes in order to provide prolonged exposure to the chocolate candy bar cue, without explicitly informing them that the cue exposure is part of the purpose of the study. They were monitored on a video camera during this time to ensure that they were not eating the candy during this portion of the experiment. One participant was observed to have eaten the candy at this time, and her data was removed from the analysis.

Ad Libitum Intake After five minutes, the researcher returned to the room and asked the participant to complete the FCQ-S, FPQ-C, and VAS for a second time. After completing these questions, the researcher provided the participant a form for rating various qualities of the taste of the chocolate

candy and provided the following instructions: “You are only required to taste enough to make the ratings, however you can have as much as you would like because we have to throw away whatever you don’t eat. I’ll be back in ten minutes to collect your ratings. If you finish early, just wait in here for me to return.” Participants were then left alone for ten minutes to complete the *ad libitum* food intake task. They were monitored on a video camera to ensure that they were not attempting to take any food items outside of the laboratory. However, no participants were observed attempting to remove candy. After ten minutes had passed, the experimenter returned and participants were asked to complete a third set of FCQ-S, FPC-C and VAS questionnaires (this third set of questionnaires was not utilized in the current study). The bowl of candy was weighed prior to and after its presentation to the participant on a digital food scale that was calibrated daily using a standardized weight.

Table 1. Energy content and macronutrient content of chocolate candies utilized.

	Reese’s Peanut Butter Cups miniature	Snickers miniature	Butter- fingers miniature	Kit Kat miniature	Nestle Crunch Bars miniature	Milky Way miniature
Kcals/100g	500	472	450	488	500	441
% fat	53	48	35	49	45	33
% sugar	42	42	44	33	44	53
% complex carbohydrates	5	9	20	15	10	11
% protein	7	7	4	5	4	4
Units served	21	20	18	21	18	21
Grams served	184.8	180	180	180.6	180	180.6
Kcals served	924	850	810	882	900	798

Note. % macronutrient expressed as percentage of kilocalories from that macronutrient of total kilocalories in the food. Percent may not add to 100 due to imprecision in manufacture provided nutritional information.

Following their second visit, participants were asked to complete a questionnaire assessing their belief as to the purpose of the study. After all data had been collected for the current study, participants received an email with information on the actual purpose of the study and provided with contact information for the researcher to direct any questions or concerns.

RESULTS

Participant Characteristics

Participants mean age was 19.86 years ($SD = 1.93$). The average BMI was 23.70 kg/m² ($SD = 3.87$), which is in the normal weight range. One participant was in the underweight range (BMI < 18.5 kg/m²), nine participants were in the overweight range (25.0 kg/m² < BMI < 29.9), and two participants were obese (BMI > 30.0 kg/m²). The majority of participants were Caucasian (65.7%). A smaller portion of participants were African American (22.9%), Asian/Asian American (5.7%), Hispanic (2.9%), or of another race/ethnicity (2.9%). Additional participant characteristics are presented in Table 2. Participants' scores on measures of eating

Table 2. Participant Characteristics at Baseline.

	Completed Participants
Age, $M (SD)$	19.86 (1.93)
BMI (kg/m ²), $M (SD)$ ^a	23.70 (3.87)
BMI range	16.30 – 35.20
Race	
Caucasian, %, n	65.7 (23)
African American, %, n	22.9 (8)
Asian/ Asian American, %, n	5.7 (2)
Hispanic, %	2.9 (1)
Other, %	2.9 (1)
EAT-26, $M (SD)$	6.34 (4.63)
BULIT, $M (SD)$	42.00 (10.28)
EI Dietary Restraint, $M (SD)$	8.60 (4.25)
EI Dietary Disinhibition, $M (SD)$	6.11 (3.68)
EI Hunger, $M (SD)$	5.26 (3.52)
BDI-II Total Score, $M (SD)$	6.60 (5.49)
BSQ Total Score, $M (SD)$	76.29 (29.31)

Note. BMI = Body Mass Index. EAT-26 = Eating Attitudes Test-26. BULIT = The Bulimia Test-Revised. EI = Eating Inventory. BDI-II = Beck Depression Inventory-II. BSQ = Body Shape Questionnaire. $N = 35$ unless otherwise noted.

^a 1 cases missing.

behavior and depression were indicative of minimal eating disorder and depressive disorder symptomatology.

Preliminary Analyses

Participants' hunger, fullness, mood state and premenstrual symptoms were compared between late follicular and late luteal phase laboratory sessions utilizing within subjects t-tests. VAS ratings of hunger, fullness and mood were from the first set of questionnaires given during each session (i.e., VAS questions given prior to cue exposure). See Table 3 for mean values, standard deviations, and results of statistical tests. No significant differences were found between the two phases on variables examined.

Table 3. Hunger, fullness, mood and menstrual-related symptoms during the follicular and luteal phase.

	Phase		<i>t</i> value	<i>p</i> value
	Follicular	Luteal		
VAS Hunger	52.26 (27.09)	54.79 (25.36)	- 0.57	.57
VAS Fullness ^a	33.6 (22.72)	36.43 (22.49)	- 0.68	.50
VAS Stress ^b	31.23 (29.65)	29.32 (25.13)	0.29	.77
VAS Relaxed ^b	54.13 (25.04)	55.35 (25.31)	- 0.22	.83
VAS Anxious ^b	32.58 (26.65)	28.00 (24.18)	0.74	.47
DSR Mood	3.47 (3.81)	3.06 (3.23)	0.79	.43
DSR Behavioral ^c	3.48 (4.12)	2.85 (2.86)	1.34	.19
DSR Pain	0.88 (1.32)	1.09 (1.03)	- 1.00	.33
DSR Physical symptoms	0.97 (0.97)	1.09 (1.03)	- 0.66	.51

Note. VAS = Visual Analog Scale. DSR = Daily Symptom Ratings. *N* = 34 unless noted.

^a 4 cases missing. ^b 3 cases missing. ^c 1 case missing

Specific Aim 1

In order to determine if food cravings differed from the late follicular to the late luteal phase and if cue presentation moderated effects of menstrual cycle phase on food cravings, a 2 × 2 within-subjects analysis of variance (ANOVA) was conducted with the independent variables

menstrual cycle phase (late follicular and late luteal) and cue exposure status (pre-cue and post-cue). The dependent variable was the FCQ-S Intensity subscale ratings. No main effect of phase was found, $F(1,33) = 0.129$, $p = .722$, partial $\eta^2 = .004$, indicating that food cravings intensity did not differ overall from the follicular phase ($M = 10.44$, $SD = 2.61$) to the luteal phase ($M = 10.62$, $SD = 2.07$). A significant main effect of cue exposure status was found, $F(1,33) = 37.69$, $p < 0.001$, partial $\eta^2 = .533$. Cravings were rated lower prior to the cue ($M = 9.71$, $SD = 1.97$) compared to post-cue ($M = 11.35$, $SD = 2.08$). The interaction of phase and cue exposure status was not significant, indicating that craving intensity did not change from pre-cue (follicular: $M = 9.71$; $SD = 2.84$; luteal: $M = 9.71$, $SD = 2.39$) to post-cue (follicular: $M = 11.18$, $SD = 2.72$; luteal: $M = 11.53$, $SD = 2.50$) differentially in the two cycle phase, $F(1, 33) = .372$, $p = .546$, partial $\eta^2 = .011$. See Figure 3 for graphical representation of craving ratings across phases and cue exposure status.

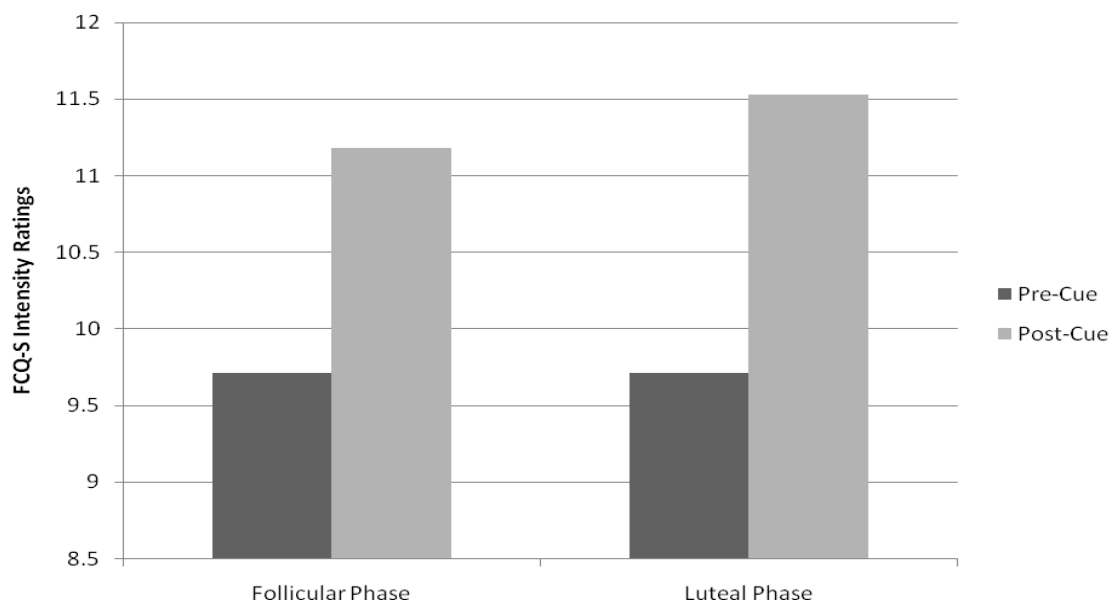


Figure 3. Ratings of craving intensity on Food Craving Questionnaire-State Intensity during the follicular and luteal phases pre- and post-cue.

Specific Aim 2

Within subject t-tests were conducted to determine the effects of menstrual cycle phase on food consumption in response to a food cue. Utilizing kcals eaten as the dependent variable, no significant difference were found between the late follicular phase ($M = 252.6$; $SD = 115.3$) and the late luteal phase ($M = 246.2$, $SD = 134.5$), $t(1,32) = -0.08$, $p = .94$. Similarly, no significant difference were found between phases when grams eaten was the dependent variable, $t(1, 32) = .29$, $p = .77$ (follicular: $M = 52.63$, $SD = 24.85$; luteal: $M = 52.95$, $SD = 26.83$).

Specific Aim 3

A $2 \times 2 \times 3$ within subjects ANOVA was conducted to test the hypothesis that menstrual cycle phase has a specific effect on desire to eat high fat/high sugar foods. The dependent variable was ratings on the first FPQ-C completed by participants (i.e., the FPQ-C completed prior to cue exposure). Independent variables were cycle phase (late follicular and late luteal), fat content of foods (high fat and low fat) and other macronutrient content of foods (high sugar, high complex carbohydrate, and high protein). This analysis thereby allowed for the examination of desire ratings for the six cells of the FPQ-C (High Fat/High Simple Sugar, High Fat/High Complex Carbohydrate, High Fat/High Protein/Low Carbohydrate, Low Fat/High Sugar, Low Fat/High Complex Carbohydrate, and Low Fat/High Protein) during both menstrual cycle phases. Assumptions of sphericity were evaluated and in the case of violations, results were presented with Greenhouse-Geisser adjustments.

No main effect of menstrual cycle phase was present (follicular: $M = 2.98$; $SD = 1.10$; luteal: $M = 3.19$, $SD = 1.10$), $F(1,33) = 2.15$, $p = .152$, partial $\eta^2 = .06$, suggesting no overall difference in desire to eat foods across cycle phases. A main effect of fat level was found,

indicating that individuals reported a greater desire to eat high fat foods ($M = 3.38$, $SD = 1.11$) than low fat foods ($M = 2.79$, $SD = 1.02$), $F(1, 33) = 18.98$, $p < .001$, partial $\eta^2 = .37$. A main effect of other macronutrient level was also found, $F(1, 33) = 6.26$, $p = .003$, partial $\eta^2 = .16$. Post hoc comparisons utilizing Bonferroni adjustments showed that the desire to eat high sugar foods ($M = 3.47$, $SD = 1.05$) was significantly greater than desire to eat high complex carbohydrate foods ($M = 2.86$, $SD = 1.20$), $p = .01$, and high protein foods ($M = 2.93$; $SD = 1.34$), $p = .04$. The desire to eat high complex carbohydrate foods did not differ from the desire to eat high protein food, $p = 1.0$.

The interaction of fat level and menstrual cycle phase was not significant, $F(1,33) = 0.258$, $p = .62$, partial $\eta^2 = .01$. Similarly, the interaction of other macronutrient content and menstrual cycle phase was non-significant, $F(2,66) = 1.26$, $p = .29$, partial $\eta^2 = .04$. The interaction of fat level and other macronutrient was also not statistically significant, however a non-significant trend was detected, $F(2, 66) = 2.64$, $p = .07$, partial $\eta^2 = .08$. An exploratory follow-up test was performed. The high fat/high sugar foods ($M = 3.65$, $SD = 1.10$) were rated significantly higher than the low fat/high complex carbohydrate foods ($M = 2.39$, $SD = 1.17$), $p < .001$, and the low fat/high protein foods ($M = 2.58$, $SD = 1.44$), $p = .01$. The high fat/high complex carbohydrate foods ($M = 3.32$, $SD = 1.42$) and high fat/high protein foods ($M = 3.17$, $SD = 1.42$) were also rated higher than the low fat/high complex carbohydrate foods, $p < .001$ and $p = .004$, respectively. Finally, the low fat/high sugar foods ($M = 3.28$, $SD = 1.42$) were rated more highly than the low fat/high complex carbohydrate foods, $p = .02$. (See Figure 4).

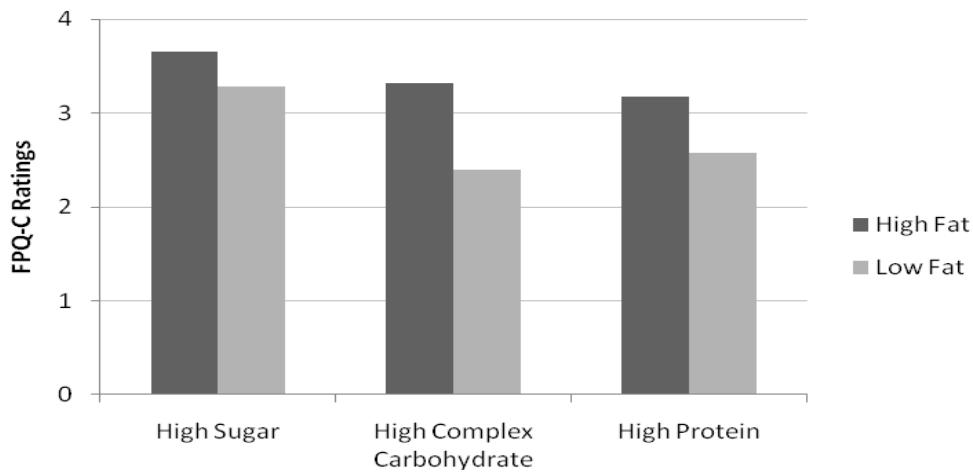


Figure 4. Ratings for the six macronutrient combination cells of the Food Preference Questionnaire-Crave, collapsed across menstrual cycle phase.

The three way interaction of menstrual cycle phase, fat level, and other macronutrient was not statistically significant, however a non-significant trend was detected, $F(1.38, 45.40) = 2.64, p = .10, \text{partial } \eta^2 = .07$. Exploratory follow-up analyses were conducted to compare each of the six FPQ-C cells (High Fat/High Simple Sugar, High Fat/High Complex Carbohydrate, High Fat/High Protein/Low Carbohydrate, Low Fat/High Sugar, Low Fat/High Complex Carbohydrate, and Low Fat/High Protein) across late follicular and late luteal phases. See Table 4 for FPQ-C cell values and results of dependent-subjects t-tests. No significant differences were found at the $p < 0.05$ level. A non-significant trend was found such that high fat/high complex carbohydrate and low fat/high protein ratings were higher during the luteal phase compared to the follicular phase.

Additional Analyses

Some past studies have suggested that the increase in food cravings may be particularly prominent during the few days prior to menses (Bancroft et al., 1988; Rozin et al., 1991). Thus,

Table 4. Values for Food Preference Questionnaire-Crave cells during follicular phase and luteal phase.

	Phase		<i>t</i> value	<i>p</i> value	Cohen's <i>d</i>
	Follicular	Luteal			
High Fat/High Sugar	3.73 (1.47)	3.57 (1.23)	0.593	.56	.08
High Fat/High Complex Carbohydrate	3.11 (1.51)	3.54 (1.61)	-1.93	.06	.33
High Fat/High Protein	3.05 (1.57)	3.29 (1.47)	-1.25	.22	.22
Low Fat/High Sugar	3.17 (1.50)	3.40 (1.51)	-1.35	.19	.23
Low Fat/High Complex Carbohydrate	2.29 (1.18)	2.50 (1.36)	-1.15	.26	.21
Low Fat/High Protein	2.55 (1.41)	2.81 (1.60)	-1.72	.09	.30

Note. *N* = 34.

we re-examined the effects of menstrual cycle phase on FCQ-S scores (Aim 1) utilizing only those participants who had fewer than three days between their laboratory session and the first day of their menses. Eighteen participants met this criterion. For these participants, craving ratings during the follicular phase ($M = 9.58$, $SD = 2.84$) did not differ significantly from luteal phase ratings ($M = 10.61$, $SD = 2.04$), $F(1, 17) = 1.76$, $p = .20$, partial $\eta^2 = .094$. Craving intensity ratings were greater post-cue ($M = 10.72$; $SD = 2.16$) compared to pre-cue ($M = 9.47$, $SD = 1.95$), $F(1,17) = 9.54$, $p = .007$, partial $\eta^2 = .36$. The craving rating did not differ across cue trials as a function of cycle phase, $F(1, 17) = 0.148$, $p = .705$, partial $\eta^2 = .009$.

Next, differences in amount eaten between the follicular and luteal phase (Aim 2) were re-examined utilizing only those 18 participants who had completed their luteal session with fewer than three days between the session and menses onset. No difference in amount eaten was found between kcals eaten during the follicular phase ($M = 272.1$, $SD = 117.9$) and the luteal phase ($M = 279.4$, $SD = 118.8$), $F(1,17) = .04$, $p = .84$, partial $\eta^2 = .002$.

Finally, the macronutrient specificity of changes in desire for foods over cycle phases (Aim 3) was examined, utilizing only those individuals tested within three days of their menses. As above, a $2 \times 2 \times 3$ within subjects ANOVA was conducted with the dependent variable of

ratings on the FPQ-C Intensity and independent variables of cycle phase (late follicular and late luteal), fat content of foods (high fat and low fat) and other macronutrient content of foods (high sugar, high complex carbohydrate, and high protein). The effect of phase was not significant, $F(1,17) = 1.36, p = .26, \text{partial } \eta^2 = .07$. Cycle phase did not significantly interact with fat level, $F(1,17) = 0.14, p = .71, \text{partial } \eta^2 = .008$, or with other macronutrient content, $F(2,34) = 0.60, p = .56, \text{partial } \eta^2 = .03$. Additionally, the interaction of cycle phase \times fat level \times other macronutrient content was not significant, $F(1.38, 23.45) = 0.07, p = .87, \text{partial } \eta^2 = .004$. In this analysis, a main effect of fat level was found, $F(1,17) = 10.66, p = .005, \eta = .39$. High fat foods ($M = 3.61, SD = 1.19$) were rated as more desired than low fat foods ($M = 2.93, SD = 1.15$). No main effect of other macronutrient content was found, $F(2,34) = 0.89, p = .42, \eta = .05$, nor was the interaction of fat level and other macronutrient content significant, $F(1,17) = 0.76, p = .48, \eta = .04$.

An additional analyses was done in which the other FCQ-S subscales (Positive Reinforcement, Negative Reinforcement, Lack of Control, and Physiological) were examined to determine if cycle phase or cue presentation affected these dimensions of craving, with the FCQ-S subscales as dependent variables. Four 2×2 ANOVAs were conducted with the independent variables of cycle phase (follicular and luteal) and cue status (pre- and post-cue). All 35 eligible participants were included in this analysis. Results are summarized in Table 5. No significant effects of cycle phase were found, and the phase by cue status interaction was not significant. Significant main effects of cue were found for Positive Reinforcement, Negative Reinforcement,

and Lack of Control, with participants rating these dimensions of food craving higher post cue compared to pre cue (see Table 5 for means, standard deviations, and *F*-values).

Table 5. Means and standard errors for Food Craving Questionnaire- State subscale rating during follicular and luteal phase, pre- and post-cue

	Follicular Phase		Luteal Phase		Total		Phase Effect <i>F</i> -value	Cue Effect <i>F</i> -value	Inter-action <i>F</i> -value
	Pre-Cue	Post-Cue	Pre-Cue	Post-Cue	Pre-Cue	Post-Cue			
FCQ-S Positive Reinforcement ^a	8.97 (1.89)	9.72 (2.32)	9.06 (1.93)	9.69 (2.04)	9.02 (1.58)	9.70 (1.87)	0.01	12.70 [†]	0.07
FCQ-S Negative Reinforcement ^b	8.79 (2.53)	9.09 (2.96)	9.09 (2.50)	9.76 (2.83)	8.94 (2.12)	9.42 (2.53)	1.14	4.89*	1.02
FCQ-S Lack of Control ^b	6.36 (2.06)	7.85 (2.67)	6.09 (1.89)	7.97 (2.87)	6.23 (1.61)	7.91 (2.41)	0.04	36.25 [†]	0.81
FCQ-S Physiological	9.76 (2.85)	9.91 (2.82)	10.00 (2.82)	10.65 (2.60)	9.88 (2.62)	10.28 (2.33)	1.63	2.19	1.55

Note. *N* = 34 unless otherwise noted. * $p < .05$, [†] $p < .001$. ^a 2 cases missing. ^b 1 case missing.

DISCUSSION

The current study tested three specific hypotheses related to differences in food cravings and food intake between the late follicular and late luteal phases of the menstrual cycle. Contrary to the first hypothesis, the intensity of cravings for preferred high fat/high sugar chocolate candy was not stronger during the late luteal phase, nor did cue exposure moderate the relationship between cycle phase and craving. The second hypothesis, that the intake of chocolate candy during an *ad libitum* eating episode would be greater during the luteal phase, was also not supported. Lastly, contrary to the third hypothesis, participants did not report a luteal phase increase in desire to eat high fat/high sugar foods when rating their desire to eat a wide variety of foods varied in macronutrient content. Interestingly, however, a nonsignificant trend was detected suggesting a luteal phase increase in participants' desires to eat high fat/high complex carbohydrate foods and low fat/high protein foods.

Specific Aim 1

The absence of a luteal phase increase in cravings for chocolate candy found in the present study contradicts past findings in which women have reported a late luteal phase increase in food cravings, and especially chocolate cravings (Cohen et al., 1987; Hill & Heaton-Brown, 1994; Rozin et al., 1991; Yen et al., 2010). However, these past studies had many notable limitations that were addressed in the current study. For example, in the present study, food cravings were examined utilizing a laboratory-based approach to avoid retrospective bias and to control for potentially confounding factors, such as amount of food previously eaten. Additionally, a validated measure of food craving was utilized, in contrast to many past studies. Furthermore, whereas some previous researchers have failed to carefully identify menstrual cycle phases and to verify ovulation, the current study precisely defined and categorized menstrual cycle phases and had participants utilize a urinary LH test to confirm ovulation.

Unlike most past research examining food cravings across the menstrual cycle, the present study focused specifically on food cravings in response to a food cue. These results indicate that changes in cravings for chocolate candy before or after a chocolate candy cue do not vary significantly across the cycle phases examined. Though luteal phase increases in chocolate cravings have been reported in retrospective studies (Rozin, et al., 1991; Zellner, et al., 2004), the current data suggests that retrospective biases may play a role in these reports. It is noteworthy that while researchers utilizing retrospective accounts have found higher levels of chocolate craving during the late luteal phase, no known prospective or quasi-prospective studies have reported luteal phase increases in chocolate cravings.

It is possible that a luteal phase increase in chocolate craving exists, but was unable to be detected in the current study due to the specificity of this studies focus on cravings in response to food cues. Though food cues appear to be an important trigger for food cravings (Hill, 2007), surprisingly little research has examined the proximal causes of food cravings in individuals' natural environment. However, there is some evidence that in addition to food cues, negative emotional experiences are common triggers of food cravings (Christensen, 2007; Lafay et al., 2001). For example, Schlundt et al. (1993) found that boredom occurred during cravings for high sugar foods more often than when food isn't craved, and Hill et al. (1991) report that dysphoric mood often precedes cravings. Given that that many women report an increase in dysphoric mood premenstrually (Gallant et al., 1991; Reed, Levin, & Evans, 2008), it is possible that the discrepancy between this study and past studies is due to luteal phase increases in food cravings being fully mediated through emotional triggers. The current study was not designed to evaluate

the effects of the menstrual cycle on food cravings triggered by events other than exposure to food cues.

An effort was made to have participants be in a state of mild acute caloric deficit and moderate hunger at the beginning of the laboratory session. Though the effects of acute caloric restriction on food cravings have not been well studied, extreme hunger was avoided in the current study because concern about a ceiling effect, i.e., that all participants would rate their craving for chocolate as very high. Thus, participants' cravings were assessed after they had refrained from consuming any foods or beverages with kilocalories for three hours, and had only consumed between 270-290 kilocalories (i.e., the Lean Pocket lunch) within the six hours prior to the testing. This approach appeared to be effective in producing moderate hunger, as the average hunger rating at the beginning of the experiment was 52 in the follicular phase and 55 in the luteal phase on a 100 point visual analog scale. However, it is possible that different effects would be found if participants were in greater acute caloric deficiency at the time of testing, given the known relationship between hunger/caloric deficits and food cravings (Cepeda-Benito et al., 2001). Future research should examine if menstrual cycle-related changes in cravings are detectable when participants are in a state of greater food deprivation than in the current study.

Though cue-related cravings did not differ across menstrual cycle phases in the current study, participants did report an increase in craving for chocolate candy following exposure to the chocolate candy cue. This is consistent with past research showing cue-induced increases in food cravings (Ferriday & Brunstrom, 2011; Nederkoorn et al., 2000; Rejeski et al., 2010), and provides further evidence that environmental food cues contribute to food cravings.

Specific Aim 2

A second aim of this study was to determine if intake of a palatable high fat/high sugar food would be greater during the late luteal phase of the menstrual cycle than the late follicular phase. Contrary to the hypothesis, no difference was found in the amount of candy eaten between the cycle phases examined. This appears inconsistent with the vast majority of studies examining food consumption across the menstrual cycle, which have typically found greater food intake during the late luteal phase (Bryant et al., 2006; Buffenstein et al., 1995; Lyons et al., 1989; Pelkman et al., 2001). However, these studies have typically examined food intake over the course of multiple days, utilizing either self-report food diaries (Bryant et al., 2006; Reimer, Debert, House, & Poulin, 2005) or laboratory-based measurements of food intake in which food is weighed (Fong & Kretsch, 1993; Gong, Garrel, & Calloway, 1989). Unlike these past studies, the current study examined changes in food intake during two discrete eating episodes in which only one type of food was available. It is feasible that measuring food intake during only one eating session in which only one type of food was provided contributed to the absence of the expected effect of phase on food intake. A few other studies have recently examined food intake across the menstrual cycle in single eating episodes. In one study, no difference in food intake was found between follicular and luteal phases in women without PMDD during a single eating episode in which a wide variety of foods were available (Reed et al., 2008). In another study utilizing a single eating episode and six types of foods, a significant difference between the follicular and luteal phase was reported when oral contraceptive users and non-oral contraceptive users were combined, however an examination of the means revealed that the difference was greater in oral contraceptive users (Tucci, Murphy, Boyland, Dye, & Halford, 2010), and it is

unclear if the difference would have reached statistical significance in the non-oral contraceptive users alone.

Thus, the current study adds to past research suggesting that a single eating episode may not be sufficient to detect menstrual cycle-related changes in appetite that are commonly found in studies that measure food intake over an entire day or multiple days (Gong et al., 1989; Pelkman, et al., 2001). In addition to the effects of utilizing a single eating episode, it is also possible that the use of a single food item contributed to the null findings. Indeed, researchers have found that individuals tend to eat more when a greater number of foods are presented (Rolls et al., 1981; Stubbs, Johnstone, Mazlan, Mbaiwa, & Ferris, 2001). The current results suggest that this effect could be exacerbated in the late luteal phase of the menstrual cycle. Regardless, the current findings shed doubt upon the hypothesis that the luteal phase is a time of specific difficulty for the control of chocolate candy intake.

Specific Aim 3

The hypothesis that there would be a specific increase in desire to eat high fat/high sugar foods during the late luteal phase was not supported. Though this hypothesis was not supported, evaluation of the changes in desire to eat foods with other macronutrient content profiles over the menstrual cycle revealed interesting preliminary results. Though the differences were not statistically significant, there were trends suggesting that high fat/high complex carbohydrate and low fat/high protein foods were more strongly desired in the luteal phase compared to the follicular phase. Indeed, an examination of mean ratings indicated that foods in the high fat/high sugar category were the only ones for which participants reported, on average, a lower desire to eat in the luteal phase. Furthermore, the effect size (Cohen's *d*) for the follicular to luteal phase

change in desire ratings for all macronutrient categories with the exception of high fat/high sugar was $d = .21$ or greater, which is in the small effect range, whereas the high fat/high sugar effect size was $d = .08$, well below the cutoff authors have suggested for a small effect (Cohen, 1988).

In addition to the absence of a luteal phase increase in desire to eat high fat/high sugar foods, no difference was found between the phases in overall desire to eat foods. Given the substantial evidence that food intake increase in the luteal phase, these results indicate that there may be a discrepancy between individuals' subjective, explicit desire to eat food, and objectively measured changes in food intake during the luteal phase.

Whereas past researchers examining the effects of cycle phase on macronutrient content of food intake have reported equivocal results, those studying food cravings have typically not assessed for cycle-related differences in macronutrient content of craved foods. One of the few studies that reported on the macronutrient content of craved foods across cycle phase did not find a difference in the types of foods craved (Hill & Heaton-Brown, 1994). However, the method utilized to classifying foods in this study was not transparent, and the study relied on retrospective self report and utilized imprecise menstrual cycle definitions (Hill & Heaton-Brown, 1994). In Yen et al. (2010), the FCI was utilized to compare types of foods craved during the luteal and follicular phase, and the authors reported a luteal phase increase in the Carbohydrates/Starches and Fast Food Fats subscales in non-PMDD women, and an increase in High Fat Foods in PMDD women. However, as described above, the food groupings utilized in the FCI are based on factor analytic methods and not on the specific macronutrient content of the foods, therefore limiting conclusions with regards to the macronutrient content of craved foods across the menstrual cycle in this study. Nonetheless, it is notable that those foods found to be

elevated in the luteal phase in non-PMDD women in Yen et al., i.e., those grouped as Carbohydrates/Starches and Fast Food Fats on the FCI, were similar in macronutrient content to those found to be elevated in the luteal phase in the current study, i.e. the high fat/high complex carbohydrate foods of the FPQ-C. For example, french fries, rolls, biscuits, and chips are high complex carbohydrate/high fat foods that are included on subscales elevated in the luteal phase in both the present study and Yen et al.

Regardless of menstrual cycle phases, statistically significant differences were found in the macronutrient content of foods that participants desired to eat. High fat foods were desired more than low fat foods, and high sugar foods were preferred over high complex carbohydrate or high protein foods. These results are consistent with past data suggesting that most foods cravings are for high fat foods (Gilhooly et al., 2007; White et al., 2002) and extend this to also suggest that high sugar foods are among the most highly craved or desired foods among young women. Additionally, a trend was present such that high fat/high sugar foods were desired more than some other macronutrient groups investigate, and low fat/high complex carbohydrate foods were the least desired.

Interpretation of the macronutrient content of craved foods should be considered in light of the larger task that participants were involved in on the day they completed the questionnaire. Participants were informed prior to beginning in the laboratory sessions that they would be completing a chocolate taste test. Furthermore, on the second visit participants were aware that they would be provided with a large amount of chocolate candy, as they were informed that the second visit was identical with the first. It is possible that this aspect of the study interacted with

menstrual cycle phase as to influence participants' desire for high fat/high sugar foods differently during the follicular and luteal phase.

General Discussion

Food cravings are a potential contributor to obesity and eating disorders, and appear to negatively influence overweight and obese individuals' efforts at weight loss (Gilhooly et al., 2007; Sitton, 1991; White et al., 2002). Past studies have suggested that food cravings are greater during the luteal phase in women, with potential relevance for the etiology of obesity and weight loss efforts. However, the absence of a menstrual cycle phase effect on food cravings in the current study does not support a significant role for menstrual cycle variations in obesity development or weight loss outcomes in women. Nonetheless, changes in food intake across the menstrual cycle have been well documented in past studies, and the implication of these cyclical appetite changes on weight loss efforts are not known and are worthy of further study.

The participants in our study did not differ in their reports of menstrual cycle symptoms during the day of their late follicular and late luteal visits, suggesting that our sample overall experienced low levels of premenstrual symptoms. Results of extant research has been equivocal with regards to the covariance of luteal phase changes in appetite-related symptoms and other commonly reported premenstrual symptoms, i.e., bloating, cramps, mood disturbances, etc. Reed and colleagues (2008) found that women with clinically significant premenstrual affective and other symptoms, i.e, PMDD, had more substantial increases in food intake during the luteal phase compared to women without PMDD. Similar results were obtained by Cross et al. (2001). However, other studies have also found no relationship or the opposite relationship between premenstrual symptom severity and changes in appetite-related variables (Bryant et al., 2006;

Gallant, Bowering, Short, Turkki, & Badawy, 1987). For example, Bryant et al. (2006) found that women with minimal premenstrual symptoms had greater increase in food intake than those with more severe premenstrual symptoms. Thus, though it is possible that women with greater levels of menstrual cycle symptomatology than in the current study might experience greater luteal phase increases in food cravings, past research does not strongly support that assertion.

The hypothesis that cravings for high fat/high sugar foods would be higher during the luteal phase was based on data suggesting that women have a specific increase in intake of high fat foods during the luteal phase (Reimer et al., 2005; Tarasuk & Beaton, 1991), as well as evidence that cravings for chocolate foods, which are frequently high fat/high sugar, have been reported to increase in the late luteal phase in retrospective self-reports (Rozin et al., 1991; Zellner et al., 2004). However, it is relevant to note that not all studies have found a specific increase in intake of high fat foods during the luteal phase (Bryant, et al., 2006; Martini, Lampe, Slavin, & Kurzer, 1994; Pelkman et al., 2001). Though more research is needed to determine the macronutrient specificity of food intake changes, the current study suggests that if the menstrual cycle is confirmed to have a specific effect on high fat food intake, it is not likely accompanied by subjective awareness of an increased desire to eat high fat foods.

Neurophysiological studies in animal models have found that estrogen is associated with increased dopaminergic activity and inhibition of gamma-hydroxy-butyric acid (GABA) activity in the striatum (Becker & Taylor, 2007; Carroll & Anker, 2010). As anticipated based on the role of these neurotransmitters on reward processes, it has been found that exogenous estrogen introduced to ovariectomized rodents results in greater effort to obtain cocaine (Becker & Taylor, 2007). Similar differences emerge when examining the estrous cycle of rodents, with greater

drug taking motivation observed during the estrus phase of the cycle, when estrogen levels are elevated (Becker & Taylor, 2007). Recent research has expanded these findings of different reward-related neurophysiological processing according to cycle phase to humans. In the first study of its kind, Dreher et al. (2007) found an increase in activity in reward-related circuitry (including the caudate nuclei, midbrain region, and orbitofrontal cortex) in humans during the follicular phase compared to the luteal phase during the anticipation and delivery of a monetary reward. As the follicular phase is associated with high levels of estrogen and low levels of progesterone, this is consistent with the animal literature.

Though this line of research has primarily focused on the implications of these menstrual cycle-related neurophysiological changes for substance use, it is well known that the reward circuitry for food and drugs are overlapping (Volkow, Wang, Fowler, & Telang, 2008). In a recent study examining brain activity in response to pictures of low calorie and high calorie foods, it was found that reward-related areas (nucleus accumbens, amygdala and hippocampus) were more responsive to food images during the follicular phase, similar to the results found for a monetary reward (Frank, Kim, Krzemien, & Van Vugt, 2010). Unfortunately, the implications for this differing neurological activity on food cravings and food intake across cycle phases are not clear. It has been found that reduced dopaminergic activity is associated with obesity, and has been suggested that overeating is a compensatory mechanism for weaker reward processing (Volkow et al., 2008; Wang et al., 2001). If this is accurate, the neurophysiological findings would be consistent with past findings of greater food intake during the luteal phase and possibly inconsistent with current findings suggesting no change in food cravings. Additional research is

needed to identify the implications of differing neurophysiological activity patterns on food cravings and food intake across the menstrual cycle.

Limitations

This study has a number of limitations. Not all potentially relevant variables were controlled. Though an attempt was made for nutritional status to be equivalent prior to the follicular and luteal laboratory sessions, it is possible that this was not the case. Participants were instructed to consume the same breakfast for both sessions, however, it is possible that they inadvertently or knowingly ate more breakfast or a different breakfast during their luteal phase. Additionally, food eaten the day or night prior to the session was not controlled, and phasic differences may have existed, with potential implications for craving ratings. More specifically, it is possible that participants consumed more chocolate or more high fat/high sugar foods on the day of testing or days prior to testing. Sensory specific-satiety, the tendency for consumed foods to be rated less hedonically pleasing or less desired than foods dissimilar to recently eaten items (Rolls, 1986), could therefore contribute if participants had recently eaten foods similar to the chocolate candy provided in the study.

Our study was limited by our methods of cycle phase verification. Though we conducted more extensive cycle verification than past studies examining food cravings by having participants conduct and report on urinary LH tests and report how many days between their luteal phase visit and menses. However, it is possible that participants were inaccurate or dishonest in their reporting. Obtaining serum hormone levels or performing ultrasounds provides the most accurate measurement of menstrual cycle phases, though it is not practical for all studies due to the costs (Hampson & Young, 2007). Despite these concerns, confidence in the

accuracy of these reports are increased because we only included participants who were tested within seven days of their menses starting, and therefore excluded participants whose menses start date was inconsistent with their reported LH surge date.

An additional limitation of the current study is the absence of a control cue. Without a control cue comparison condition, we cannot verify that changes in craving ratings from pre- to post-cue were specific to the cue presented, as an alternative explanation is that they were affected by repeated testing/time effects. Future studies would benefit from the use of a control group exposed to a non-food cue.

Another limitation of the current study is that participants were aware that the study was focused on changes in food responding across the menstrual cycle, and thus responses may have been influenced by demand characteristics and expectancies about menstrual cycle fluctuations in appetite. Awareness that a study is assessing menstrual cycle symptoms has sometimes been found to result in an increased reporting of symptoms in the luteal phase (AuBuchon & Calhoun, 1985). Gallant et al. (1991) found few effects of awareness of study focus on menstrual cycle symptom reporting, however they did find that women who were aware of the study focus reported lower food cravings in the follicular phase than women who were not aware. These findings suggest that study focus awareness may result in a greater contrast in craving ratings between follicular and luteal phases. However, Gallant et al.'s study did not focus specifically on eating behavior across the menstrual cycle. Such a specific focus could have a different impact on the effect of study awareness on outcomes. Additionally, the food craving variable utilized by Gallant et al. (1991) was actually a composite of rating for food cravings and self-reported

weight gain rating. Thus, it cannot be ruled out that study awareness in the current project led to an attenuation of contrasts in craving ratings between the follicular and luteal phases.

Conclusion

The current study did not lend support to the hypothesis that cravings for a high fat/high sugar preferred chocolate candy increase during the late luteal phase of the menstrual cycle in response to a food cue. This suggests that any increases in food craving that occurs during the late luteal phase may be mediated by other triggers, such as emotional states. In addition to an absence of a menstrual cycle phase effect on cue-related craving, participants also did not report a luteal phase increase in desire to eat high fat/high sugar foods when rating desire to eat a variety of foods on a well-validated measure that systematically and significantly varies macronutrient content of foods. In fact, the presence of a nonsignificant trend suggested that the luteal phase may be a time of increased desire to eat high fat/high complex carbohydrate and low fat/high protein foods. Though past studies have consistently shown luteal phase increases in amount of food eaten, participants in the current study did not consume more chocolate candy in the late luteal phase, possibly due to measuring food intake in one eating session and providing only one type of food. These results suggest that cue responding, at least to a high fat/high sugar chocolate food, does not differ in the late follicular and late luteal phase, and that changes in desire to eat food during the luteal phase may be most prominent in foods that are not high fat/high sugar.

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VITA

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