AND I'M HUNGRY LIKE THE MOM: INFLUENCES ON APPETITE DURING PREGNANCY AND POSTPARTUM

by

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ABSTRACT

JAN T. MOONEY. And I'm Hungry Like the Mom: Influences on Appetite During Pregnancy and Postpartum. (Under the direction of DR. JENNIFER B. WEBB)

Maternal eating patterns during pregnancy and the first year postpartum contribute to short and long-term maternal and child health outcomes. Food choices result from an interaction between individual-level appetite and the diversity and quantity of foods available to the individual. Appetite, the motivational drive to eat, is regulated by both internal and environmental factors and occurs both within and outside of physiological energy deprivation. Through three manuscripts, this work examined psychophysiological influences on maternal appetite and their interrelations to understand how these factors present in pregnancy and postpartum, how they change over time, and their role in predicting the development of specific food desires. The Power of Food Scale (PFS), a measure of hedonic hunger, assesses perceived responsiveness to food stimuli in the environment. PFS retains stable psychometric properties and remains at similar levels across its subscales through pregnancy and the first year postpartum. In contrast, leptin, a hormone with roles in satiety, reward, and reproduction, shows a positive mean change over the same time. Neither these appetitive influences nor dietary restraint was associated with variability in cravings concurrently or prospectively during pregnancy or postpartum. Overall, the results of these studies suggest that these appetite influences vary relatively independently during pregnancy and postpartum, in contrast to relationships observed outside this time. Future research could build upon these findings by incorporating additional appetitive influences and/or increasing the frequency of assessments to capture fluctuations within trimesters or the first year postpartum.

DEDICATION

To my grandmother and very first friend, Janaki, whose unconditional love, zest for learning, and boundless curiosity were the very definition of resilience.

To my mother, Gita, whose immeasurable labor and sacrifice gifted me with the time, opportunity, and privilege to learn.

To my brother, Nathan, with whom I have laughed, cried, and persisted through a great many hard things.

To my aunt, Latha, who has shared both her wisdom and her unending sense of wonder.

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To Lena, who knows me well enough to remind me who I am when I forget myself.

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BMI	Body-mass index
CFI	Comparative fit index
FIML	Full-information maximum likelihood
NEXT	Next Generation Health Study
PFS	Power of Food Scale
PEAS	Pregnancy Eating Attributes Study
RMSEA	Root-mean-squared error of approximation
SRMR	Standardized root-mean-squared residual
TLI	Tucker-Lewis index
US	United States

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW AND SCOPE

Maternal eating behaviors during pregnancy and the first year postpartum influence short- and long-term maternal and fetal health outcomes, in part through their effect on maternal diet quality. Diet quality itself results from an interaction between individual-level appetitive processes and the diversity and quantity of foods available at any given time. Maternal diet quality is associated with early childhood cognitive functioning (Borge et al., 2017), heart rate variability in infants (Krzeczkowski et al., 2020), lower odds of preterm birth and low birthweight (Abdollahi et al., 2021), and inversely associated with maternal depressive symptoms (Boutté et al., 2021; Khan et al., 2020) and pregnancy hypertension (Abdollahi et al., 2021).

While hunger describes a sense of acute or impending energy deprivation (Lowe & Butryn, 2007), appetite, defined here as the motivational drive to eat, is regulated by both internal and environmental factors and occurs both within and outside of energy-deprived states (Levine & Billington, 1997; Rogers & Brunstrom, 2016). The Embodied Self Model (Cook-Cottone, 2020; Figure 6.1) serves as an organizing framework for examining influences on appetite because it centers embodiment: the experience of living in one's body (Piran & Teall, 2012). The Embodied Self Model posits that positive embodiment is an important facilitator of well-being and is maintained by interpreting and responding to internal signals (e.g., thoughts, emotions, physiological sensations) while also managing external demands (e.g., interpersonal, sociocultural). Body experiences such as appetite may thus be the result of interacting internal and external influences. Consequently, depending on individual characteristics and environment, internal and external forces vary in their impact on individuals' appetites.

From a psychological perspective, hedonic hunger, measured by the Power of Food Scale (PFS; Cappelleri et al., 2009), describes an individual's self-reported responsiveness to food cues in the environment (Lowe et al., 2009; Lowe & Butryn, 2007). PFS is associated with increased activity in reward-related brain regions when viewing palatable food cues, regardless of satiety (Espel-Huynh et al., 2018). Hedonic hunger was initially conceptualized as a trait and thought to be relatively stable over time. Yet, it has been observed to change in response to weight loss interventions (Cushing et al., 2014), suggesting that the psychological and physiological changes common to pregnancy and postpartum may also be associated with changes in hedonic hunger. For example, comparing across samples, PFS was higher in pregnant (M = 2.3, SD = 0.7) (Liziewski, 2020) versus non-pregnant individuals (M = 1.7, SD = 0.7; Cohen's d for difference in independent samples = 0.8) (Cappelleri et al., 2009). In a previous analysis of the present sample (pregnant/postpartum women in the southeastern United States), diet quality was inversely associated with overall PFS (averaged across pregnancy trimesters); however, postpartum diet quality and PFS were unrelated (Nansel et al., 2020). To ensure that these are actual differences in hedonic hunger rather than differences in how the measure is functioning, the psychometric properties of the PFS should first be evaluated across pregnancy and postpartum.

Appetite is also regulated physiologically within the neuroendocrine system: leptin is one well-established contributor (Woods & Langhans, 2012). Leptin is a metabolic messenger that communicates between adipose tissue and the hypothalamus to downregulate food intake, informed by how much stored energy is available, termed the "hypothalamic pathway" (Boyle & Le Foll, 2020). Leptin levels are also negatively associated with reward activity in the brain (Figlewicz & Benoit, 2009): higher leptin levels are associated with less reward signaling, which is thought to reduce the perceived potential reward of food and thereby reduce intake. Leptin is also associated with reproductive functioning, increasing throughout pregnancy and decreasing sharply following birth. Pregnancy has often been described as a "leptin resistant" state, meaning that weight gain occurs throughout pregnancy even with increasing leptin levels (Andrikopoulou et al., 2021). However, research has not yet examined whether changes in leptin during pregnancy and postpartum are associated with self-perceptions of food responsiveness (i.e., hedonic hunger) during this time.

As they are both influences on appetite, metabolic and reward-related physiological regulation (leptin) and sensitivity to environmental food cues (hedonic hunger) may contribute to food cravings, defined as strong desires to eat a specific food item (Hormes & Rozin, 2010). Hedonic hunger has previously been associated with cravings in United States undergraduate students (Forman et al., 2007). Though seemingly counterintuitive, given its typical role in satiety and in downregulating reward, leptin has been positively associated with cravings in a community adult sample (Chao et al., 2017). As leptin is thought to downregulate the dopaminergic response to cues to reduce food-seeking, cravings may represent a state of perceived deprivation which may motivate food-seeking (Laque et al., 2015; Macedo & Diez-Garcia, 2014). Another mechanism may be leptin resistance, in which the reward and satiety systems become insensitive to the effects of leptin, making it possible to have both strong desires for food and a high concentration of leptin (Reichelt et al., 2015), as has been thought to occur during pregnancy (Chehab, 2014). Yet, psychological responses to the idea of gaining weight or bodily change during pregnancy and postpartum may modify how appetite influences relate to cravings.

Socio-cultural narratives regarding eating behaviors continue to influence individuals during pregnancy and postpartum, such as the importance of protecting the fetus from any potential risk (Nash, 2012) and the need to "bounce back" after birth to emulating the "thin ideal" (Nippert et al., 2021). As a result, individuals may exert dietary restraint via effortful control to prevent weight gain (Lowe & Butryn, 2007). Individuals may respond differently to the experience of hedonic hunger when exerting effortful control over their dietary intake, modifying the relationship between hedonic hunger and cravings with variable resulting diet quality. Yet, these efforts may have an inconsistent or limited effect. Dietary restraint was not related to diet quality in a sample of undergraduate students in the United States (Jeffers et al., 2020) nor a sample of pregnant women in the United States (Most et al., 2019). In contrast, previous analyses of the sample examined in this work found a positive association between dietary restraint and diet quality during pregnancy and postpartum (Nansel, Lipsky, & Faith, 2020). These inconsistencies may be due to sub-factors within the measurement of dietary restraint. Thus the psychometric properties of this measure should be re-examined prior to testing its relationship with other influences on appetite.

In sum, individual-level variability in effects on appetite and efforts to respond to appetite may present differently within compared to outside of pregnancy and postpartum. Physiological changes in organ functioning, weight, and metabolism during pregnancy and postpartum, as well as psychological changes in response to the personal or interpersonal dynamics of pregnancy and postpartum, have the potential to influence relationships among leptin, hedonic hunger, cravings, and dietary restraint, necessitating formal tests of these relationships during pregnancy and postpartum. The current project examined influences on appetite during pregnancy and postpartum within the internal setting of the Embodied-Self Model (Cook-Cottone, 2020; see Figure 6.1), including physiological and cognitive-affective signals.

The first aim of this work was to evaluate the psychometric properties of a widely-used self-report measure of hedonic hunger, the PFS (Lowe et al., 2009), during pregnancy and postpartum. Measurement equivalence was examined across pregnancy trimesters, within postpartum, and in comparison to a nationally representative sample of young women in the United States to determine whether this measure is appropriate for use in pregnancy and postpartum and, if so, whether hedonic hunger persists during these periods. Additionally, convergent validity was examined by testing relationships of hedonic hunger with constructs thought to be conceptually related but empirically distinct, including emotional eating, external eating, food-related delay of gratification, and dietary restraint. The second aim of this project was to investigate the concordance between physiological and psychological manifestations of the reward potential of food by examining time-varying associations of hedonic hunger and leptin over the three trimesters of pregnancy and through the first year postpartum. To better understand the role of general appetite influences on specific food desires, the third aim of the project was to explore concurrent and prospective relations of hedonic hunger, leptin, and dietary restraint with cravings during pregnancy and postpartum.

1.2 SIGNIFICANCE

Pregnancy and postpartum involve changes in the structure and function of multiple body systems, including the endocrine system and metabolism (Soma-Pillay et al., 2016), and changes in the socioemotional experience of the body, such as how connected to or present in the body one feels (Talmon et al., 2019; Talmon & Ginzburg, 2018). These changes may influence how individuals recognize and interpret external (e.g., food cues in the environment) and internal (e.g., hunger, satiety, desire for food) appetite signals during this time. The Embodied-Self Model posits that awareness of and responsiveness to internal cues (e.g., physiological sensations, emotions, cognitions) in balance with external demands (e.g., socio-cultural, interpersonal) facilitates and maintains well-being (Cook-Cottone, 2006, 2015, 2020). Given the need to balance multiple internal (e.g., physiological, psychological) and external (e.g., interpersonal, community, socio-cultural) sources of information and feedback during pregnancy and postpartum, assessing linkages among metabolic, cognitive, and emotional influences on appetite during pregnancy and postpartum has the potential to inform targets for improving maternal well-being.

While hedonic hunger is conceptualized as a temporally stable construct (Lowe et al., 2009; Lowe & Butryn, 2007), behavioral and dietary modifications are associated with changes in hedonic hunger (Espel-Huynh et al., 2018), suggesting that hedonic hunger may also fluctuate in response to physiological changes during pregnancy and postpartum. Therefore, to ensure that hedonic hunger can be compared longitudinally, the stability of the psychometric properties of the PFS as a measure of hedonic hunger throughout pregnancy and during postpartum must be established. Consistent psychometric properties across pregnancy, postpartum, and in comparison to non-pregnant adults would indicate that mean differences in PFS over time or during pregnancy or postpartum compared to outside of this time reflect construct-level differences (i.e., changes in hedonic hunger) versus differences in the relevance of items or other psychometric properties of the measure during pregnancy and postpartum.

Metabolic influences on appetite may also differ during pregnancy and postpartum. While leptin is stable in proportion to adipose tissue (Boyle, 2019), it usually increases during pregnancy, decreases following delivery, and increases during the early postpartum period (Liu et al., 2000; Skalkidou et al., 2009). Pregnancy has often been described as a "leptin resistant state." Yet, it remains uncertain how long this resistance persists after leptin reduces after birth, or how pregnant and postpartum individuals may subjectively experience these changes in terms of their responsiveness to food stimuli. Examining covariation in leptin and hedonic hunger trajectories over time could help clarify how individuals may subjectively experience changes in metabolic regulation and identify critical periods of greatest risk for low diet quality.

Cravings for specific foods are very salient during pregnancy and are perceived as different from physiological hunger cues (i.e., homeostatic hunger) (Blau et al., 2020). During postpartum, women may experience a resurgence of cravings and/or preference for highly palatable foods (Aubuchon-Endsley et al., 2015; George et al., 2005), following their decrease in late pregnancy (Tepper & Seldner, 1999), mirroring the trajectory observed in leptin. In addition, narratives regarding eating during pregnancy are marked by a sense of loss of control over food choices and alienation from the sense of self (Nash, 2012). Individuals may attempt to restrain their diet in order to counteract this effect. Relationships between craving type, frequency, intensity with leptin, hedonic hunger, and dietary restraint during pregnancy and postpartum had not previously been examined. Insights regarding the network of appetitive influences during pregnancy and postpartum could help individualize patient recommendations to modify influential factors on appetite and support intentional choice. Overall, results of these studies suggest that the appetite influences examined vary independently of one another during pregnancy and postpartum. Future research could build upon these findings by incorporating additional appetitive influences and/or increasing the frequency of assessments to capture fluctuations within trimesters or the first year postpartum.

CHAPTER 2: LITERATURE REVIEW

2.1 THEORETICAL AND CONCEPTUAL FRAMEWORK

Pregnancy and postpartum represent transitional periods during which multiple sources of information, demand, and need, such as maternal emotional and physiological needs, fetal physiological needs, familial, community, and socio-cultural demands, and provider recommendations, may factor into eating behaviors (Nash, 2013; Olson, 2005). Cultural, social, and interpersonal transmissions of public health guidance designed to reduce the risk for birth defects and infant mortality (ACOG, 2021), provider recommendations, and other external sources of feedback may expand beyond their original intention or purpose to take on a moral or ethical tone. Qualitative work summarizing the perspectives of pregnant women in Australia places maternal desires and fetal needs at odds with one another: "[food] consumption in pregnancy is something of a nine-month battle between the selfish habits of a pregnant woman and the developmental needs of her unborn child" (Nash, 2012, p. 134). This description highlights the theme of maternal[1] responsibility for fetal health, such that eating behaviors during pregnancy become "more than the physical act of consumption…[They become] a social act charged with moral weight." (Nash, 2012, p. 132). In turn, "giving in" to (i.e., satisfying or eating in accordance with) cravings during pregnancy is experienced by some pregnant individuals as an inability to control oneself and a prioritization of maternal desires over fetal needs (Nash, 2013).

Yet, despite the focus on fetal health, women continue to experience pressures to maintain control of body shape and weight through exercising dietary restraint, to avoid socially undesirable outcomes such as postpartum weight retention (Nash, 2012, 2013). In contrast,

[1]The terms "maternal" and "mother" are used here as gender-inclusive terms, to recognize the diversity of individuals who experience pregnancy or postpartum. To acknowledge limitations inherent in existing theory, frameworks, and the composition of samples in prior research, we use the term "women" when applicable.

others attribute cravings to the needs or preferences of the baby or focus on the baby in order to avoid “giving in” when cravings occur (Blau et al., 2020). In sum, socio-cultural discourses dictate that mothers should be highly conscious of their food choices during pregnancy, often for external reasons not clearly linked to their own health and well-being. Socialization of these externally-driven practices may, in turn, have implications for diet quality.

This dichotomous narrative may also extend into postpartum. For example, a recent review including studies from the United States, Australia, Singapore, and China reported that greater alignment with dietary guidelines during postpartum is associated with fewer symptoms of postpartum depression (Opie et al., 2020), highlighting the public and individual health importance of a focus on factors influencing diet quality. Yet, much-published research maintains a focus on reducing or minimizing postpartum weight retention (positioning food choice as an avenue to attain weight loss), either to avoid higher weight in the long term or to avoid a negative impact on children (Bijlholt et al., 2020; Huseinovic et al., 2014, 2016). Narratives such as these are consistent with “problematizing the body,” which refers to viewing the body as an object to be controlled (e.g., Cook-Cottone, 2020; Duncan, 1994). Qualitative research has identified influences on this problematization, including cultural and personal beliefs, provider directives, and family dynamics (Moore et al., 2021; Nash, 2013).

In contrast, positive embodiment reflects connectedness between the mind and the body at the intersections of internal and external settings (Piran, 2016), such that demands from larger, external systems such as socio-cultural, community, and interpersonal systems, are recognized as such and balanced with the prioritization of internal signals such as cognitions, emotions, and physiological needs. Piran and colleagues have advanced a program of research to define embodiment and how it is constructed through interactions in physical, mental, and social power domains (Piran & Teall, 2012). Qualitative research with young adult Canadian women (as described in Piran, 2017; Piran et al., 2002; Piran & Teall, 2012) illustrates the importance of body ownership (Physical Freedom), the impact of societal expectations on the experience of the body (Mental Freedom), and the impact of systems of oppression on the experience of the body (Social Power) in shaping (dis)embodiment over the developmental life course. Disruptions in embodiment might manifest as disordered eating patterns, preoccupation with body shape and/or weight, or self-injurious behaviors. On the other end of this spectrum, a sense of connectedness, caring for and joy in one's body, or positive embodiment, results from interactions with the environment that are characterized by physical and mental freedom and social power (Piran & Teall, 2012). Cook-Cottone's work (e.g., Cook-Cottone, 2006, 2015, 2020) emerges from this broader socio-political study of embodiment to examine embodiment as an illustration of the level of attunement among external and internal aspects of the self.

The Embodied-Self Model (Figure 6.1) posits that awareness of and responsiveness to internal signals (e.g., physiological sensations, emotions, cognitions) in balance with external demands (e.g., socio-cultural, interpersonal) facilitates and maintains positive embodiment, which is supportive of overall well-being (Cook-Cottone, 2020). A recent meta-analysis (Linardon et al., 2021) found that intuitive eating, which describes eating in response to hunger and satiety cues as opposed to emotional or situational cues (Tribole and Resch, 1995, as summarized in Tylka, 2006), is associated with interoceptive awareness, the conscious perception of internal sensations (Khalsa et al., 2018; Mehling et al., 2012). Intuitive eating is also inversely associated with eating restraint and shape and weight concerns (Linardon et al., 2021).

Awareness and interpretation of internal signals may differ during pregnancy and postpartum (compared to experiences outside of these periods). From one perspective, pregnancy and postpartum may involve increased internal attunement and intensified bodily sensations (Rubin & Steinberg, 2011; Shelton, 2007; Zaides et al., 2021). Pregnant individuals may orient toward internal sensations because of their focus on the developing fetus (Rubin & Steinberg, 2011; Talmon & Ginzburg, 2018). During postpartum, mothers may identify their body experience as a way to connect with their babies. First-time Israeli mothers who interpreted their bodily sensations and the baby's bodily language as communicating important information tended to rely on these interpretations to self-regulate and to calm the baby (Shuper Engelhard et al., 2021). In contrast, neuroendocrine research indicates that although peripheral concentrations of hormones may be increased during pregnancy, sensitivity to hunger and satiety signals may be lessened, resulting in reduced effectiveness of metabolic signaling (Douglas et al., 2007). Mothers who viewed theirs and the baby's "body knowledge" as inaccessible tended to seek out external, concrete recommendations (Shuper Engelhard et al., 2021), suggesting that individuals who feel unable to access and use their internal sensations may seek out external stimuli or feedback. During both pregnancy and postpartum, mothers must navigate socio-cultural and biomedical expectations as well as personal/internal signals (Nash, 2012). Viewed through the lens of embodiment, responsiveness to external food stimuli may reflect the degree to which pregnant and postpartum individuals are able to orient to bodily signals and support overall well-being.

2.2 THE ROLE OF FOOD CUES IN THE ENVIRONMENT

In environments in which a diverse range of foods are widely available, the omnipresence of highly palatable foods may contribute to an ongoing appetite for these foods, even when subjective satiation has been reached. Hedonic hunger describes this appetitive drive to consume palatable foods, driven in part by thoughts and emotions about food, environmental exposure to these foods, and thoughts and emotions regarding the consumption of palatable foods (Lowe & Butryn, 2007). Conceptually, hedonic hunger varies between individuals, and those who exert effortful control (i.e., restraint) over their eating behaviors may do so in response to hedonic hunger (e.g., in order to prevent weight gain; Lowe & Butryn, 2007), such that individuals higher in hedonic hunger would also be more likely to exert effortful control to avoid or resist eating. Paradoxically, this ongoing restraint may contribute to a state of perceived deprivation, which may in turn be associated with cravings (Forman et al., 2007; Orloff & Hormes, 2014). As such, hedonic hunger as examined here is thought to be relevant primarily to contexts in which food is readily and plentifully available (Lowe et al., 2009; Lowe & Butryn, 2007).

The Power of Food Scale (PFS; Lowe et al., 2009) is a self-report measure of hedonic hunger containing three factors, though many studies use overall PFS (calculated by averaging the subscale scores) to represent hedonic hunger (e.g., Appelhans et al., 2012; Burger, 2017; van Dillen et al., 2013; Werthmann et al., 2011). The Food Available (PFS-Available) factor is conceptualized as the strength of response to the general availability of food in the environment. The Food Present (PFS-Present) factor reflects the strength of response to food cues (e.g., visual, olfactory) in the immediate environment. Finally, the Food Tasted (PFS-Tasted) factor is the strength of response to or anticipation of tasting food (Cappelleri et al., 2009). PFS is associated with brain activity in regions related to food reward (Burger et al., 2016) and with palatable food intake when impulsivity is high (Appelhans et al., 2012), suggesting when impulsivity is high, it may be more difficult to inhibit the influence of hedonic hunger on food intake. PFS has also been associated with other indicators of external influences on appetite, such as emotional and external eating (Aliasghari et al., 2020; Lowe et al., 2009; Ribeiro et al., 2015). In addition, PFS measurement properties (e.g., item-subscale relationships) appear to be stable across several sub-populations of non-pregnant individuals, including weight status, race categories, and the gender binary (Serier et al., 2019). However, measurement properties and convergent validity of the PFS have not been examined during pregnancy and postpartum, contributing to uncertainty regarding the interpretations of any comparisons made across this time or with other groups.

As one example, a previous analysis of the present sample (pregnant women in the southeastern United States) indicated that diet quality was inversely associated with overall PFS (averaged across pregnancy trimesters); however, postpartum diet quality and PFS were unrelated (Nansel, Lipsky, Faith, et al., 2020). Similarly, while previous research posited that dietary restraint is a response to hedonic hunger to avoid weight gain (e.g., as summarized by Lowe & Butryn, 2007), this relationship may not be present or may present differently in pregnancy and postpartum given the internally conflicting messages regarding permission to increase food intake to support fetal development and breastfeeding while also underscoring the need to return to and/or maintain the thin body ideal, a pressure which may persist into postpartum (Clark et al., 2009; Coyne et al., 2018). Yet, interpretations of these findings rely on consistent psychometric properties of the measure during this time, which still need to be tested. If PFS measurement equivalence is supported during pregnancy and postpartum, replicating relationships between hedonic hunger and related constructs such as dietary restraint would further support the validity of the PFS during pregnancy and postpartum.

Measurement equivalence is supported by the accumulation of evidence of consistent measurement properties across multiple avenues, of which the following are the most relevant to the present work:

a. *configural equivalence*, which tests the consistency of the overall structure of the measurement (e.g., which items are associated to each of the hypothesized subscales),
b. *metric equivalence*, which tests the consistency of the relationships between the latent factors and indicators (i.e., the associations between PFS-Tasted, PFS-Present, PFS-Available, and their respective items),
c. and *scalar equivalence*, which tests the consistency of item values when there is no contribution from the underlying factor (i.e., the equivalence of item intercepts).

If supported, these types of equivalence suggest that mean scores on the measure can be compared over time with confidence that any differences or change observed can be attributed to differences in the underlying construct (i.e., hedonic hunger) rather than being an artifact of changes in the measurement over time. Alternatively, the lack of evidence for equivalence could suggest that different underlying concepts are being measured across pregnancy and postpartum or that items have different relevance to the underlying concept of hedonic hunger at these different points. Evaluation of item-subscale relationships could identify irrelevant or malfunctioning items that may need to be reformulated, removed, or shifted to another subscale, given that some experiences may be unique to the periods of pregnancy and postpartum.

Once equivalence is established, the next step would be to test associations of pregnancy and postpartum PFS with other eating-related measures with previous theoretical/conceptual or empirical support for their relationship with PFS. Support for these associations would determine the applicability of the previous nomological network of hedonic hunger during pregnancy and postpartum, allowing interpretations of observed relationships, differences, and examination of new potential mediators or moderators of hedonic hunger. Along with changes in weight and eating pressures during pregnancy and postpartum, these critical reproductive periods are also marked by changes in metabolism, including large fluctuations in leptin, a hormone with roles in multiple systems, including the reproductive system, weight regulation, and the reward system, with relevance for the regulation of appetite.

2.3 METABOLIC INFLUENCES ON APPETITE

While some research draws a clear distinction between hypothalamic and mesolimbic pathways influencing appetite as "homeostatic" versus "non-homeostatic," research in both animal and human samples supports a close interplay across these pathways, both of which are focused on maintaining a state of balance (Reichelt et al., 2015). Hypothalamic pathways operate in response to fluctuations in blood glucose induced by stresses on the system (e.g., pain, exercise, illness), as well as longer-term availability of stored energy in the form of adipose (i.e., fat) tissue (Myers & Olson, 2012; Timper & Brüning, 2017). Food-related environmental cues can activate dopamine signaling in the mesolimbic pathway, contributing to a positive feedback loop that increases sensitivity to these food-related cues over time (Reichelt et al., 2015). Fluctuations in leptin, an adipokine that modulates food intake via hypothalamic and mesolimbic pathways (Boyle & Le Foll, 2020), illustrate this integrative set of feedback mechanisms.

In non-pregnant individuals, leptin signals how much stored energy is available in the body, thus regulating food intake via indirect mechanisms such as changing sensitivity to satiation signals (Knight et al., 2010). Low leptin is associated with greater brain dopamine activity, such that food is experienced as more rewarding to prompt greater intake (Figlewicz & Benoit, 2009). In contrast, high leptin is associated with leptin resistance and disturbances in the brain reward system in animal models, suggesting that increased motivated action may occur to compensate for blunted reward signaling (Laque et al., 2015), resulting in more "seeking" as evidenced by greater self-reported food responsiveness, craving frequency, or craving intensity (Macedo & Diez-Garcia, 2014).

Leptin typically increases during pregnancy, decreases at delivery, and increases during early postpartum (Liu et al., 2000; Skalkidou et al., 2009). During pregnancy and postpartum, higher-than-typical leptin concentrations may be associated paradoxically with increased activity in the brain reward system, as observed in leptin-resistant states outside of pregnancy (Aliasghari et al., 2019). Thus, hedonic hunger may be positively associated with leptin during pregnancy and postpartum. However, the relationships between maternal hedonic hunger and maternal leptin levels throughout pregnancy and postpartum have not been examined. Testing associations between hedonic hunger and leptin levels could yield insight regarding the interplay of physical and cognitive/emotional sub-domains of the internal signals mentioned in the Embodied Self Model (Cook-Cottone, 2020) as relates to influences on appetite. Negotiating and balancing these internal influences amidst changes in weight, shape, and external pressures to monitor eating behaviors may precipitate cravings, defined here as strong drives toward specific foods (Hormes & Timko, 2011; Orloff & Hormes, 2014).

2.4 DESIRES FOR SPECIFIC FOODS

Cravings are common during pregnancy (Orloff & Hormes, 2014) with published estimates ranging from 33-50% in the United States dating back to the late 1800s (as summarized by Bayley et al., 2002; Weingarten & Elston, 1990) though less is known regarding cravings in postpartum (Tepper & Seldner, 1999). Earlier work suggested that individuals experience cravings even at 12 months postpartum regardless of lactation status (Worthington-Roberts et al., 1989), and more recent work indicates that there may not be differences across pregnancy or between pregnancy and postpartum (Most et al., 2020). However, a recent review indicated that cravings might have a stronger influence during pregnancy versus during postpartum, and encouraged continued research in this area toward clarification (Bijlholt et al., 2020).

Based on research in the United States, cravings typically peak (in both frequency and intensity) during the second trimester of pregnancy and drop following delivery (Belzer et al., 2010; Orloff & Hormes, 2014). Research examining cravings across the menstrual cycle indicates that non-cued cravings may change in intensity and targeted food across cycle phases, in alignment with hormonal fluctuations (Hallam et al., 2016). Similarly, hormonal changes typical to pregnancy and postpartum may also precipitate craving type, intensity, and frequency shifts.

Previous investigations of cravings in pregnancy and postpartum have focused on specific types (e.g., sweet; Belzer et al., 2010), specific populations (pregnant adolescents; Pope et al., 1992), or cravings in the setting of specific conditions (e.g., gestational diabetes mellitus; Belzer et al., 2010; Tepper & Seldner, 1999), largely neglecting influences on appetite identified outside of pregnancy or postpartum including hedonic hunger, leptin, and dietary restraint. The

Embodied Self Model (Cook-Cottone, 2020) posits that embodiment experiences are the result of negotiations between internal and external influences. As a result, testing psychometric properties of the PFS, mapping the longitudinal trajectories of psychological and metabolic influences on appetite, and evaluating the contributions of these influences and intentional dietary restraint to the experience of cravings during pregnancy and postpartum will improve our understanding of pregnant and postpartum embodiment in the domain of appetite.

2.5 SPECIFIC AIMS

The present work investigates influences on appetite during pregnancy and postpartum, through the following specific aims:

1. Evaluate the psychometric properties of the PFS in women during each trimester of pregnancy and at six months postpartum:
    a. Test measurement equivalence across pregnancy trimesters, in postpartum, and in comparison to a nationally representative sample of United States young adult women.
    b. Examine convergent validity with dietary restraint, emotional eating, external eating, and food-related delay of gratification.
2. Examine time-varying associations of hedonic hunger and leptin throughout pregnancy and during postpartum.
3. Test associations among leptin, hedonic hunger, dietary restraint, and craving frequency and intensity:
    a. Examine cross-sectional associations during the first trimester of pregnancy.
    b. Investigate prospective associations of first-trimester leptin, hedonic hunger, and dietary restraint with second-trimester food cravings.
    c. Investigate prospective associations of first trimester leptin, hedonic hunger, and dietary restraint with 12 months postpartum food cravings.
    d. Examine cross-sectional associations during 12 months postpartum.
    e. Test whether dietary restraint moderates the concurrent and prospective relationships of hedonic hunger with cravings.

CHAPTER 3: BILLBOARDS, BABY BUMPS, AND BIRTH: PSYCHOMETRIC PROPERTIES OF THE POWER OF FOOD SCALE DURING PREGNANCY AND POSTPARTUM

Journals planned for submission: *Appetite, Eating Behaviors*

3.1 ABSTRACT

Pregnancy diet quality contributes to short and long term maternal and infant health outcomes and is thought to be inversely associated with hedonic hunger, the drive to consume highly palatable foods (independent of subjective satiety). The Power of Food Scale (PFS), a self-report measure of hedonic hunger, comprises three subscales (response to general availability of food, immediate availability of food, and anticipation or actual tasting of food). PFS is often represented as an overall mean and is thought to remain stable over time. Yet, pregnancy dietary and physical changes may co-occur with changes in hedonic hunger and its measurement with the PFS. In this study, measurement equivalence of the PFS was investigated using confirmatory factor analysis across pregnancy and during postpartum, using data collected from an observational cohort study conducted in the southeastern United States. Findings suggest that, when present, factor score differences on the PFS across pregnancy and postpartum likely reflect true differences in construct levels rather than an artifact of changes in the measurement itself. In addition, the PFS in this sample of women during pregnancy and postpartum demonstrated partial measurement equivalence with a representative sample of US young adult women. Future work should test the implications of multiple scoring models (e.g., factor scores, overall average, composite, etc.) to determine the most appropriate way to score the PFS when used during pregnancy and postpartum to improve efficiency and parsimony of analyses. Future use of the PFS in pregnant and postpartum samples may benefit from a cognitive assessment approach or open-ended questions to assess how the items are being interpreted in this context and whether they need to be revised.

Keywords: pregnancy, postpartum, appetite, hedonic hunger, measurement

3.2 INTRODUCTION

Maternal diet quality influences short- and long-term maternal and child health through its effects on the intrauterine environment, maternal mental health, and child neurodevelopment (Borge et al., 2017; Boutté et al., 2021; Englund-Ögge et al., 2014; Khan et al., 2020; Krzeczkowski et al., 2020). Foods such as fruits, vegetables, grains, and lean protein sources contribute to higher diet quality. In contrast, foods higher in added sugar, fat, and sodium are often more palatable but contribute to lower diet quality. Diets with a greater proportion of highly palatable foods contribute to adverse health outcomes, including risk for gestational diabetes (Shin et al., 2015) and symptoms of postpartum depression (Opie et al., 2020). Average diet quality during pregnancy (Marshall et al., 2022) and postpartum (Opie et al., 2020) is suboptimal. A recent review of diet-related interventions during pregnancy and postpartum emphasized that interventions should be individualized to target behavior (Beulen et al., 2020). Examining inter-individual differences in responsiveness to food cues in the environment, measured by the Power of Food Scale (PFS) (Cappelleri et al., 2009), may inform development of individualized interventions. However, it is uncertain whether the PFS is appropriate to measure responsiveness to environmental food cues during pregnancy and postpartum. Thus the present study examines the psychometric properties of the PFS during this time.

Hunger, a state of acute energy deprivation or subjective experience of impending energy deprivation (Lowe & Butryn, 2007) is considered the cause of appetite, defined here as the motivational drive to eat. However, most individuals in varied, plentiful food environments are unlikely to experience long-term energy deficits (Rogers & Brunstrom, 2016). As changes in energy reserves from one meal to the next tend to be minimal, factors outside of energetic need may also contribute to motivation to eat (Rogers & Smit, 2000). Internal and external factors influence appetite and may do so individually and interactively (Levine & Billington, 1997; Rogers & Brunstrom, 2016; Rogers & Smit, 2000). Internal factors may include physiological sensations, hormonal signals, thoughts, and emotions, whereas external factors may include food cues in the environment, interpersonal dynamics, and societal expectations related to eating (Cook-Cottone, 2020; Levine & Billington, 1997).

Hedonic hunger refers to "thoughts, feelings, and urges about food in the absence of any short- or long-term energy deficit" (Lowe & Butryn, 2007, p. 432) and represents an individual's self-evaluated responsiveness to food cues in the environment. The PFS (Lowe et al., 2009) was created to measure hedonic hunger as a general tendency or trait which summarizes an individual's responsiveness at three levels of food proximity (Cappelleri et al., 2009). Though hedonic hunger is commonly operationalized as the PFS overall mean (Appelhans et al., 2011; Burger, 2017; van Dillen et al., 2013; Werthmann et al., 2011), the PFS contains three subscales reflecting the perceived proximity of the food stimuli. The "Food Available" (PFS-Available) construct describes responses to perceiving food as accessible, the "Food Present" (PFS-Present) construct represents the response to food cues in the immediate environment (e.g., smell, sight of food), and the "Food Tasted" (PFS-Tasted) construct reflects responses to tasting (or anticipation of tasting) food. This three-factor (subscale) structure has been tested and supported in United States children and adolescents (Mitchell et al., 2016), college students across varying racial/ethnic identity, gender, and weight status (Serier et al., 2019), as well as in Iranian (Aliasghari et al., 2020) and Portuguese (Ribeiro et al., 2015) adult samples.

As a trait, hedonic hunger was conceptualized as stable over time (Lowe et al., 2009; Lowe & Butryn, 2007). The PFS demonstrates moderate test-retest reliability in United States undergraduates (r = .77) (Cappelleri et al., 2009) and in emerging adults (ICCs ranging from .50

to .59) (Lipsky et al., 2016), with time intervals ranging from several months to one year. However, other evidence indicates that hedonic hunger is modifiable. For example, hedonic hunger differed between individuals who have versus have not undergone gastric bypass surgery (Schultes et al., 2010), hedonic hunger decreased in individuals after they had completed a 15-week weight-loss program (Theim et al., 2013), and hedonic hunger showed nonlinear change in adolescents over 24 months following bariatric surgery (Cushing et al., 2014). There is little, if any support for a relationship between body-mass index (BMI) and the PFS (Espel-Huynh et al., 2018; Lipsky et al., 2019). Instead, it may be that weight-related interventions initiate cognitive, behavioral, affective, physiological, and/or environmental changes, which manifest as changes in hedonic hunger.

Physical and psychological changes common to pregnancy and postpartum may similarly cause hedonic hunger to (1) be different relative to non-pregnant or postpartum individuals and/or (2) change over time within pregnancy and postpartum. Comparing across studies, hedonic hunger may be higher in pregnant (M = 2.3, SD = 0.7) (Liziewski, 2020) versus non-pregnant individuals (M = 1.7, SD = 0.7; Cohen's d for difference in independent samples = 0.8) (Cappelleri et al., 2009). Yet, comparisons of hedonic hunger across groups assume that the PFS functions similarly in both groups, which may not be the case. For example, items which function differently during pregnancy or postpartum might inaccurately inflate or deflate the overall score, causing differences that do not reflect actual differences in hedonic hunger. Before making these comparisons, measurement equivalence of PFS across pregnancy and postpartum must be established to ensure that observed differences reflect differences in the construct of hedonic hunger rather than how the measure (PFS) functions.

To further evaluate the validity of the PFS for measuring hedonic hunger during pregnancy and postpartum, PFS should also be associated with correlates or outcomes of hedonic hunger suggested by prior research or theory (convergent validity). In previous work, overall PFS has been associated with emotional eating and external eating in Portuguese students and candidates for bariatric surgery (Ribeiro et al., 2015), in US and UK university students (Lowe et al., 2009), and in Iranian adults (Aliasghari et al., 2020). Dietary restraint has evidenced inconsistent and weak associations with overall PFS or subscales (Ribeiro et al., 2015) though it has been proposed to occur alongside hedonic hunger (Lowe & Butryn, 2007). In women with overweight or obesity, PFS was not associated with inhibitory control, but for women who had less inhibitory control, PFS was associated with palatable food intake (Appelhans et al., 2011). Based on theory and prior research, validity of the PFS as a measure of hedonic hunger during pregnancy and postpartum could be further evaluated by testing relationships of PFS with emotional eating, external eating, dietary restraint, and delay of gratification (inhibitory control).

In sum, testing the psychometric properties of the PFS through measurement equivalence and convergent validity testing throughout pregnancy and postpartum will evaluate support for the validity of PFS as a measure of hedonic hunger during these periods. To support cross-group and longitudinal inferences regarding hedonic hunger during pregnancy and postpartum, the structure of the PFS, item-subscale relationships, and item properties must be systematically examined. Thus, the primary aim (Aim 1A) of the present study is to test the longitudinal measurement equivalence of the PFS during pregnancy and postpartum and in comparison to a sample of United States emerging adult women (Lipsky et al., 2016). The PFS may also be differentially related to typical correlates of hedonic hunger during pregnancy and postpartum. Yet, relationships between hedonic hunger and other eating-related constructs, such as dietary restraint, emotional eating, external eating and food-related delay of gratification, have been tested infrequently during pregnancy or postpartum. The secondary aim (Aim 1B) of this study is to evaluate the convergent validity of the PFS during the first trimester of pregnancy and 6 months postpartum using constructs thought to be conceptually related to and empirically distinct from hedonic hunger: emotional eating, external eating, dietary restraint, and food-related delay of gratification.

3.3 METHOD

3.3.1 PEAS

The present study uses data from the Pregnancy Eating Attributes Study (PEAS; Nansel et al., 2016), a longitudinal observational cohort study. The overarching goal of PEAS was to investigate neurobehavioral influences on eating behavior and weight change during pregnancy and through the first year postpartum.

3.3.1.1 PARTICIPANTS

Recruitment for PEAS occurred at two obstetric clinics within the University of North Carolina at Chapel Hill Healthcare System from November 2014 to October 2016. Participant inclusion criteria included: gestational age ≤ 12 weeks, early pregnancy Body-mass index (BMI) ≥ 18.5 kg/m^2, ability to read and write English, plan to give birth at the University of North Carolina Women's Hospital and plan to remain in the geographical area for at least one year postpartum. Exclusion criteria were multiple pregnancy, use of medication known to affect diet or weight, and medical or psychiatric conditions that would present a contraindication for participating in the study (e.g., self-reported eating disorder, pre-existing diabetes, or other major chronic illness). A total of 458 women were enrolled in the study, and planned data collection was complete for all time points by June 2018.

3.3.1.2 PROCEDURES

Potential participants were identified for PEAS by reviewing the electronic medical record of scheduled pregnancy clinical visits. Potential participants were offered information about the study and the opportunity to provide informed consent. Study visits were conducted at first trimester (≤12 weeks gestation; $M = 9.8$, $SD = 1.7$), 16-22 weeks gestation (second trimester), 28-32 weeks gestation (third trimester), four to six weeks postpartum, six months postpartum, and 12 months postpartum. Survey measures were completed online for the first trimester visit before 15 weeks, six days gestational age. For the second trimester, survey measures were completed between 16 weeks and 27 weeks, six days. For the third trimester, surveys were completed between 28 weeks and 36 weeks, six days. In postpartum, time 4 visits were completed between four and 14 weeks postpartum, time 5 visits were conducted between 23 and 31 weeks postpartum, and time 6 visits were completed between 50 and 58 weeks postpartum. Participants accessed a study website (hosted by the data coordinating center) to complete online questionnaires. Research staff at the University of North Carolina at Chapel Hill followed up with participants regarding survey completion. The University of North Carolina at Chapel Hill Institutional Review Board approved all procedures. The University of North Carolina at Charlotte Institutional Review Board granted permission to conduct secondary analyses with these data.

3.3.1.3 MEASURES

3.3.1.3.1 HEDONIC HUNGER

Hedonic hunger was assessed using the PFS (Lowe et al., 2009), during first, second, and third trimesters, six months postpartum, and 12 months postpartum. The PFS is a 15-item self-report measure of hedonic hunger, “a generalized tendency toward preoccupation with food despite the absence of a short-term energy deficit” (Lowe & Butryn, 2007, p. 438). The PFS has been conceptualized as having a general factor representing hedonic hunger, comprised of three subscales: Food Available (six items; general availability/accessibility of food, e.g., “When I know a delicious food is available, I can’t help myself from thinking about having some”), Food Present (four items; responsiveness to food that is immediately present, e.g., “If I see or smell a food I like, I get a powerful urge to have some”), and Food Tasted (five items; responsiveness to food that is tasted or about to be tasted, e.g., “Just before I taste a favorite food, I feel intense anticipation”). Response options for each item are provided on a five-point scale and range from don’t agree at all (1) to strongly agree (5) and are not anchored to a specific period. The authors (Cappelleri et al., 2009) indicate that the measure should be scored by averaging the item scores for items within subscales for the individual subscale scores, and across subscales to create an overall score (ranging from 1-5), with higher values indicating a higher level of hedonic hunger.

3.3.1.3.2 DIETARY RESTRAINT, EMOTIONAL EATING, AND EXTERNAL EATING

The Dutch Eating Behavior Questionnaire (van Strien, 2002; van Strien et al., 1986 Original Dutch version - 1986, English version - 2002), which measures dietary restraint, emotional eating, and external eating, was administered at first trimester, six months postpartum, and 12 months postpartum. Items are rated on a five-point scale ranging from never (1) to very often (5) and scores are averaged within each scale to create composites (ranging from 1-5) with higher levels indicative of greater levels of the construct measured by the scale. The scales are not anchored to time. The Dietary Restraint scale contains 10 items, such as “Do you try to eat less at mealtimes than you would like to eat?” Previously proposed dimensions of intentions to restrict food intake and behavioral restraint (Larsen et al., 2007) have not previously been examined during pregnancy or postpartum. Thus, a confirmatory factor analysis was undertaken to evaluate support for a two-factor versus one-factor structure prior to using the measure in any subsequent analyses. The Emotional Eating scale contains 13 items, with higher levels indicating a greater self-perceived tendency to eat in response to emotions. Of the 13 items, nine query specific emotions, such as “Do you have a desire to eat when you are anxious, worried, or tense?” and four query diffuse emotional experiences, such as “Do you have a desire to eat when you are feeling lonely?” The External Eating scale contains 10 items, with higher levels indicating a greater self-perceived tendency to eat in response to external cues. An example item is, "If you see or smell something delicious, do you have a desire to eat it?"

3.3.1.3.3 ABILITY TO DELAY FOOD-RELATED GRATIFICATION

The Delaying Gratification Inventory-Food (DGI-Food) is a subscale within the Delaying Gratification Inventory, and comprises seven items measuring the tendency to delay immediate satisfaction for an anticipated longer-term reward, specifically in the domain of food rewards (Hoerger et al., 2011). The DGI-Food was administered during the first trimester, third trimester, six months postpartum, and 12 months postpartum. Items are rated on a scale from strongly disagree (1) to strongly agree (5). Higher scores reflect a greater tendency to delay food-related gratification.

3.3.1.3.4 ANTHROPOMETRICS

BMI was calculated at the baseline visit from measured height and weight. Trained study staff measured participants' height at the initial visit to the nearest 0.1 cm using a stadiometer. Once each trimester, a standing scale measured weight to the nearest 0.1 kg. Each measurement was duplicated, and a third was taken only if the two initial measurements differed more than 0.2 kg (weight) or 1 cm (height). The two closest measurements were averaged to calculate the final value.

3.3.1.3.5 SOCIODEMOGRAPHIC CHARACTERISTICS

Participants self-reported sociodemographic information including race, ethnicity, education, household composition, receipt of social assistance programs, and family income at the initial visit; maternal age and parity were obtained from the medical record system. Income-to-poverty ratio was calculated by identifying the appropriate poverty threshold (indicated by household size and composition) and dividing the total reported household income by the poverty threshold (US Census Bureau, n.d.).

3.3.2 NEXT

Data from the NEXT Generation Health Study (*Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD), 2009), a longitudinal observational cohort study, was included to further evaluate PFS measurement equivalence in a non-pregnant adult sample (not matched on age or other demographic characteristics; demographics of the participants of the NEXT study are listed next to PEAS demographic data in Table 3.1).

3.3.2.1 PARTICIPANTS

Recruitment for NEXT used a stratified sample of school districts and a random sample of schools and constituent classrooms (as described below), resulting in an initial cohort of 2785 10th-grade students in the United States. Any participant recruited to the study was eligible for subsequent assessments. Potential participants were excluded if their parent or guardian did not provide informed consent (if they were under the age of 18) or if they did not provide assent or informed consent (when over the age of 18), if they had any developmental limitation that limited their ability to understand and provide age-appropriate responses to questions posed.

3.3.2.2 PROCEDURES

NEXT identified school districts as primary sampling units stratified by the nine major United States census divisions. In total, 137 schools were selected, of which 81 (59%) agreed to participate in recruitment. Schools with large reported percentages of students identifying as African American were oversampled to improve reliability of estimates and permit subgroup analyses. Similar considerations with respect to students identifying as Hispanic were evaluated, but existing sampling procedures yielded an appropriate subsample of these participants without additional need for oversampling. Within the participating schools, 10th-grade classrooms were randomly selected for inclusion into the recruitment process. Within these classrooms, parents were provided with information about study procedures, aims, and participation, and were encouraged to review the information with students. At the initial assessment (2009-2010 school year; and at all subsequent years when youth were below 18 years of age), parents provided informed consent and youth provided assent. After youth had reached the age of 18, they were directly approached for informed consent for all subsequent assessments. Participants completed self-administered surveys every year that queried a variety of indicators of adolescent health and health behaviors, as well as their hypothesized predictors. Wave 1 occurred in 2010 and assessments were conducted yearly until Wave 7 occurred in 2017. The PFS was administered at Waves 5 and 6, corresponding to two and three years post-high school (approximately age 20 and 21 years). Thus, only female participants who responded to assessments during either Wave 5 or Wave 6 were included in these analyses, resulting in a total possible sample size of 1333. All procedures were approved by the Institutional Review Board of the National Institute of Child Health and Human Development.

3.3.2.3 MEASURES

3.3.2.3.1 HEDONIC HUNGER

The PFS described above was administered at Wave 5 and Wave 6.

3.3.2.3.2 SOCIODEMOGRAPHIC CHARACTERISTICS

Participants self-reported age, sex, and racial/ethnic identity at the initial (grade 10) assessment.

3.3.3 ANALYTIC PLAN

All data analyses were conducted in *R* v4.1.3 through the graphical user interface *RStudio* v2022.02.3 (R Core Team, 2022; RStudio Team, 2022). Pre-analysis data management included: data missingness analysis using the *naniar* package (Tierney et al., 2021), descriptive statistics, and univariate (e.g., histograms) and multivariate (e.g., scatterplots, Mahalanobis distances) normality testing, to evaluate support for assumptions underlying planned analyses. To establish the initial structure, an initial confirmatory factor analysis (CFA) tested the fit of a three-factor PFS model at the baseline time point relative to a one-factor model. Scaling across all models was accomplished through the constraint of latent factor variances rather than through constrained factor loadings so that all factor loadings could be estimated.

Internal consistency of the PFS in this sample was assessed with McDonald's omega and Cronbach's alpha. Cronbach's alpha was reported because this is a typical convention and to provide a point of comparison. Cronbach's alpha is a function of item intercorrelations and thus reflects the extent to which scale variance can be attributed to a common source. However, assumptions underlying the use of Cronbach's alpha include: tau equivalence (the equivalence of all item loadings in the measure), unidimensionality of the measure, normal distribution of the scale items, continuous scale of the scale items, and no covariance among errors of the items (McNeish, 2017). In cases where these assumptions are violated, Cronbach's alpha might under- or overestimate internal consistency. In contrast, McDonald's omega is designed for congeneric scales wherein the factor loadings may differ between items, but items are equally weighted when calculating the scale score. Omega-hierarchical, used in this study to characterize the internal consistency of the PFS, allows for a multidimensional structure incorporating both a general and sub-factors.

The first aim was addressed through measurement equivalence testing, which imposes a series of constraints on parameters in the measurement model (e.g., item loading patterns for each factor, factor-to-item loadings, item intercepts) to test how similar these parameters are across groups or across time (Putnick & Bornstein, 2016; Vandenberg & Lance, 2000). A stepped approach was used to evaluate measurement and structural equivalence via configural equivalence, metric equivalence, and scalar equivalence. Configural equivalence indicates that the same structure is imposed for all groups (and model fit remains adequate). Metric equivalence indicates that items retain the same relationship to the latent factor across groups by testing whether factor loadings for each item can be constrained to equivalence across all groups without a noticeable worsening of fit. Scalar equivalence indicates that changes in the value of an item would be equally indicative of a greater level of the factor across groups, by testing whether item intercepts can be constrained to equivalence across all groups without a significant worsening in fit. These forms of equivalence were chosen because they are required in order to support comparisons of the latent means across groups or in this case, time.

Fit was assessed for models by examining the chi-square test, Root Mean Squared Error of Approximation (RMSEA) and standardized root-mean residual (SRMR), along with the CFI. Changes in Comparative Fit Index (CFI) greater than .01 and statistically significant chi-square difference test results were used as primary indicators of nonequivalence (Cheung & Rensvold, 2002; Putnick & Bornstein, 2016). For RMSEA and SRMR, smaller values indicate better fit (Shi et al., 2019). For CFI, larger values indicate better fit. For the chi-squared test, a non-significant result would indicate better fit. However, chi-squared tests are sensitive to sample size and evaluate for exact fit (i.e., indicate any deviation from the data) in the model. Thus a significant chi-square alone was not interpreted as an indication of poor fit. If increasing constraints did not result in a noticeable decrement in fit, the model was retained to the next stage. Equivalence was tested between first trimester, second trimester, third trimester, and six months postpartum in data from PEAS, and with the NEXT sample. Measurement equivalence testing was conducted using packages *lavaan* (Rosseel, 2012), *semTools* (Jorgensen et al., 2021), and *semPlot* (Epskamp, 2019).

To examine convergent validity, we specified an additional CFA model that hypothesized that the three correlated subscales of responsiveness to food (food available, food present, and food tasted), would demonstrate associations with emotional eating, external eating, and dietary restraint, and would be inversely associated with food-related delay of gratification. Before examining these relationships, we tested competing models of a 1-factor and 2-factor structure for the Dutch Eating Behavior Questionnaire dietary restraint scale. The 2-factor structure included the "intention" and "behavior" subscales as outlined by Larsen and colleagues (2007). Convergent validity was tested with both first trimester and six months postpartum data, based on when all relevant measures were administered in PEAS. Post-hoc power analyses were conducted using the *semPower* package (Jobst et al., 2021; Moshagen & Erdfelder, 2016) to estimate power dependent on the sample size, degrees of freedom, and desired ability to detect global model misfit (RMSEA >.10).

3.4 RESULTS

3.4.1 SAMPLE CHARACTERISTICS

Approximately 28% of the PEAS sample reported that they had not obtained a four-year college degree. Approximately 32% self-identified as Black, Asian, Native American/Native Hawaiian, Hispanic/Latinx, Multi-race, or "Something not listed." Additional sociodemographic information is reported in Table 3.1. Of those enrolled in the study, 91 women voluntarily withdrew or were withdrawn by study staff during pregnancy, and 46 were withdrawn or lost to follow-up during postpartum. Missingness percentages were typical, as observed in longitudinal work (Enders, 2001). Missingness on specific item-level indicators of the PFS ranged from 13% to 34% across time points, with greater rates of missingness at later time points. By time point, approximately 13% of observations were missing at baseline, 26% of observations were missing at trimester 2, 26% at trimester 3, and 34% at six months postpartum. Of note, one item ("Just before I taste a favorite food, I feel intense anticipation.") was omitted for some participants due to an error during the creation of the online questionnaires (n = 306 in the first trimester, n = 223 in the second trimester, n = 178 in the third trimester). After being identified, this was rectified and any participants who completed questionnaires after this point had the opportunity to respond to this question. Missingness patterns for this indicator are likely non-systematic as administration of the item was based on enrollment timeline (i.e., when individuals became pregnant). Sensitivity analyses conducted across withdrawal status and missingness on the item described above did not reveal any differences.

Self-report data were only available for approximately 70 (~20%) participants at 12 months postpartum, due to an administrative decision in March 2017 (after 122 participants had already completed the final visit) to reduce participant burden by reducing the number of psychosocial/self-report questionnaires at that time point. After this decision was made, no participants had the opportunity to complete these questionnaires, so missingness is not thought to be systematic. Given the small number of participants completing the PFS at 12 months postpartum (maximum $n = 70$), PFS item-level data and factor structure were not tested at this time point and missingness is thought to be non-systematic. Ninety-one women were withdrawn from the study during pregnancy, and 46 were withdrawn or lost to follow-up during the first year postpartum (see Nansel et al., 2020 for the detailed flow of participants through the study and withdrawal reasons). Sensitivity analyses using chi-square tests examined item-level differences between those who withdrew and those who did not, as well as between those who did and did not answer item 8 of the PFS. Across these analyses, items had similar mean scores in both groups except for one item on the PFS, which demonstrated a statistically significant difference. As this difference was only observed once at the item-level and specific item-level means were not of interest, it was thought to be a minor and likely negligible influence on the results of the present analyses.

3.4.2 MEASUREMENT PROPERTIES OF THE PFS

Across time points, PFS inter-item correlations ranged from $r < .01$ to 0.82 and item means ranged from 1.39 to 3.11. As expected, item-level response distributions appeared non-normal and exhibited skewness, kurtosis, and gaps in the distribution. Based on simulation work, robust full-information maximum likelihood (FIML) estimation was selected as an approach to estimate model parameters with all available information, given its ability to achieve convergence, estimate model parameters with minimal bias, and produce stable estimates even in non-normal conditions with small sample sizes (Jia, 2016). Robust FIML was used for as many models as possible, although it became untenable in the larger combined models. Comparing robust and typical estimates when available revealed that they were consistent. Thus, typical FIML was used when robust estimates were not produced. The advantage of robust FIML lies in the calculation of standard errors rather than in estimating the parameters themselves.

The Kolgroff-Smirnov test for normality and the distribution of histograms indicated that item-level data were not normally distributed, but the estimation method (FIML) was thought to be robust to non-normality and results are interpreted with caution. While using a response scale for the items of the PFS restricted options to a set of ordered categories, a latent continuous distribution is thought to underlie responses for each item, and variables with five or more response categories approximate a normal distribution (Rhemtulla et al., 2012).

A model ($N = 353$) in which one general factor loaded onto all items demonstrated worse fit ($\chi^2 = 472.72$, $df = 90$, $p < .001$, CFI = .793, RMSEA = .110[.100, .120], SRMR = .080) in comparison to a model with three correlated latent factors representing the three subscales ($\chi^2 = 296.43$, $df = 87$, $p < .001$, CFI = .887, RMSEA = .083[.072, .093], SRMR = .068). The three subscales (PFS-Available, PFS-Present, PFS-Tasted) demonstrated moderate covariance (.704 - .739) but the inclusion of a second-order general “hedonic hunger” factor did not improve fit ($\chi^2 = 296.43$, $df = 84$, $p < .001$, CFI = .885, RMSEA = .085[.074, .095], SRMR = .068). (Note: larger values of CFI and smaller chi-square, RMSEA, and SRMR indicate better fit. Recent recommendations emphasize relative evaluation rather than adhering to absolute fit index thresholds (Hooper et al., 2008)). Modification indices suggested a cross-loading item: the item “If I see or smell a food I like, I get a powerful urge to have some” is within the PFS-Present subscale, yet had a strong loading from the PFS-Tasted factor. However, no changes were made to the items or structure as this was a preliminary test of equivalence in a new population.

Because the higher-order factor did not improve fit, the correlated three-factor model was retained for further testing.

3.4.3 PFS LONGITUDINAL MEASUREMENT EQUIVALENCE

This factor structure served as the basis for a configural equivalence model tested across pregnancy. No additional constraints (beyond those already described) were imposed in this model, except for correlated errors (residual covariances) between the same item at different time points. In addition, all residual covariances were allowed to be freely estimated. Latent factors were allowed to co-vary freely both within and across time, and the latent factor variances were again constrained to 1 to allow the factor loadings to be estimated. The configural model fit (N = 377) was similar to that of the first-trimester-only model, (χ^2 = 1740.27, df = 864, p < .001, CFI = .886, RMSEA = .052[.048, .055], SRMR = .070). The metric equivalence model, which constrained factor loadings to be equivalent over time, resulted in little if any decrement in fit (χ^2 = 1786.89, df = 894, p < .001, CFI = .884, RMSEA = .051[.048, .055], SRMR = .073). Finally, a scalar equivalence model throughout pregnancy (constraining intercepts for the same item measured at different time points) demonstrated essentially equivalent fit (χ^2 = 1860.26, df = 924, p < .001, CFI = .878, RMSEA = .052[.048, .055], SRMR = .073).

Subsequently, 6 months postpartum data were incorporated into the existing model and tested against the already constrained set of parameters for data collected at the three pregnancy trimesters (N = 383). The configural model was one in which no constraints on parameters (beyond their structure) were made for six months postpartum data (χ^2 = 3231.03, df = 1614, p < .001, CFI = .854, RMSEA = .051[.049, .054], SRMR = .076). The metric equivalence model, which constrained six months postpartum factor loadings to be equivalent to the factor loadings at the previous time points, demonstrated a similar degree of fit to the data (χ^2 = 3198.76, df =

1629, $p < .001$, CFI = .850, RMSEA = .051[.049, .054], SRMR = .091). Finally, the scalar model for first, second, third trimester, and six months postpartum did not demonstrate a marked change in fit indices ($\chi^2 = 3309.57$, $df = 1644$, $p < .001$, CFI = .848, RMSEA = .051[.049, .054], SRMR = .091) so it was retained. Factor loadings from this final model for the PEAS sample are displayed in Table 2.

3.4.4 COMPARISON WITH NEXT SAMPLE

In the NEXT sample ($N = 1333$), the PFS evidenced configural ($\chi^2 = 1910.07$, $df = 375$, $p < .001$, CFI = .939, RMSEA = .055[.052, .057], SRMR = .035), metric ($\chi^2 = 1939.24$, $df = 390$, $p < .001$, CFI = .938, RMSEA = .054[.051, .056], SRMR = .044), and scalar equivalence ($\chi^2 = 1995.82$, $df = 405$, $p < .001$, CFI = .937, RMSEA = .054[.051, .056], SRMR = .044) across Wave 5 and 6 with excellent model fit.

A combined model (N = 353 PEAS, N = 1333 NEXT) indicated unchanged fit at the configural ($\chi^2 = 1250.04$, $df = 174$, $p < .001$, CFI = .920, RMSEA = .086[.081, .090], SRMR = .048) and metric ($\chi^2 = 1304.16$, $df = 189$, $p < .001$, CFI = .917, RMSEA = .084[.079, .088], SRMR = .091) levels, though fit was decremented and suggested non-equivalence at the scalar level ($\chi^2 = 1463.18$, $df = 201$, $p < .001$, CFI = .906, RMSEA = .086[.082, .090], SRMR = .093). Formal comparisons of equivalence models with significance tests are displayed in Table 3.

3.4.5 RELIABILITY

Omega total for the PFS in PEAS ($\omega_t = .92$) was comparable to alpha ($\alpha = .91$), though omega hierarchical ($\omega_h = .75$) indicated that only about three-fourths of the variance was attributable to a general factor (assuming a bi-factor model where items load both onto a general factor as well as onto the three subscale factors), whereas a considerable quarter of the variance was attributable to specific factors, affirming the multidimensionality. Of note, the omega models constructed for the calculation of these indices were also suggestive of cross-loadings as discussed above.

3.4.6 CONVERGENT VALIDITY

The model testing convergent validity (*N* = 374) included emotional eating, external eating, dietary restraint, and hedonic hunger measured as latent variables (with all items), whereas the food-related delay of gratification measure was included as an observed variable with corrections for measurement error (loading and error variance constraints informed by a fixed reliability of .8) (Allen & Shanock, 2013; Savalei, 2019), as we had not planned to test the structure of this measure. The DEBQ-R proposed two-factor structure was not supported (inter-factor covariance = .96), so we elected to retain the 1-factor model for further testing. The final convergent validity model allowed all latent variables to freely covary (χ^2 = 2562.18, *df* = 1107, $p < .001$, robust CFI = .819, robust RMSEA = .061[.058, .064], SRMR = .072) and demonstrated some misfit globally (CFI, RMSEA) as well as locally (SRMR). A post-hoc power analysis conducted using the *semPower* package (Jobst et al., 2021; Moshagen & Erdfelder, 2016) estimated >99% power to detect misfit of RMSEA >.10. Examination of modification indices suggested cross-loadings across factors within the PFS as well as the possibility of correlated errors among items in the DEBQ with very similar item stems. This model supported covariation of all three PFS factors with DEBQ scales measuring emotional eating and external eating, and inverse covariation of the PFS factors with delay of food-related gratification. However, there was minimal support for covariation between the PFS and dietary restraint. Dietary restraint demonstrated little covariance with any other measure examined. Latent variable associations from this model are displayed in Table 4.

A model testing convergent validity at six months postpartum (N = 228; χ^2 = 1868.75, df = 1107, p < .001, robust CFI = .871, robust RMSEA = .057[.052, .061], SRMR = .065) also demonstrated some misfit globally (CFI, RMSEA) and locally (SRMR). Consistent with findings from the first-trimester visit, this model also supported covariation of all hedonic hunger subscales with emotional eating and external eating, and inverse covariation of the subscales with delay of food-related gratification. Dietary restraint was not associated with hedonic hunger or any other variables in the model, with the exception of a moderate covariance between dietary restraint and emotional eating (standardized covariance = .32). Model fit indices for the first trimester and six months postpartum convergent validity models are summarized in Table 3 for comparison purposes.

3.5 DISCUSSION

The present study examined the psychometric properties of the PFS (Lowe et al., 2009) during pregnancy and postpartum. Similar to what has been observed outside of pregnancy and postpartum, a three-factor model was supported by the data in our sample, though fit indices were lower than those documented for other samples (Aliasghari et al., 2020; Cappelleri et al., 2009). Our analyses revealed cross-loadings due to an item querying a sensory experience (i.e., smell, taste), specifically between the PFS-Tasted subscale and an item referencing the smell of food, which may have decremented model fit because that item was part of a different PFS subscale (PFS-Present). A higher-order "hedonic hunger" factor did not improve fit, and the three factors were moderately correlated. Reliability testing (with McDonald's omega) indicated that while a single general factor captured the majority of variation in items, a substantial factor-level variance was attributable to multiple dimensions. We are not aware of any published work reporting omega values for the PFS in other samples. In addition, support for this three-factor structure calls into question the typical use of the overall PFS. Averaging across the three subscales may result in some information loss, given that there remains some unique variance that is not accounted for by the relationships among factors.

Across all three trimesters of pregnancy and six months postpartum, models with the same factor structure (configural equivalence), factor loadings on specific items (metric equivalence), and intercepts (i.e., scalar equivalence, which represents equivalence of the item responses when the factor mean is zero), remained an adequate fit for the data. Considered together, these observations suggest that, if observed, factor score differences on the PFS across pregnancy and postpartum likely reflect actual differences in levels of the construct, as opposed to being an artifact of the measurement. We are unaware of any other longitudinal measurement equivalence testing having been conducted with the PFS, and this is expected given that it is not thought to be malleable except with specific intervention (e.g., weight-loss programs).

In addition, the PFS demonstrated configural and metric equivalence between the PEAS sample and a representative sample of US young adult women (NEXT study). However, the intercepts of individual items were not consistent across the PEAS and NEXT samples, suggesting that rating these items higher or lower during pregnancy and postpartum may not indicate an increase or decrease in the construct itself. Thus, comparing factor scores across these two samples would not be appropriate, as inflation or deflation of factor scores could be attributable to differences in responses to specific items, which may not represent any change in hedonic hunger. This is inconsistent with previous research indicating broad support in the literature for configural, metric, and scalar equivalence across various sub-populations (Aliasghari et al., 2020; Ribeiro et al., 2015; Serier et al., 2019). One possible reason for item response differences may be that pregnancy influences how items are interpreted. For example, items regarding unexpected, random, or powerful appetite might be less reflective of hedonic hunger if they are interpreted as being largely driven by the fetus, breastfeeding, early parenting time constraints, or other concepts unique to pregnancy/postpartum. Future qualitative work could expand on these possibilities by exploring how PFS items are interpreted by pregnant and postpartum individuals or by prompting with the overarching construct and using interview data to inform new item development.

Tests of associations of the PFS with dietary restraint, emotional eating, external eating, and food-related delay of gratification (expected inverse association) were consistent with published work and theoretical/conceptual expectation (Appelhans et al., 2011; Lawson et al., 2020; Ribeiro et al., 2015), except for a lack of support for an association between hedonic hunger and dietary restraint as theoretically expected (Lowe & Butryn, 2007). It is possible that dietary restraint may be experienced or expressed differently within pregnancy and/or postpartum (e.g., Clark & Ogden, 1999) such that it is not related to hedonic hunger during this time. Instead, individuals may be more focused on "restraint" in the sense of the quality of foods, inclusion of specific foods (e.g., fruits and vegetables), or avoidance of specific foods (e.g., foods considered harmful to the fetus or infant), rather than broad restriction of overall intake (Kidd et al., 2019; Mooney et al., 2021; Reyes et al., 2013). However, the lack of support for a relationship between hedonic hunger and dietary restraint is consistent with prior empirical findings in a Portuguese population sample (Ribeiro et al., 2015). As both studies used the same scale (Dutch Eating Behavior Questionnaire Dietary Restraint Scale; van Strien et al., 1986), this observation raises the possibility that dietary restraint and hedonic hunger may not be related.

3.5.1 STRENGTHS, LIMITATIONS, AND FUTURE DIRECTIONS

Strengths of the present study include its relatively large sample size, retention rates across several time points, and use of repeated measures permitting longitudinal measurement equivalence testing. Including the NEXT sample allowed us to make more nuanced comparisons regarding the psychometric differences of the PFS when used for pregnant and postpartum individuals. Our rigorous and systematic measurement equivalence testing approach used robust full-information maximum likelihood estimation when possible to use all available data and manage bias that may have been introduced through natural non-normality in the item-level data. Multiple competing models were tested to establish the initial factor structure, lending additional rigor to the analyses. Finally, we incorporated measures of other eating behavior constructs to test the convergent validity of the PFS in pregnancy and postpartum.

Even with these advantages, there remain some limitations to the design, data, and analyses. Although we did not identify any indications of systematic missingness, known missingness (e.g., item 8 of the PFS) and natural missingness (e.g., withdrawal and dropout) reduced the overall amount of data available, which may have contributed to estimation difficulties. The time intervals between pregnancy trimesters and six months postpartum and between the waves of the NEXT study and the pregnancy trimesters were not equivalent, so the determination of equivalence or non-equivalence may be specific to the examined interval and may not generalize to other intervals. No data was collected regarding how participants interpreted the items or their relevance to the participants' pregnancy or postpartum experience, thus we are unable to speculate regarding item-level reasons for nonequivalence.

Future work should test the implications of multiple models of scoring (e.g., factor scores, overall average, composite, etc.) to determine the most appropriate way to score the PFS when used during pregnancy and postpartum. The use of a total score implies a tau-equivalent, congeneric underlying measurement model (Little et al., 2013). Yet, as our analyses suggest, the PFS is best represented as a multidimensional scale within which items have different loadings and are associated with a specific factor. However, future testing should evaluate the real-world impacts of full-scale mean scoring, perhaps through criterion validity testing, to determine whether there are any observable implications of this scoring versus another algorithm. In addition, for those interested in the measurement of hedonic hunger using the PFS during pregnancy and postpartum, it may be helpful to incorporate some open-ended responses and/or a cognitive assessment approach to soliciting feedback regarding the questions in a future study, to assess how they are being interpreted and whether they may need to be revised. Similarly, though not unique to this study, environmental, social, and historical factors have not yet been examined about their relation to hedonic hunger and subscales, which may improve recognition of the factors influencing or moderating hedonic hunger. For now, providers or pregnant/postpartum individuals may choose to discuss hedonic hunger at a conceptual level if considered relevant in their care, to understand better how exposure to food stimuli may affect eating behaviors on an individual level.

3.5.2 CONCLUSION

Though considered a trait or general tendency that does not change without intervention, hedonic hunger may differ during pregnancy and postpartum compared to outside of these times. Our tests of the PFS's measurement equivalence, reliability, and convergent validity suggested that it is a multifactorial measure of hedonic hunger with consistent measurement properties within pregnancy and postpartum, though different from its measurement outside of these times. Hedonic hunger subscales were moderately positively associated with emotional and external eating, inversely related to the ability to delay gratification, and not associated with dietary restraint. Researchers could use this foundation of measurement equivalence and convergent validity to test for change over time in hedonic hunger during pregnancy and postpartum. Future work focusing on the measurement and use of the PFS could use a qualitative approach to explore pregnant and postpartum individuals' interpretation of PFS items alongside tests of criterion validity to inform the use and revision of the measure as needed.

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Table 3.1

PEAS and NEXT Sample Characteristics (at baseline)

Sociodemographic characteristic	PEAS		NEXT	
	Mean ± SD *or* N (%)	Range	Mean ± SD *or* N (%)[1]	Range[2]
Age	30.46 ± 4.74	18-42	20.22 ± .48	18.15-22.43
Education				
High school graduate or less	34 (9.26%)	-	626 (46.7%)	-
Some college or associate's degree	70 (19.07%)	-	637 (52.65%)	-
Bachelor's degree	108 (29.43%)	-	4 (.31%)	-
Master's or advanced degree	155 (42.23%)	-	3 (.23%)	-
Early Pregnancy Body-mass index (BMI)	27.19 ± 6.94	18.6-59.8	25.71 ± 6.53	14.53-71.66
Race/Ethnicity				
White	264 (67.3%)	-	505 (60.79%)	-
Black	59 (15.05%)	-	365 (15.84%)	-
Hispanic/Latinx	33 (8.41%)	-	357 (19.4%)	-
Asian	19 (4.85%)	-	66 (3.96%)	-
Native American/Native Hawaiian	1 (<1%)	-		
Multi-race or Something not listed	16 (4.08%)	-		
Pregnant	100%	-	41 (4.1%)	-
Nulliparous	250 (54.5%)	-	-	-
Income to poverty ratio	3.84 ± 1.97	0.39-8.41	-	-
%WIC Eligible	24.3	-	-	-

Sociodemographic characteristic	PEAS		NEXT	
	Mean ± SD *or* N (%)	Range	Mean ± SD *or* N (%)[1]	Range[2]
Gestational age at delivery	39.3 ± 2.09	23 - 42.1	-	-
Marital status				
Married/Partnered	333 (90.7%)	-	668 (52.18%)	-
Single/Separated/ Divorced/Widowed	34 (9.26%)	-	62 (4.84%)	-
Other	-	-	550 (42.96%	-

Note. Race/ethnicity identification categories are mutually exclusive.
[1]Values have been survey-weighted; [2]These values are not survey-weighted.

Table 3.2

Confirmatory Factor Analysis of the Power of Food Scale - Pregnancy and 6 Months Postpartum

PFS item	Factor loadings (constrained across time)
1. I find myself thinking about food even when I am not physically hungry. (PFS-Available)	.75
2. I get more pleasure from eating than I do from almost anything else. (PFS-Available)	.64
3. If I see or smell a food I like, I get a powerful urge to have some. (PFS-Present)	.83
4. When I'm around fattening food I love, it's hard to stop myself from at least tasting it. (PFS-Present)	.94
5. It's scary to think of the power that food has over me. (PFS-Available)	.54
6. When I know a delicious food is available, I can't help myself from thinking about having some. (PFS-Present)	.93
7. I love the taste of certain foods so much that I can't avoid eating them even if they're bad for me. (PFS-Present)	.79
8. Just before I taste a favorite food, I feel intense anticipation. (PFS-Tasted)	.82
9. When I eat delicious food I focus a lot on how good it tastes. (PFS-Tasted)	.65
10. Sometimes, when I'm doing everyday activities, I get an urge to eat "out of the blue" (for no apparent reason). (PFS-Available)	.60
11. I think I enjoy eating, a lot more than most other people. (PFS-Available)	.81
12. Hearing someone describe a great meal makes me really want to have something to eat. (PFS-Tasted)	.79

PFS item	Factor loadings (constrained across time)
13. It seems like I have food on my mind a lot. (PFS-Available)	.87
14. It's very important to me that the foods I eat are as delicious as possible. (PFS-Tasted)	.59
15. Before I eat a favorite food my mouth tends to flood with saliva. (PFS-Tasted)	.57

Note. N = 383. Loadings displayed are standardized values from factors to items in the scalar equivalence model including data from each trimester of pregnancy and 6 months postpartum, such that latent variables have a mean of zero and a variance of one. PFS-Available = Food Available factor, PFS-Present = Food Present factor, PFS-Tasted = Food Tasted factor.

Table 3.3

Measurement Equivalence Model Fit Indices

Model	CFI	ΔCFI	χ^2	*df*	$\Delta\chi^2$	Δdf	RMSEA	SRMR	Sample-size adjusted BIC
Across pregnancy - configural[a]	.886	-	1740.27	864	-	-	.052	.070	31275.05
Across pregnancy - metric[b]	.884	.002	1786.89	894	46.63*	30	.051	.073	31238.89
Across pregnancy - scalar[c]	.878	.006	1860.26	924	73.37*	30	.052	.073	31229.48
Pregnancy, 6mos PP - configural[a]	.852	-	3231.03	1614	-	-	.051	.076	38945.05
Pregnancy, 6mos PP - metric[b]	.850	.002	3271.56	1629	40.53*	15	.051	.091	38943.95
Pregnancy, 6mos PP - scalar[c]	.848	.002	3309.57	1644	38.01*	15	.051	.091	38940.33
With NEXT - configural[a+]	.920	-	1250.04	174	-	-	.086	.048	67485.45
With NEXT - metric[b+]	.917	.003	1304.16	189	54.12*	15	.084	.091	67428.11
With NEXT - scalar[c+]	.906	.011	1463.18	201	159.03*	12	.086	.093	67497.98

Note. [a]This model tests the degree to which the data supports the same structure of the measure over time/across groups. [b]This model retains the structural constraints and adds a test of whether the data supports the same factor loading for each item across time/groups. [c]This model retains the structural and loading constraints and adds a test of whether the data supports the same intercepts for each item across time/groups. [+]these models were tested between groups of pregnant (baseline Pregnancy Eating Attributes study data, first trimester pregnancy) and non-pregnant individuals (NEXT Generation Health Study young adults). PP = postpartum; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual; BIC = Bayesian Information Criterion. *Indicates change is statistically significant at $p < .05$.

Table 3.4

Convergent Validity Model Fit Indices

Model	CFI	χ^2	*df*	RMSEA	SRMR	Sample-size adjusted BIC
Trimester 1[a]	.819	2562.18	1107	.061	.072	37659.83
6 Months Postpartum[b]	.871*	1868.75*	1107	.057*	.065*	24959.57*

Note. $^{a}N = 374$. $^{b}N = 228$. CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual; BIC = Bayesian Information Criterion. *Indicates the difference between models is statistically significant at $p < .05$.

Table 3.5

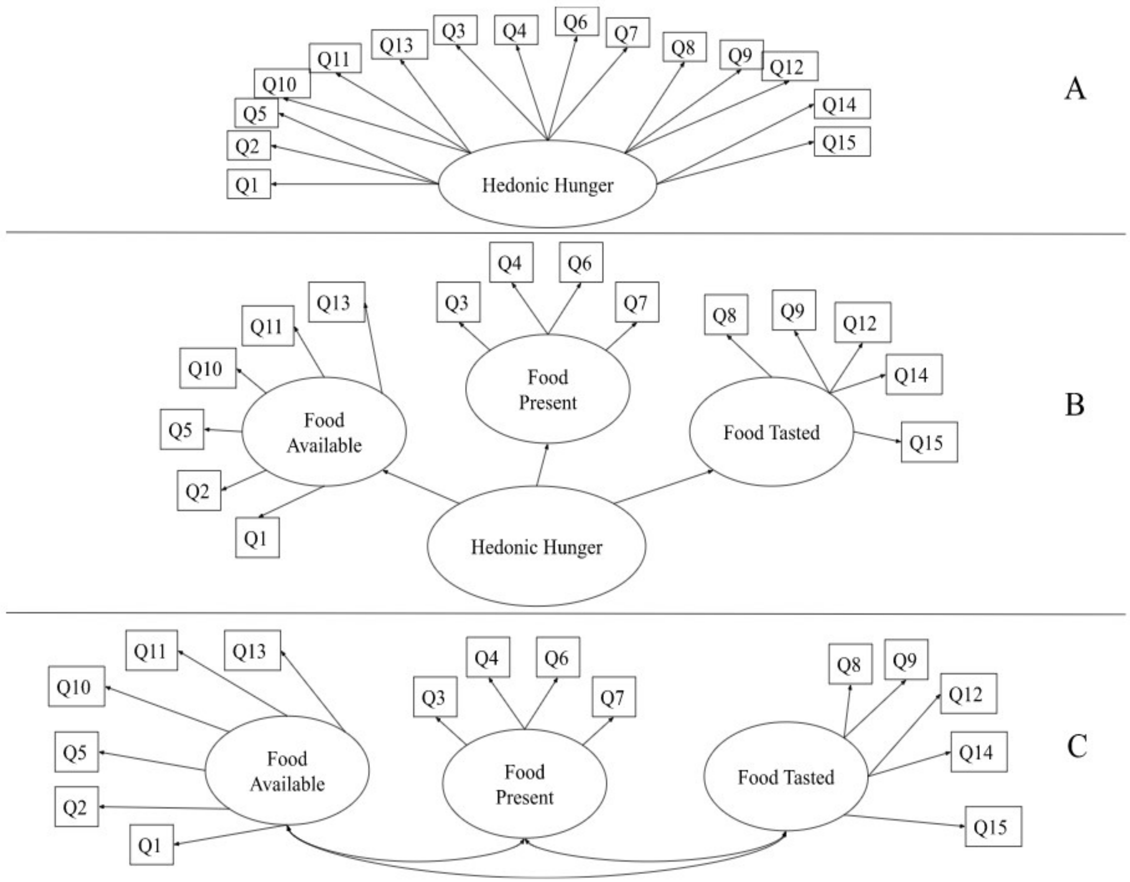
Latent Variable Associations

	PFS-Available	PFS-Present	PFS-Tasted	DEBQ Dietary Restraint	DEBQ Emotional Eating	DEBQ External Eating
PFS-Available						
PFS-Present	.72***					
PFS-Tasted	.74***	.69***				
DEBQ Dietary Restraint	.07	.12	.02			
DEBQ Emotional Eating	.49***	.55***	.33**	.29***		
DEBQ External Eating	.55***	.57***	.49***	.22**	.58***	
Delay of Gratification - Food	-.66***	-.67***	-.67***	.03	-.54***	-.65***

Note. **p* < 0.05, ***p* < 0.01, ****p* < 0.001. Values are standardized latent covariances. PFS = Power of Food Scale; PFS-Available = Food Available subscale of the Power of Food Scale; PFS-Present = Food Present subscale; PFS-Tasted = Food Tasted subscale; DEBQ = Dutch Eating Behavior QuestionnaireFigures

Figure 3.1

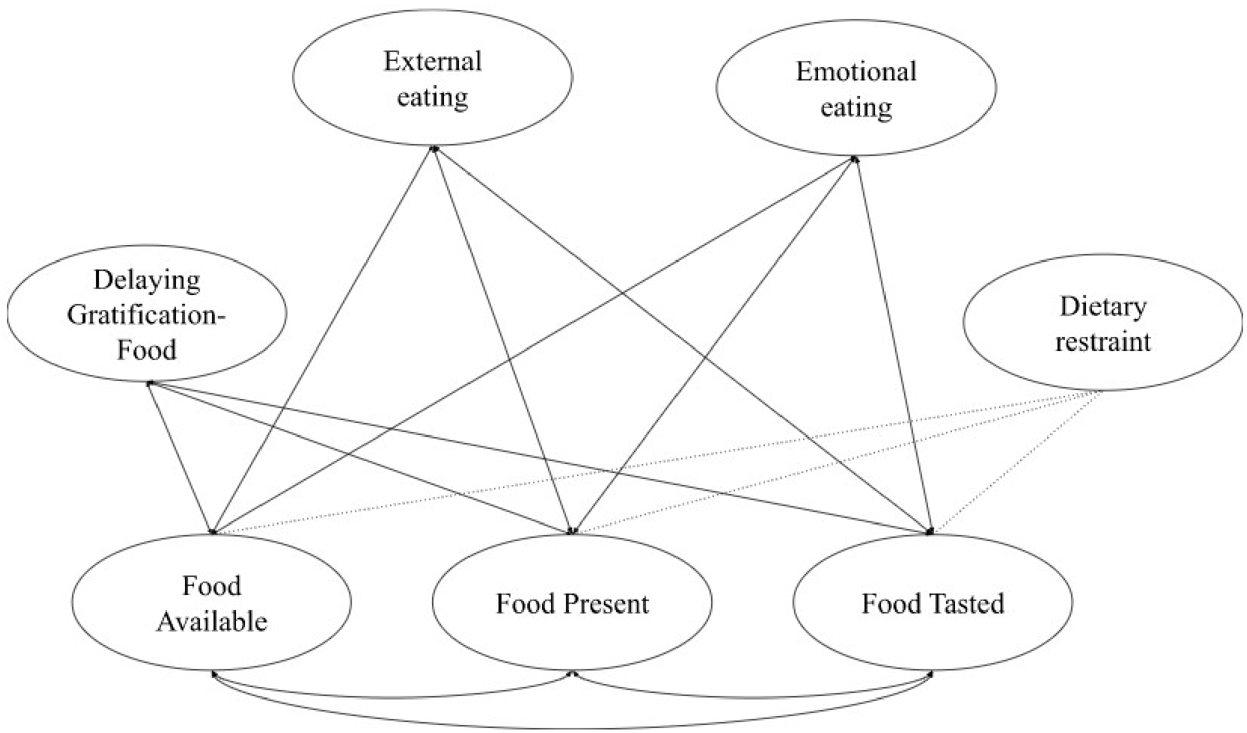
Factor Structures Tested for Power of Food Scale



Note. A = one-factor structure; B = three-factor second-order structure; C = correlated three-factor structure (retained).

Figure 3.2

Hypothesized Convergent Validity Diagram of Hedonic Hunger



Note. Solid paths indicate support for associations; dotted paths indicate unsupported directly hypothesized associations. Associations with food-related delay of gratification were inverse associations.

CHAPTER 4: THE GROWTH (OF THE) CURVE: LATENT TRAJECTORIES OF PSYCHOPHYSIOLOGICAL APPETITE INFLUENCES OVER PREGNANCY AND POSTPARTUM

Journals planned for submission: *Psychoneuroendocrinology*

4.1 ABSTRACT

Hedonic hunger, an individual's psychological responsiveness to environmental food stimuli, influences diet during pregnancy and postpartum. Leptin, an appetite-regulating hormone that increases during pregnancy and decreases after birth, may be associated with hedonic hunger because it is also thought to modulate the brain's reward response to food stimuli. However, it is unknown whether hedonic hunger changes during pregnancy and postpartum, or whether there are time-varying associations between leptin and hedonic hunger during this period. Examining longitudinal trajectories of influences on appetite could help identify ways to modify these influences. This was a secondary analysis of data from an observational cohort study conducted in the southeastern US (N = 377, mean age = 31). Participants self-reported hedonic hunger measured at three levels of proximity: "food available," (PFS-Available) "food present," (PFS-Present) and "food tasted," (PFS-Tasted) measured at each pregnancy trimester and six months postpartum; leptin was measured at each pregnancy trimester and 12 months postpartum. Latent growth curve analyses enabled tests of inter-individual and intra-individual variation in starting level and change over time, accounting for measurement error. A model including hedonic hunger subscales and leptin had an overall adequate fit across indices and reflected a moderate positive association between initial PFS-Present levels and the rate of change in leptin over time. However, there was no support for inter-individual variability in hedonic hunger subscales, suggesting that hedonic hunger remains a consistent within-person, trait-level characteristic in pregnancy and postpartum. Associations of steeper leptin change over pregnancy and postpartum with higher PFS-Present levels could indicate more leptin release to downregulate higher perceived susceptibility to immediately available food stimuli.

Keywords: pregnancy, postpartum, appetite, leptin, hedonic hunger

4.2 INTRODUCTION

Pregnancy and postpartum are periods of rapid physiological and psychological change. Changes in dietary intake during this time are often socially scrutinized and frequently framed as a matter of personal choice (Garbes, 2018). Yet, diet quality, or the extent to which one's diet is aligned with national dietary guidelines, has multiple influences. Food availability in the environment and the psychophysiological factors regulating appetite or the drive to eat (Rogers & Smit, 2000) are two key drivers of diet quality. During pregnancy and postpartum, changes in organ functioning, hormones (Soma-Pillay et al., 2016) and societal narratives about food intake (Nash, 2012, 2013) may manifest in changes in psychophysiological indicators of appetite.

The psychophysiological regulation of appetite comprises cognitive-affective aspects and biochemical factors. Hedonic hunger is defined as psychological responsiveness to food cues in the environment (Lowe & Butryn, 2007). It is considered a trait or general tendency but can change with significant eating behavior change and/or weight loss (Cushing et al., 2014; Theim et al., 2013), so it may also change during pregnancy and postpartum. Leptin is a hormone that regulates eating and body weight through satiety pathways in the gastrointestinal tract, central nervous system, and in reward pathways in the brain (Figlewicz & Benoit, 2009). It is also active in the reproductive system and rises throughout pregnancy (Andrikopoulou et al., 2021; Chehab, 2014). As leptin is active in multiple signaling pathways related to food intake and reproduction, it may also be associated with changes in food-related cognition and affect during pregnancy and postpartum. It is unknown whether fluctuations in leptin during pregnancy and postpartum are associated with hedonic hunger over this time. Examining time-varying associations of leptin and hedonic hunger could yield insight into direct associations between biochemical changes and cognitive-affective responses to food throughout pregnancy and postpartum.

The concept of embodiment, or mind-body integration, provides a relevant framework in which to consider potential time-varying relationships between leptin, a biochemical satiety and reward signal, and hedonic hunger, a response to the external food environment. The Embodied Self-Model posits that well-being is supported by positive embodiment, defined as responding to internal signals while also managing external pressures (Cook-Cottone, 2020; Piran, 2016). For appetite regulation, positive embodiment would involve recognizing and balancing the influence of food cues in the environment with internal signals communicating satiety and reward. Intuitive eating is one form of positive embodiment and describes an orientation toward internal, physiological cues in contrast to situational cues to guide the eating process (Tylka, 2006). Results of a recent meta-analysis indicated that intuitive eating is associated with interoceptive awareness, which is the ability to recognize and use physiological signals regarding the state of the body (Linardon et al., 2021). Individuals with low levels of interoceptive awareness may be more likely to eat in response to external cues, such as food advertisements (Chung et al., 2022) because they have difficulty recognizing and responding to internal signals. Balancing internal signals and external cues may be further complicated by changes in psychological and physical experiences during pregnancy and postpartum. For example, sociocultural narratives regarding what constitutes "healthy" eating during pregnancy may interfere with reliance on internal signals. Biochemical regulators of appetite, such as leptin, a satiety hormone, are also sensitive to reproductive changes.

Leptin regulates weight indirectly by signaling how much stored energy (i.e., adipose tissue) is available (Boyle & Le Foll, 2020; Knight et al., 2010; Savino & Liguori, 2008) and likely acts in concert with other hormones to downregulate food intake (Mendoza-Herrera et al., 2021). Leptin may downregulate intake within a meal (i.e., meal size) peripherally by increasing the sensitivity of receptors for cholecystokinin, a satiety factor in the gut (Andermann & Lowell, 2017; Grattan et al., 2007; Wever et al., 2021) and also centrally by acting on the arcuate nucleus and other areas within the hypothalamus to downregulate appetite-stimulating factors through melanocortin receptors (Grattan et al., 2007), and may thus exert longer-term influences over total daily food intake (Andermann & Lowell, 2017). Leptin is detected along the reward (mesolimbic) pathway of the brain. Low leptin upregulates food intake (Figlewicz & Benoit, 2009) by influencing dopaminergic activity in the midbrain, which is associated with reward. Paradoxically, leptin is elevated in some individuals with higher weight relative to those with lower weight. In animal models, high fat diets result in systemic inflammation and excess release of leptin, which is hypothesized to lead to leptin resistance, or insensitivity to the modulatory effects of leptin (Figlewicz & Benoit, 2009; Knight et al., 2010; Thaler et al., 2010). Leptin resistance is considered to be maladaptive in the weight regulation context. During pregnancy, leptin resistance is one potential explanation for how weight is able to rapidly increase even with increases in leptin (Chehab, 2014) and may be viewed as more adaptive in this context because weight gain is consistent with fetal growth. In the setting of leptin resistance, leptin concentrations which previously upregulated satiety and downregulated reward signaling may no longer do so (Nuamah et al., 2003). In the context of pregnancy and postpartum, leptin resistance may interfere with the ability to utilize internal, physiological signals to regulate appetite, shifting the balance toward external influences, such as food stimuli in the environment.

Hedonic hunger was associated with oral somatosensory brain activity following presentation of a palatable food cue in United States university women, suggesting that hedonic hunger may align with anticipated pleasure (Burger et al., 2016). Hedonic hunger is measured with the Power of Food Scale (PFS), a self-report measure assessing the construct as a tendency (rather than an acute state), though one that is influenced by the food abundance of the surrounding environment (Lowe et al., 2009). Hedonic hunger is conceptualized as stable within individuals across time. Yet, evidence from weight-loss interventions suggests that changes in weight are associated with intraindividual changes in hedonic hunger (Cushing et al., 2014; Schultes et al., 2010; Theim et al., 2013). However, there is little support for a direct association of body-mass index (BMI) with PFS (Espel-Huynh et al., 2018).

As suggested by the Embodied Self Model, positive embodiment as it relates to appetite regulation would involve balancing influences of external food cues with internal satiety and reward signals. During pregnancy and postpartum, biochemical and psychological changes common to this period may result in an imbalance characterized by rises in leptin concentration along with rises in hedonic hunger. This imbalance may contribute to difficulty orienting toward internal signals. Serum leptin concentrations increase during pregnancy as leptin is secreted from the placenta into general circulation with a precipitous drop just after birth, though this trajectory may differ depending on the amount of white adipose tissue present prior to pregnancy (Jara et al., 2020; Skalkidou et al., 2009). From a developmental perspective, leptin serves as a permissive signal for fertility (Henson & Castracane, 2006), signaling the body's ability to sustain pregnancy. During pregnancy, the body adapts to quickly metabolize stored energy to increase its availability for fetal development, while food intake and nutrient absorption capacity increase and physical activity decreases or remains at the same level (Clarke et al., 2021). Leptin was associated with hedonic hunger in non-pregnant women with overweight or obesity (Aliasghari et al., 2019), and both leptin and hedonic hunger have been associated with palatable food intake and with activity in neural reward circuitry, though they are thought to have opposite effects on appetite. Resistance to the downregulating effects of leptin during pregnancy and postpartum may manifest by rising circulating leptin along with rising hedonic hunger, or it may be that the trajectory of each is modified by levels of the other. Thus, pregnancy and postpartum is an opportune time period within which to examine these influences in tandem over time. The current study examines the time-varying association of leptin with hedonic hunger during pregnancy and postpartum, to identify potential connections between psychological and biochemical influences on appetite.

4.3 METHOD

This study is a secondary analysis of data collected during the Pregnancy Eating Attributes Study (PEAS; Nansel et al., 2016), a longitudinal observational study. The primary aim of PEAS was to investigate neurobehavioral influences on eating behavior and weight change from early pregnancy through 12 months postpartum.

4.3.1 PARTICIPANTS

Participants were recruited between November 2014 and October 2016 from two obstetric clinics in North Carolina in the University of North Carolina at Chapel Hill Healthcare System. Inclusion criteria for potential participants included the following: BMI ≥ 18.5 kg/m^2, ability to read and write English, gestational age ≤ 12 weeks, plan to remain in the geographical area for at least one year postpartum (including a plan to give birth at the University of North Carolina Women's Hospital). Exclusion criteria for PEAS included the following: use of medication that is known to affect diet or weight, medical or psychiatric conditions that would contraindicate study participation (e.g., self-reported eating disorder, pre-existing diabetes, or other major chronic illness), and multiple pregnancies. The total initial enrollment sample was 458 women.

4.3.2 PROCEDURES

Trained study staff reviewed electronic medical records of patients with upcoming obstetric appointments and approached eligible potential participants with information about the study and obtained informed consent. In-clinic study visits included a baseline visit at ≤12 weeks gestation, time 2 visit at 16-22 weeks gestation, time 3 visit at 28-32 weeks gestation, time 4 visit at 4-6 weeks postpartum, time 5 visit at approximately 6 months postpartum, and time 6 visit at approximately 12 months postpartum. Participants completed questionnaires online within a specified time window associated with each visit as follows: baseline surveys were completed prior to 15 weeks, 6 days gestation, time 2 surveys were completed between 16-27 weeks, 6 days gestation, time 3 surveys were completed between 28-36 weeks, 6 days gestation, time 4 surveys were completed between 4-14 weeks postpartum, time 5 surveys were completed between 23-31 weeks postpartum, and time 6 surveys were completed between 50-58 weeks postpartum. Participants completed online questionnaires by accessing a secure website with a study-assigned login. Trained research staff affiliated with the University of North Carolina at Chapel Hill monitored questionnaire completion and followed up with participants as needed. The University of North Carolina at Chapel Hill Institutional Review Board approved all procedures. All planned data collection was complete by June 2018. The University of North Carolina at Charlotte Institutional Review Board granted permission to conduct secondary analyses on these data.

4.3.3 MEASURES

4.3.3.1 HEDONIC HUNGER

Hedonic hunger was assessed using the PFS (Cappelleri et al., 2009) during pregnancy trimesters 1, 2, and 3, and at 6 months postpartum. The PFS is a 15-item self-report questionnaire designed to measure hedonic hunger, described as “a generalized tendency toward preoccupation with food despite the absence of a short-term energy deficit” (Lowe & Butryn, 2007, p. 438). The PFS consists of three subscales reflecting levels of proximity to environmental food stimuli: Food Available (PFS-Available, six items assessing perceptions of general availability/accessibility of food, e.g., “When I know a delicious food is available, I can’t help myself from thinking about having some”), Food Present (PFS-Present, four items; responsiveness to food that is immediately present, e.g., “If I see or smell a food I like, I get a powerful urge to have some"), and Food Tasted (PFS-Tasted, five items; responsiveness to food that is tasted or about to be tasted, e.g., "Just before I taste a favorite food, I feel intense anticipation"). Response options for each item are provided on a five-point scale and range from *don't agree at all* (1) to *strongly agree* (5) and are not anchored to a specific time period. The PFS was conceptualized to have three sub-factors with a second-order aggregate factor representing hedonic hunger. Previous measurement work by this research group indicated that the most parsimonious representation of shared variance among indicators was a correlated three-factor structure (Chapter 3 of this work).

4.3.3.2 LEPTIN

Leptin (i.e., maternal serum leptin levels) was measured during trimester 1 (non-fasting), trimester 2 (fasting visit), and trimester 3 (non-fasting) of pregnancy, as well as at one year postpartum (fasting). As addressed above, leptin does not directly signal satiety but rather affects satiety thresholds through its impact on satiety signaling hormones (i.e., cholecystokinin) and effects on neural sensitivity to gastrointestinal distension signals (Moran et al., 2006). While leptin may vary with manipulated carbohydrate content of meals in controlled experimental settings, detection of these differences is restricted to within a short delay (90 minutes) after meals, suggesting that it can be examined comparably in both fasting and non-fasting states (Chamorro et al., 2022; Romon et al., 1999). In the present work, as participant data was modeled in growth curves, individuals functioned as their own baseline or control.

Maternal blood was collected (30-40 mL total whole blood during non-fasting visits; 40 mL whole blood during fasting visits), separated into 17 tubes, processed as serum (that is, blood cells, fibrinogen, and clotting factors were processed out) and frozen at -80°C before being shipped to the NICHD bio-repository for analysis. Leptin was measured in an Enzyme-Linked

Immunosorbent Assay (ELISA), using the sandwich method (R&D Systems, Minneapolis, MN). Post-processing of leptin concentrations included an adjustment for a dilution factor of 100 and conversion from picograms per milliliter (pg/mL) to nanograms per milliliter (ng/mL). Laboratory equipment was not able to detect leptin concentrations above 1050 pg/mL, therefore all concentrations at or above 1050 pg/mL were reflected as 1050 pg/mL (and the resultant adjusted concentrations at 105 ng/mL). Leptin values were square root transformed to simulate normal distributions and to place them in a more interpretable metric relative to the other variables.

4.3.3.3 DEMOGRAPHICS

Participants self-reported education, household composition, family income, receipt of social assistance programs, race, and ethnicity at the time 1 visit. Additional information (parity, maternal age) was extracted from medical records. Income-to-poverty ratio was calculated by dividing the total reported household income by the poverty threshold (corrected for household size and composition; US Census Bureau, n.d.).

4.3.4 ANALYTIC PLAN

All data analyses were conducted in *R* v4.1.3 through the graphical user interface *RStudio* v2022.02.3 (R Core Team, 2022; RStudio Team, 2022). Data missingness was examined using the *naniar* package (Tierney et al., 2021). Data exploration and evaluation of distributional assumptions was conducted using the *mvn* package (Korkmaz et al., 2014). Histograms and distributional characteristics (e.g., mean, standard deviation, median, skew, kurtosis) as well as the Anderson-Darling test were used to evaluate univariate normality assumptions, and the Henze-Zirkler test was used to evaluate multivariate normality via statistical significance testing. Though significance testing results suggested that distributions may deviate from the standard normal distribution, models were estimated using full-information maximum likelihood (FIML) estimation, which has been demonstrated to be robust to violations of the assumption of normal distributions. Still, results were interpreted with caution and when possible, models were estimated using robust FIML, which has been shown to provide standard error estimations which are robust even to large deviations from the normal distribution (Enders, 2001).

Distributions of leptin concentrations were positively skewed and non-normal. Although robust full-information maximum likelihood estimation was used for most of the models and is robust to even severely non-normal distributions, the scale of the leptin was several times larger than the item-level data of the PFS indicators and their scaled latent factors. To standardize the scale of variability, leptin concentration values were square-root transformed. Following transformation, their distributions more closely resembled a normal distribution and the mean and variance were closer to the scale/range of the self-report scale items of the PFS.

The primary aim of this work was addressed with a latent growth curve analysis. Support of strong measurement equivalence was evaluated in our previous work (see Chapter 3) as a prerequisite condition for a curve of factors model (CUFFS; Isiordia & Ferrer, 2018) to model the trajectory of hedonic hunger over time. Composite scores introduce potential bias, thus a structural equation modeling framework with a full underlying measurement model (CUFFS) was selected so that measurement error could be explicitly modeled and considered.

Growth curves were modeled in two stages for each construct thought to vary over time.

Informed by prior findings with this sample (Chapter 3 of this work), hedonic hunger subscales (PFS-Available, PFS-Present, PFS-Tasted) were modeled as three correlated factors (Cappelleri et al., 2009). Each subscale was modeled initially as a separate growth curve (described below) and then entered into a multivariate growth curve model along with the leptin growth curve. Initial growth curves constrained loadings, intercepts, observed variances, and observed covariances to equivalence for the same item across time points, and constrained latent covariances at each time point to zero to indicate that the covariance between time points should be reflected as a function of the latent slope factor. Growth curves were specified similar to the curve of factors or CUFFS model (Isiordia & Ferrer, 2018). Latent variable variances for each time point were scaled relative to the first time point, which was fixed at 1.

Aligned with the CUFFS model, the latent intercept and slope were modeled with their indicators as the subscales at each time point, and those subscales were modeled with their indicators as the individual items. Following recommendations regarding the specification of latent growth curve models with multiple indicators (as is the case for our representation of subscales of hedonic hunger), intercept means were fixed to zero, and the intercept variance, slope variance, and slope mean were permitted to freely vary (i.e,. estimated by the model). Loadings for the latent intercept were all constrained to 1, to indicate that the intercept has the same influence on each time point. Testing was systematically undertaken first to incorporate only an intercept mean with no variance, then intercept variance, then a slope with a variance and a mean of zero, and finally, a model in which slopes and intercepts were permitted to covary. The latent slope factor was only retained if the model with the slope factor represented a noticeable improvement in fit indices upon the model with only an intercept factor. Only select models are reported in the text for clarity.

For leptin, latent growth curves were modeled in a traditional, observed-variable framework. The initial model was an intercept-only model in which unique variances across time points were constrained to equality, after which subsequent models included variation in the intercept, variation in the slope, a mean slope, and then finally, covariance between the slope and intercept factors. The slope factor was only retained if this model fit was noticeably improved relative to the model with no slope factor (i.e., intercept-only model).

After establishing an adequately-fitting latent growth curve model for each construct, a second stage modeled multivariate latent growth curves for which intercepts and slopes were permitted to freely vary given limited guidance regarding these relationships in theory or literature (many of the slopes were constrained to zero variance as described above). Indicators of global (e.g., RMSEA, CFI) and local (e.g., SRMR, covariances) fit were examined to assess the fit and the need for model respecification (if also aligned with previous research and theory; Byrne, 2016). Finally, a post-hoc power analysis was conducted to evaluate the likelihood of detecting global model misfit (as indicated by RMSEA > .10) with the given sample size and degrees of freedom (Jobst et al., 2021; Moshagen & Erdfelder, 2016). A high RMSEA threshold allowed for expected misfit given the novel context in which this model was being examined.

4.4 RESULTS

4.4.1 SAMPLE CHARACTERISTICS

Of those enrolled, 91 women voluntarily withdrew or were withdrawn by study staff during pregnancy, and 46 were withdrawn or lost to follow-up during the first year postpartum (see Nansel et al., 2020 for the detailed flow of participants through study and withdrawal reasons; see also Table 5.2 in this document). No differences in the distribution of those who withdrew from the study versus those who continued were observed, based on evaluation of split boxplots and histograms.

The prevalence of missing data increased over time. Missingness on specific item-level indicators of the PFS ranged from 13% to 34% across time points: approximately 13% of observations were missing at baseline, 26% of observations were missing at time 2, 26% at time 3, 34% at time 5, and 79% at time 6. Of note, one item ("Just before I taste a favorite food, I feel intense anticipation.") was omitted for some participants (n = 306 in first trimester, n = 223 in second trimester, n = 178 in third trimester) due to an error during the creation of the online questionnaires, which was later corrected. However, based on prior testing with this dataset, there is no known systematic difference between participants who were enrolled earlier in the study versus those enrolled later. Time 6 (12 months postpartum) data for the PFS were only available for approximately 70 participants, due to an administrative decision (in March 2017 after 122 participants had already completed the final visit) to reduce participant burden by eliminating some of the psychosocial questionnaires. Leptin data were missing for approximately 16% of participants at time 1, 21% at time 2, 23% at time 3, and 41% at time 6.

4.4.2 HEDONIC HUNGER

The final model for the food available factor (N = 383) included only an intercept factor (robust χ^2 = 685.04, df = 296, p < .001, robust CFI = .881, robust RMSEA = .067[.060, .073], SRMR = .182), as adding a slope factor did not improve model fit. Global fit indices were considered adequate, given that the measure was developed in a different population. For example, while the SRMR value (.182) was higher than is typically acceptable (often values <.05 are encouraged), this value may be suggestive of local misfit introduced by constraining the unique variances, intercepts, and covariances across time. These constraints help to support that longitudinal changes are not better explained by variations in the item properties over time. The variance for the intercept (σ^2 = .59, SE = .06, p < .001) suggested interindividual variability in the initial level of self-reported responsiveness to food available in the immediate environment. In contrast, the lack of support for a slope factor indicated a lack of support for linear change over time in responsiveness to food available in the immediate environment.

The final model for the "food present" factor (*N* = 383) included only an intercept factor (χ^2 = 278.36, *df* = 132, *p* < .001, robust CFI = .928, robust RMSEA = .057[.048, .067], SRMR = .162). The addition of a slope factor did not significantly improve fit, and the intercept variance (σ^2 = .59, *SE* = .06, *p* < .001) indicated interindividual variation in starting level of the "food present" factor.

For the "food tasted" factor, the finalized model (*N* = 383) had adequate fit (robust χ^2 = 374.85, *df* = 206, *p* < .001, robust CFI = .909, robust RMSEA = .049 [.041, .057], SRMR = .134) and specified a random intercept and a fixed slope with a mean fixed to zero. Although the slope factor mean and variance were constrained, having a slope factor in this model significantly improved the model's fit. As addressed above, multiple factors may contribute to elevated SRMR values, which are expected when the situation or population in which the measure is used is different than that in which it was developed. The retained model suggested that slopes did not vary between individuals, though starting level (intercept) varied between individuals (σ^2 = .52, *SE* = .06, p < .001).

4.4.3 LEPTIN

For leptin (N = 388), the final model had several indications of adequate global fit (χ^2 = 53.71, *df* = 6, p < .001, robust CFI = .956, robust RMSEA = .150[.115, .188], SRMR = .020). Though RMSEA is elevated and would typically indicate misfit, RMSEA is often elevated in models with few degrees of freedom, except in cases in which the sample size is large (N > 1000; Kenny et al., 2015). The slope factor's first two loadings were fixed and the latter two loadings were freely estimated. Both the intercept (μ = 4.67, *SE* = .11, p < .001) and slope factor means (μ = .48, *SE* = .06, p < .001) were significantly different from zero. Intercepts varied between individuals (σ^2 = 3.21, *SE* = .22, p < .001) as did slopes (σ^2 = .17, *SE* = .03, p < .001). In addition, the slope-intercept covariance indicated that those with higher starting levels of leptin had a flatter slope of leptin over time ($\sigma_{s,i}$ = -.49).

4.4.4 FULLY SPECIFIED LATENT GROWTH CURVE MODEL

The full multivariate latent growth model (N = 408) demonstrated a moderate degree of fit (χ^2 = 4255.21, *df* = 2043, p < .001, robust CFI = .826, RMSEA = .051 [.049, .053], SRMR = .181). Though a slope factor improved the fit of the PFS-Tasted-only model, it was not retained to the fully specified multivariate model because of the constraints necessary (i.e., fixed slope mean and variance). A post-hoc power analysis conducted using *semPower* (Moshagen & Erdfelder, 2016) estimated the power to detect model misfit of RMSEA >.10 to be >99%. Examination of latent correlations revealed strong positive relationships between hedonic hunger subscales (r = .78-.84), weak positive relationships between leptin slope and intercepts of PFS-

Available (*r* = .11) and PFS-Tasted (*r* = .07), and a moderate positive relationship between leptin slope and PFS-Present starting level (*r* = .21). The leptin intercept factor did not demonstrate strong relationships with any other variables examined (all $r < .10$).

4.4.5 POST-HOC ANALYSES

Given previously observed non-linear trajectories of leptin throughout pregnancy and postpartum (e.g., Skalkidou et al., 2009), additional data exploration was conducted to explore non-linearity in the leptin trajectory in this sample. Visual examination of violin plots (see Figure 4.2) suggested an increase over pregnancy and a decrease to the postpartum time point. Results of a one-way ANOVA supported differences between the means at each time point ($F(2.26, 541.84) = 96.47$, $p < .0001$), and the majority of Bonferroni-corrected pairwise comparisons were statistically significant except for the comparison of means for trimester 2 and trimester 3. In sum, statistically significant pairwise comparisons suggested an increase in leptin from trimester 1 to trimester 2, no increase from trimester 2 to 3, and a decrease at the 12-month postpartum time point relative to trimester 3.

4.5 DISCUSSION

The present study examined the time-varying associations of leptin with hedonic hunger, using a latent growth curve analysis. Though there was some variability in hedonic hunger subscales between individuals at the initial time point, there was no evidence to support change over time in hedonic hunger. Unexpectedly, and in contrast to relationships observed in women outside of pregnancy (Aliasghari et al., 2019) baseline leptin did not appear to be associated with baseline hedonic hunger. However, leptin demonstrated the expected trajectory over pregnancy and postpartum. Finally, the rate of change in leptin over time (i.e., leptin slope) was not associated with baseline responsiveness to availability of food (PFS-Available) or current/anticipated tasting of food (PFS-Tasted), though it was positively and moderately correlated with baseline responsiveness to food present in the immediate vicinity (PFS-Present).

Our results did not support change over time in PFS-Available, PFS-Present, or PFS-Tasted, suggesting that hedonic hunger is stable during pregnancy and the first year postpartum. Though this result is consistent with the conceptualization of hedonic hunger as a trait (Cappelleri et al., 2009), it is inconsistent with change over time observed in other populations who have experienced dietary and behavioral changes (e.g., post-bariatric surgery patients; Cushing et al., 2014). It is possible that changes in hedonic hunger only occur in response to certain types of dietary/behavioral change. However, this would suggest that we should observe some change from pregnancy to 12 months postpartum even if the trajectory was flat before this time. We were not able to model non-linear trajectories in this study. A post-hoc comparison of means over time did not suggest change in hedonic hunger from the third trimester of pregnancy to 12 months postpartum. Alternatively, it could be that in pregnancy and postpartum, other factors may modulate the influence of hedonic hunger on behavior rather than hedonic hunger itself changing over time.

Similarly, the overall positive mean change over time in leptin in our sample is consistent with and inconsistent with previously published work indicating that leptin rises over pregnancy and drops following birth (Skalkidou et al., 2009). Given that considerable change may occur between time points in this study, it is possible that this overall positive change was driven primarily by the fact that three out of four included time points were during pregnancy, though a non-linear trajectory could not be fully tested in the present work. The drop in leptin after birth can be observed as soon as 48 hours after delivery (Hauguel-de Mouzon et al., 2006), so the postpartum time point in the present work may have been too far away to model the unit-by-unit change effectively. Brief post-hoc testing revealed statistically significant mean differences between trimesters 1 and 2 in pregnancy (increase) and between trimester 3 and 12 months postpartum (decrease), which is consistent with previous work (Skalkidou et al., 2009). Based on this preliminary testing, leptin may increase over the first two trimesters, plateau, and then decrease following birth to a steady level which is observable even a year following birth. Positive slope and intercept variability suggested different starting points and different rates of change for individuals over time, though to a modest degree based on point estimates. Additionally, a negative correlation between leptin slope and intercept suggested an “upper limit” to leptin in that higher baseline values were associated with flatter trajectories over time.

PFS-Present was moderately and positively correlated with change in leptin over time. Greater initial responsiveness to food present in the environment could suggest a tendency to perceive greater reward potential of food, which may lead to sharper increases in leptin as part of a negative feedback loop to regulate food intake and energy storage. However, neither PFS-

Available nor PFS-Tasted were associated with change in leptin over time. As leptin is active in the brain's reward system, the perceived reward potential involved in PFS-Present may be more closely associated with leptin (since this is referring to food immediately present). Yet, this correlation was moderate suggesting that most variability in leptin is independent of PFS-Present. As noted above, leptin also acts on the immune system, in the reproductive system, and in the growing fetal system (Evans et al., 2021), all of which demonstrate changes during both pregnancy and postpartum. Thus, change in leptin may be largely independent of hedonic hunger. In sum, responsiveness to environmental food stimuli seems to remain stable over pregnancy and into the first year postpartum, and it seems to relate partially and modestly to change in leptin over this same period of time.

4.5.1 STRENGTHS AND LIMITATIONS, IMPLICATIONS, AND FUTURE DIRECTIONS

Strengths of this work included a relatively large sample size, repeated measurements to model change over time, and the use of an analytic approach that explicitly represented measurement error. The contributions of this work should also be considered in light of its limitations. Based on the measurements collected in this study, we were unable to reflect whether or not the leptin in the concentration value was bound to a receptor. This constrains the conclusions we may be able to draw regarding the action of this leptin, that is, whether the leptin concentration captured here indicates that leptin was able to pass into the brain and exert an influence on the reward or regulation systems as would be typical outside of pregnancy. In addition, time points in this work were spaced several months apart. Thus, change trajectories may have inadvertently omitted important fluctuations between assessments.

This work supports a modest link between the trajectory of leptin and self-reported responsiveness to food in the immediate environment. Though it is unclear how differences in leptin trajectory might be subjectively experienced, self-evaluations of responsiveness to food stimuli may be associated with leptin concentration and consequently may be a possible point of discussion between patients and providers. In addition, early pregnancy indices of hedonic hunger remained relatively stable over the time studied and may not need to be measured periodically over time. Providers might be encouraged to briefly discuss the nature of the immediate food environment and how the pregnant individual believes this environment may be influencing their eating behaviors.

Future empirical work could use more detailed physiological data as well as more closely spaced time points to provide a better illustration of change given the rapidity of change during pregnancy. Further, adding more postpartum time points would help to characterize the change over this time period better as it remains poorly studied and understood. Finally, as these trajectories are further studied and clarified, the incorporation of contextual factors, such as the history of food insecurity, current access to specific types of food (e.g., restaurants, grocery stores) may be important to understanding the system in which psychophysiological influences operate.

4.5.2 CONCLUSION

Pregnancy is a time of rapid and radical bodily change with long-lasting impacts, and pregnancy and postpartum eating behaviors have relevance for both short and long-term maternal and child health. The present work was a novel examination of the time-varying associations of hedonic hunger and maternal leptin during pregnancy and postpartum. Results suggest that leptin and hedonic hunger shared little initial variance, and hedonic hunger subscales did not reflect detectable changes over time, though the rate of change in leptin over time was moderately associated with self-reported responsiveness to food in the immediate environment. Providers might consider asking pregnant individuals about hedonic hunger early in pregnancy, which may offer opportunities to discuss how this relates to individual eating behaviors. Future work could more closely examine trajectories within pregnancy and postpartum and incorporate more nuanced and diverse measurements of physiological influences to include both hunger and satiety factors.

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Table 4.1

Sample Characteristics (at baseline)

Sociodemographic characteristic	Mean ± SD *or* N (%)	Range
Age	30.46 ± 4.74	18-42
Education		
High school graduate or less	34 (9.26%)	-
Some college or associate's degree	70 (19.07%)	-
Bachelor's degree	108 (29.43%)	-
Master's or advanced degree	155 (42.23%)	-
Body-mass index (BMI)	27.19 ± 6.94	18.6-59.8
Race/Ethnicity		
White	264 (67.3%)	-
Black	59 (15.05%)	-
Asian	19 (4.85%)	-
Native American/Native Hawaiian	1 (<1%)	-
Hispanic/Latinx	33 (8.41%)	-
Multi-race or Something not listed	16 (4.08%)	-
Nulliparous	250 (54.5%)	-
Income to poverty ratio	3.84 ± 1.97	0.39-8.41
%WIC Eligible	24.3	-
Gestational age at delivery	39.3 ± 2.09	23 - 42.1

Sociodemographic characteristic	Mean ± SD *or* N (%)	Range
Household size	3.02 ± 1.2	1 - 10
Marital status		
Married/Partnered	333 (90.7%)	-
Single/Separated/Divorced/Widowed	34 (9.26%)	-

Note. Race/ethnicity identification categories are mutually exclusive.

Table 4.2

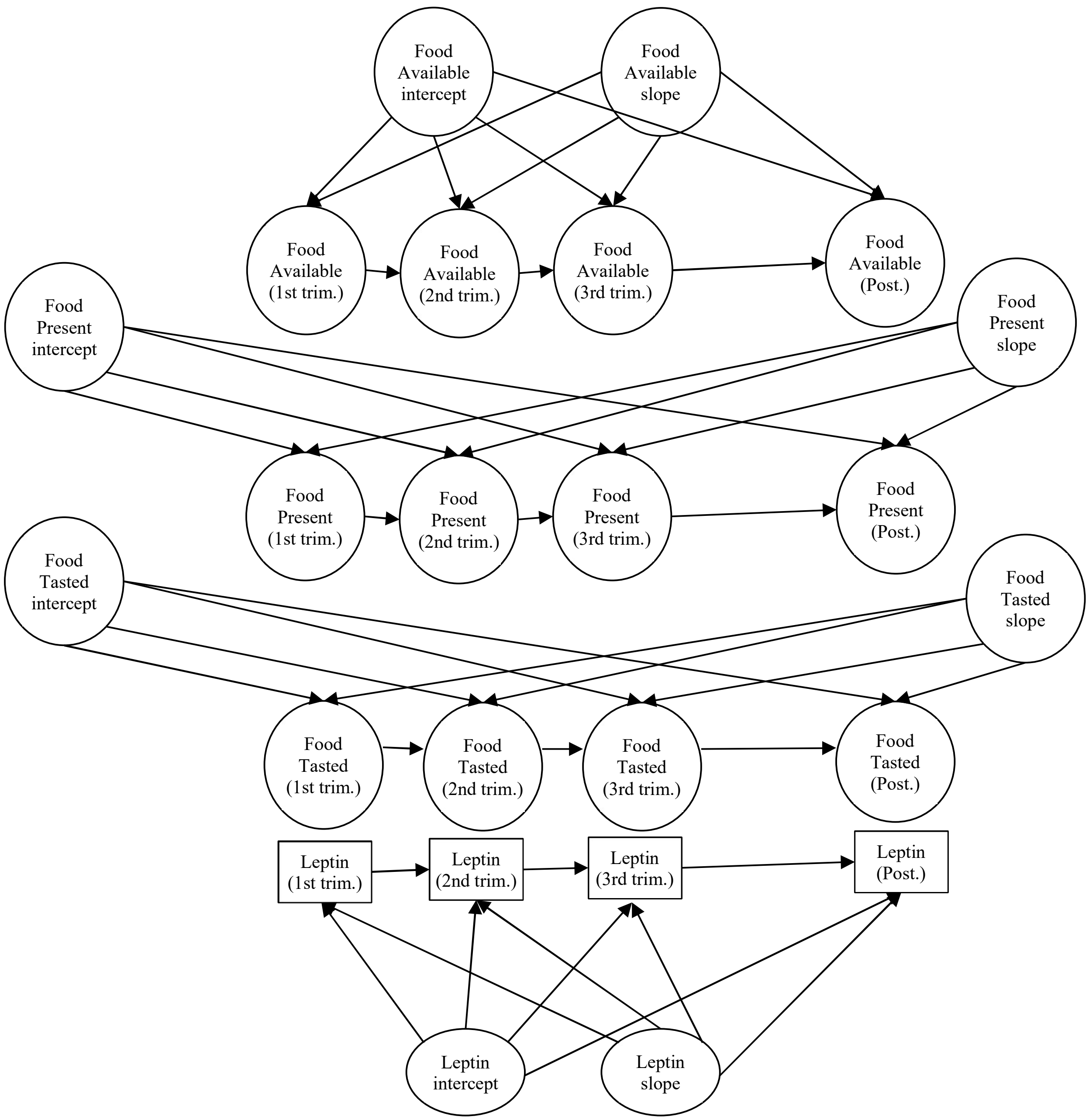
Model Fit Indices

Model	CFI	χ^2	*df*	RMSEA	SRMR
Food Available (random intercept only)	.881	685.04	296	.067 [.060, .073]	.182
Food Present (random intercept only)	.928	278.36	132	.057 [.048, .067]	.162
Food Tasted (random intercept only)	.909	374.85	206	.049 [.041, .057]	.134
All hedonic hunger subscales	.811	3868.71	1806	.055 [.052, .057]	.191
Leptin (random slope, random intercept)	.972	42.27	5	.146 [.107, .188]	.020
Full model	.824	4255.21	2043	.052 [.049, .054]	.181

Note. N = 408 for the full model. CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual.
* $p < .05$.

Figure 4.1

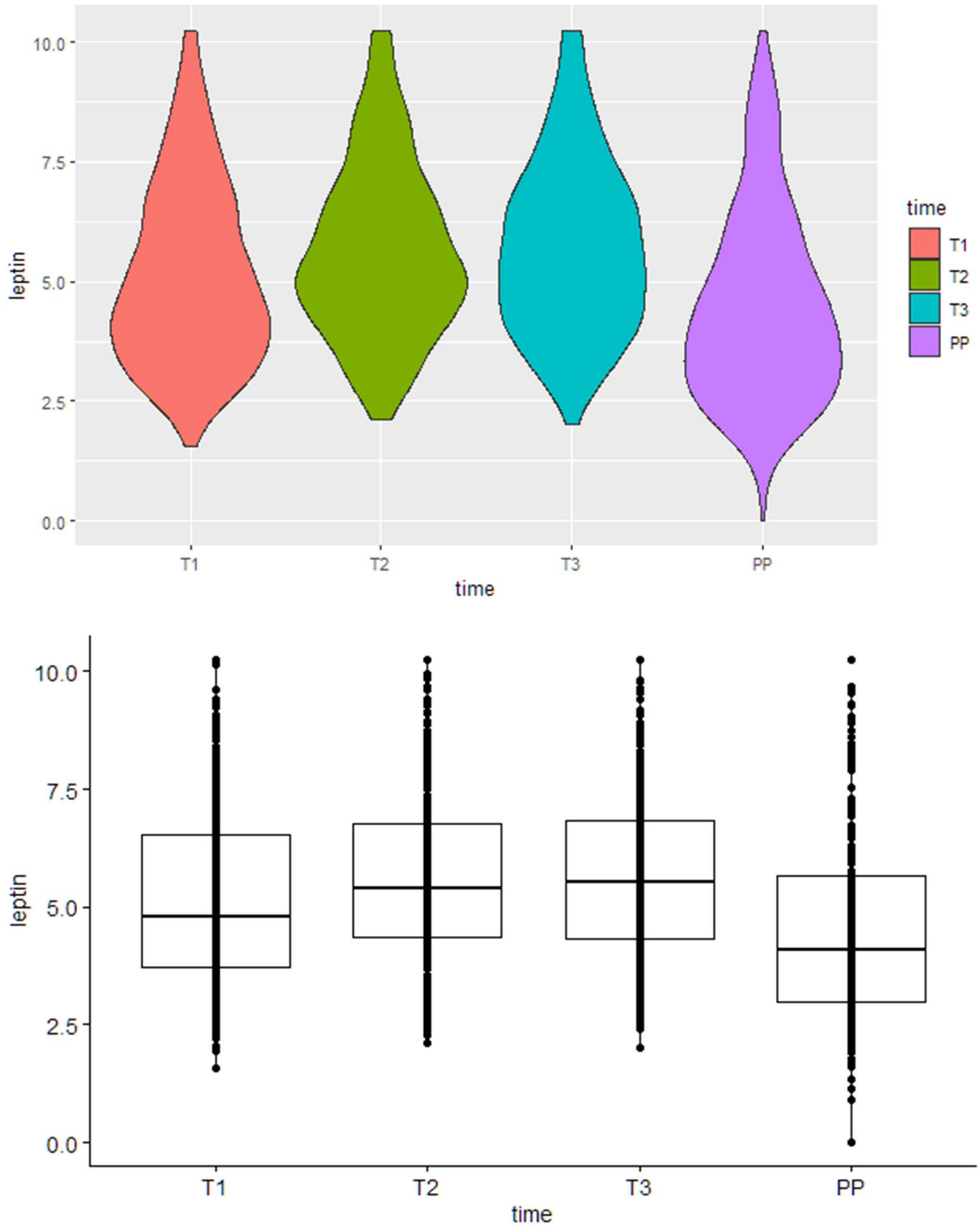
Conceptual Model for Longitudinal Relationships of Hedonic Hunger and Leptin



Note. The covariance of exogenous factors is assumed. The model is simplified for ease of view and does not include individual indicators for first-order latent factors.

Figure 4.2

Violin and Box-and-Whisker Plots of Leptin Distributions



CHAPTER 5: MYSTERIOUS EATS: PSYCHOPHYSIOLOGICAL APPETITE INFLUENCES DO NOT PREDICT CRAVINGS DURING PREGNANCY AND POSTPARTUM

Journals planned for submission: *Appetite, Eating Behaviors*

5.1 ABSTRACT

Cravings, strong desires for specific foods which are often highly palatable and calorically dense, are common during pregnancy and may contribute to low diet quality. They may be present at a reduced level after birth, but little research has examined postpartum cravings or their predictors. Cravings may be influenced by psychological responses to environmental food cues (hedonic hunger), hormonal signals (leptin), or dietary restraint, but these relationships have not been examined during pregnancy and postpartum. This work was a secondary analysis from an observational cohort study conducted in the southeastern United States. Structural equation models tested concurrent and prospective associations of cravings with leptin, hedonic hunger, and dietary restraint as a potential moderator of these relationships. Only first-trimester cravings emerged as a significant predictor of second-trimester and 12 months postpartum cravings in predictive models. Concurrently at 12 months postpartum, a hedonic hunger subscale reflecting responsiveness to food in the general environment emerged as a significant predictor. Across models, interaction terms testing moderation of relationships by dietary restraint were not statistically significant and did not appreciably increase explained variance in cravings. The lack of support for hypothesized associations could be due to the distance between measurements or because the examined factors are not strong determinants of cravings during pregnancy and postpartum. Alternatively, other internal or environmental factors may influence cravings more strongly. Future work could use intensive longitudinal designs to test for momentary or shorter-term influences or use qualitative methods to generate hypotheses regarding the contribution of other hormones, psychological responses, or social/physical environmental characteristics.

Keywords: pregnancy, postpartum, cravings, hedonic hunger, leptin

5.2 INTRODUCTION

Pregnancy cravings are commonly reported, though it remains uncertain whether they persist into postpartum. Cravings are a psychological, social, and cultural phenomenon: craved foods differ across countries and cultures (Hormes & Rozin, 2010) and do not appear to have specific medicinal or dietary purposes (Rogers & Smit, 2000; Yanovski, 2003). Cravings often target highly palatable and calorically dense foods, which are often ultra-processed, meaning that they have undergone substantial industrial or commercial alteration and tend to contain substantial added sugar and fat (Schulte et al., 2015, 2021). Ultra-processed food intake is directly associated with chronic conditions such as diabetes, cancer, and cardiovascular disease, yet these foods are often featured in food advertisements (Lesser et al., 2013). Individuals vary in how strongly they respond emotionally or cognitively to food stimuli in the environment, which may influence their eating behavior.

In United States culture, eating behavior is typically viewed as a matter of personal choice and effort (Tischner & Malson, 2012). Pregnant individuals are viewed as responsible for protecting the fetus from or subjecting the fetus to potential risks (Nash, 2012). In postpartum, individuals may experience pressure to “bounce back” or return to emulating the thin ideal (Nippert et al., 2021; K. Thompson, 2020). These themes position pregnancy and postpartum eating and drinking as behaviors with societal weight. Yet, pregnancy cravings are often described as powerful and difficult to resist (Blau et al., 2020) and postpartum eating monitoring is experienced as unrealistic (Nippert et al., 2021), suggesting that there are influences on cravings beyond effortful regulation of intake. Instead, individuals may differ in how strongly they respond to external and internal cues related to appetite, resulting in variability in the experience of cravings.

Hedonic hunger, or self-perceived responsiveness to environmental food cues (Lowe et al., 2009), is positively associated with cravings in non-pregnant individuals (Forman et al., 2007; van Dillen & Andrade, 2016). Our previous work showed that this experience is stably present during pregnancy and postpartum (see Chapter 3, Chapter 4 of this document), though it remains unknown whether cravings are influenced by hedonic hunger in pregnancy and postpartum. In addition, pregnancy is considered a period during which individuals may be "resistant" or less sensitive to the effects of leptin, a satiety, reward, and reproductive hormone. The concentration increases steadily over pregnancy and rapidly decreases following pregnancy (Jara et al., 2020). Thus, high levels of leptin during pregnancy may co-occur with more intense or frequent cravings. Leptin may then return to typical functioning following birth, resulting in an inverse relationship between leptin and cravings by 12 months postpartum.

In response to mixed messages from US culture about highly palatable foods, e.g., chocolate as "forbidden but delicious" (Lemmens et al., 2010), individuals may feel deprived and yet engage in ongoing restraint in an effort to avoid consuming craved foods, which may paradoxically amplify cravings (A. J. Hill, 2007; Rogers & Smit, 2000), particularly for those with high leptin (in the setting of leptin resistance) and high hedonic hunger during pregnancy. In contrast, postpartum may be when dietary restraint and low leptin are associated with higher cravings. Thus, leptin and hedonic hunger may each interact with dietary restraint in their influence on cravings during pregnancy and postpartum.

Recent work has begun to recognize that a societal focus on personal behavioral choices related to weight and eating may heighten weight stigma and negatively affect maternal health and well-being (Emerson et al., 2017; B. Hill & Rodriguez, 2020). Thus, insight into influences on cravings during pregnancy and postpartum could inform health promotion efforts for pregnant and postpartum individuals. The present work aimed to advance this area by testing concurrent and prospective relationships of leptin and hedonic hunger and the potential moderating role of dietary restraint in their relationships with cravings during pregnancy and postpartum.

Cravings are strong desires for specific foods (Hormes & Rozin, 2010; Zellner et al., 1999) and are frequently associated with pregnancy (Blau et al., 2020; Orloff & Hormes, 2014)[2]. In non-pregnant individuals, there is robust support for a relationship between cravings and amount of food consumed both immediately and over time, both with and without food cueing, and across weight status (Boswell & Kober, 2016). Findings from qualitative and quantitative studies of food intake during pregnancy indicate that cravings are experienced as particularly intense and difficult to resist (Blau et al., 2020; Nash, 2013; Orloff et al., 2016). Far fewer studies have examined cravings during postpartum. In one study conducted in the United States, the majority of the sample reported at least one craving at 12 months postpartum, regardless of lactation status (Worthington-Roberts et al., 1989). During postpartum, cravings may increase (Aubuchon-Endsley et al., 2015; George et al., 2005) following their decrease in late pregnancy (Tepper & Seldner, 1999). In more recent work, no differences were observed in overall cravings or cravings separated by food type (e.g., fat, sweets, fruits and vegetables) between early and late pregnancy or between pregnancy and postpartum, regardless of whether or not women lost weight over the first year postpartum (Most et al., 2020). Though there is a dearth of research, some researchers have speculated that cravings have a stronger influence during pregnancy

[2] Cravings as desires to consume specific foods are differentiated here from pica, or the desire to consume non-food substances, and olfactory cravings, or the desire to experience specific smells (Cooksey, 1995). Though some more recent work seems to suggest a potential transdiagnostic nature of cravings (Blau et al., 2018), cravings for non-food substances, smells, and psychoactive substances (e.g., nicotine) are thought to be outside of the scope of our focus on food cravings during pregnancy and postpartum and thus are not discussed further here.

versus postpartum, so a recent review emphasized the need for additional research to characterize cravings during postpartum and across pregnancy and postpartum (Bijlholt et al., 2020).

Frameworks that structure the relationships between our internal sensations and the impact of external phenomena are particularly relevant for studying cravings during pregnancy and postpartum. Drawn from broader socio-political scholarship regarding embodiment, or the experience of living in one's body (Piran & Teall, 2012), the Embodied Self Model (Figure 6.1) centers positive embodiment as an important facilitator of overall well-being (Cook-Cottone, 2020). Positive embodiment is thought to be supported and maintained by effectively balancing the internal self (responding to cognitions, emotions, and physiological sensations) with the external self (experiencing demands from interpersonal, community, and social settings). While these are reflected as two realms of influence, the figure's use of an "infinity loop" to reflect the connections between them emphasizes the ongoing negotiation between multiple influences that is thought to characterize our experiences. In sum, the frequency and intensity of cravings may reflect responses to internal physiological and cognitive-affective signals as well as environmental stimuli.

Reproductive phases such as pregnancy, postpartum, and menstruation are associated with changes in leptin, a hormone which also acts in the satiety and reward systems (Garcia-Galiano et al., 2014; Harris, 2000; Salem, 2021), raising the question of whether it may also be involved in the experience of cravings. For example, in the latter part of the menstruation cycle, high leptin concentrations co-occur with heightened perceptions of cravings and loss-of-control eating (Yen et al., 2020). As heightened leptin is typically associated with earlier satiety and lower perceptions of food reward, this association between leptin and cravings may reflect leptin resistance, similar to what is observed during pregnancy (Chehab, 2014). Accordingly, increased leptin in pregnancy may also co-occur with increased cravings, both of which may persist at least to some degree over the first year postpartum.

Hedonic hunger may also precipitate cravings, such as in response to a television commercial or a billboard depicting a certain food. During pregnancy, the link between hedonic hunger and cravings may be intensified due to leptin resistance (as noted above). By 12 months postpartum, the influence of hedonic hunger on cravings may return to a level comparable to that found outside of pregnancy. In non-pregnant adults, hedonic hunger is associated with the frequency and intensity of cravings within experimental settings (van Dillen & Andrade, 2016) as well as in naturalistic settings (Forman et al., 2007). Though this and other prior work has examined hedonic hunger as a unitary concept, the Power of Food Scale (PFS) (Cappelleri et al., 2009), which measures hedonic hunger, is conceptualized as containing three subscales: responsiveness to food generally available in the environment ("food available," PFS-Available), responsiveness to food in immediate proximity ("food present," PFS-Present), and responsiveness to food tasted or in anticipation of being tasted ("food tasted", PFS-Tasted). The present work would advance knowledge regarding hedonic hunger and cravings by incorporating consideration of the proximity of food stimuli as well as by testing these relationships in pregnant and postpartum individuals.

As discussed above, societal expectations and prescriptions regarding maternal behavior may contribute to pressure to restrict or closely monitor food intake during pregnancy and postpartum, referred to as dietary restraint. These attempts to suppress or restrain responses to food stimuli in the environment may heighten perceived deprivation (Schaumberg et al., 2016), which could amplify the effect of hedonic hunger and leptin on cravings. Considered within the Embodied Self Model, this may represent a negotiation of internal and external cues which ultimately produces stronger experiences of cravings. In previous cross-sectional analyses conducted using the same data as examined in this work, hedonic hunger, depressive symptoms, stress, and poor sleep quality were positively associated with craving strength and frequency during pregnancy (Betts et al., 2021), suggesting that cravings may co-occur with other manifestations of psychological and physical deprivation. However, the role of dietary restraint during pregnancy and postpartum remains unclear.

During pregnancy, dietary restraint is less present than in young adult women from a normative sample (Hecht et al., 2021) and may decrease over the three trimesters (Plante et al., 2020), whereas in postpartum, individuals report dietary restraint at levels comparable to those observed in non-pregnant adults (Carey et al., 2019; K. A. Thompson & Bardone-Cone, 2022). During pregnancy, dietary restraint has been associated with diet quality (Nansel et al., 2020) but not with pregnancy-related changes in food intake (Heery et al., 2016) and is inconsistently associated with gestational weight gain (no association in Nansel et al., 2020; positively associated in Heery et al., 2016). During postpartum, dietary restraint was associated with diet quality but not gestational weight gain or postpartum weight retention (Nansel et al., 2020). These divergent observations could be partly attributed to differences in the measurement of dietary restraint. A recent evaluation of dietary restraint scales indicated that while the Restraint Scale (Herman & Mack, 1975) was more closely associated with disinhibited eating, all measures of dietary restraint examined (including the one used in this study) were associated with chocolate cravings (Adams et al., 2019). Another potential contributor to these inconsistencies could be interaction effects between dietary restraint and influences on appetite, such as hedonic hunger and leptin.

Examining the relationships of cravings with hedonic hunger and leptin and the potential moderating effect of dietary restraint across pregnancy and postpartum could inform future maternal health promotion efforts. Thus, the primary aim of this work was to examine prospective and concurrent associations of hedonic hunger, leptin, and dietary restraint with cravings during pregnancy and postpartum. A secondary aim of the present work was to test whether dietary restraint modifies the relationship between hedonic hunger and cravings or between leptin and cravings.

5.3 METHOD

The present investigation was a secondary analysis of data from the Pregnancy Eating Attributes Study (PEAS; Nansel et al., 2016), a longitudinal observational cohort study. The primary aim of PEAS was to investigate neurobehavioral influences on eating behavior and weight change during pregnancy and postpartum.

5.3.1 PARTICIPANTS

Participants for PEAS were recruited from two obstetric clinics within the University of North Carolina at Chapel Hill Healthcare system between November 2014 and October 2016. Study inclusion criteria were: the ability to read and write English, plan to remain in the geographical area for at least one year postpartum, plan to give birth at the University of North Carolina Women's Hospital, gestational age ≤ 12 weeks, body-mass index (BMI) ≥ 18.5 kg/m^2, and ability to read and write in English. Exclusion criteria were: medical or psychiatric conditions contraindicated for study participation (e.g., self-reported eating disorder, pre-existing diabetes, other major chronic illness), use of medications known to affect weight or diet, and multiple pregnancy. The total number of enrolled participants was 458.

5.3.2 PROCEDURES

Potential participants were identified by reviewing electronic medical records of patients with upcoming obstetric appointments. Study staff approached potentially eligible participants during their scheduled appointments to provide information about the study and elicit informed consent. Following informed consent, participants were scheduled to visit the clinic and to complete online questionnaires at several periodic intervals during pregnancy and postpartum: baseline clinic visits were completed prior to 12 weeks gestation, and baseline surveys were completed prior to 15 weeks, 6 days gestation (first-trimester), time 2 visits were completed between 16 and 22 weeks gestation and time 2 surveys were completed between 16 and 27 weeks (second trimester), 6 days gestation, time 3 visits were completed between 28 and 32 weeks gestation and time 3 surveys were completed between 28 to 38 weeks (third trimester), 6 days gestation, time 4 visits were conducted between 4 to 6 weeks postpartum, whereas time 4 surveys were completed between 4-14 weeks postpartum, time 5 visits were completed at approximately 6 months postpartum, whereas time 5 surveys were completed between 23-31 weeks postpartum, and time 6 visits were completed at approximately 12 months postpartum, with time 6 surveys being completed between 50 and 58 weeks postpartum. At the 12 months postpartum time point, psychosocial measures were not collected for a majority of the sample in order to reduce participant burden (approximately $N = 70$ completed psychosocial measures at this time point). Data collection was completed in June 2018. The University of North Carolina at Chapel Hill Institutional Review Board approved all study procedures for PEAS. The University of North Carolina at Charlotte Institutional Review Board granted permission to conduct secondary analyses on these data.

5.3.3 MEASURES

5.3.3.1 HEDONIC HUNGER

Hedonic hunger, the "generalized tendency toward preoccupation with food" (Lowe & Butryn, 2007, p. 438), was measured using the Power of Food Scale (PFS; Lowe et al., 2009), a 15-item self-report measure. The PFS originally conceptualized hedonic hunger as an overarching concept with three subscales: Food Available (6 items), describing the general availability of food, such as "I get more pleasure from eating than I do from almost anything else," Food Present (4 items), describing food that is immediately present, e.g., "When I know a delicious food is available, I can't help myself from thinking about having some," and Food

Tasted (5 items), describing food that has just been tasted or is about to be tasted, e.g., "Just before I taste a favorite food, I feel intense anticipation." Items are rated on a five-point scale, which ranges from "don't agree at all" (1) to "strongly agree" (5). The measure is not anchored to any specific period, as it describes a general tendency. According to the authors of the initial validation study for the PFS (Cappelleri et al., 2009), the PFS is scored by averaging item scores within subscales for the individual subscale scores, after which subscale scores are averaged to calculate the overall score (ranging from 1-5), for which higher values indicate a greater level of hedonic hunger. Hedonic hunger was measured at each trimester, six months postpartum, and 12 months postpartum. Previous work has supported longitudinal measurement equivalence of the PFS over the three trimesters of pregnancy and at six months postpartum (see Chapter 3).

5.3.3.2 LEPTIN

Maternal serum leptin concentration was calculated based on Enzyme-Linked Immunosorbent Assay (ELISA; R&D Systems, Minneapolis, MN) using the sandwich method. Experimental research suggests that leptin is primarily an indirect influence on satiety through modulating the responsiveness of more direct influences (e.g., cholecystokinin; Moran et al., 2006). Meal-respondent leptin fluctuations are short-term (Romon et al., 1999), thus fasting and non-fasting values are likely similar. Leptin concentrations above 1050 picograms/milliliter were not detectable, thus all values at or above were reflected as 1050 picograms/milliliter. Concentrations were adjusted by a dilution factor of 100 and converted from picograms to nanograms per milliliter to aid in interpretation. Values were subsequently square-root transformed (as indicated below) to mimic a distribution comparable to the other variables used in the analyses. Leptin was measured in the first-trimester (non-fasting), second trimester (fasting), third trimester (non-fasting), and at 12 months postpartum (fasting).

5.3.3.3 CRAVINGS

The PEAS investigators (Nansel et al., 2016) developed a brief questionnaire to assess the presence, intensity, and frequency of food cravings and aversions. Participants were asked to list the three foods for which they experienced the strongest cravings and responded to items to rate how frequently they experienced the cravings for each food listed (on a scale from “never” (1) “very frequently” (5)), as well as how intense the cravings were (on a scale from “mild cravings” (1) to “strongest imaginable cravings” (5)), over the past month. Assessing cravings with this scale enabled women to report their cravings without being restricted to/needing to categorize specific types of food (e.g., as high fat or fast food fats) or being restricted to specific foods (e.g., chocolate). Cravings were measured in the first and second trimester of pregnancy and at 12 months postpartum.

Participants were permitted to report any three foods, which may or may not have overlapped with those reported at other time points. Previous measure development research related to the assessment of cravings suggests that individuals vary considerably concerning the type of foods craved (White et al., 2002) and that frequency and intensity are salient aspects of cravings (Orloff & Hormes, 2014). Thus, two factors (frequency and strength of specific food cravings) were hypothesized to load onto three indicators of frequency and three indicators of strength for specific craved foods at each time point.

5.3.3.4 DIETARY RESTRAINT

Dietary restraint was measured using the dietary restraint scale of the Dutch Eating Behavior Questionnaire (DEBQ; van Strien, 2002; van Strien et al., 1986), in the first-trimester and at six and 12 months postpartum. The DEBQ-R is a 10-item scale (not anchored to time), in which each item is rated on a five-point frequency scale, from “never” (1) to “very often” (5).

Items include “How often do you refuse food or drink offered because you are concerned about your weight?” Item scores are commonly averaged to create a composite, with higher levels indicating greater dietary restraint. Though Larsen and colleagues (2007) suggested that the DEBQ-R may contain two factors (intentions to restrict food intake and behavioral restraint) with differentiable relationships to eating and weight outcomes, our previous work examining the structure of the DEBQ-R (Chapter 3) did not support a two-factor structure. Thus the one-factor structure is retained for the present study. In non-pregnant United States women, DEBQ-R was inversely associated with hypothetical portion size and positively associated with expected satiation following a hypothetical meal (Labbe et al., 2017), suggesting its likely relevance to real-world behavior. Though not commonly examined with pregnant women, one study reported that early pregnancy salience of shape and weight and negative external body evaluations were associated with later pregnancy DEBQ-R. Thus, DEBQ-R may reflect enactment of sociocultural prescriptions (or attempts to do so) regarding shape and weight, even during pregnancy.

5.3.4 ANALYTIC PLAN

All data analyses were conducted in *R* v4.1.3 using the graphical user interface *RStudio* v2022.02.3 (R Core Team, 2022; RStudio Team, 2022). Structural equation modeling was used to address the study aims, via the *lavaan* package. An initial confirmatory factor analysis tested hypothesized relationships between baseline measurements of leptin, hedonic hunger, and dietary restraint. The proposed latent factors were permitted to covary freely, after which global and local fit indices were used to screen for, identify, and address model misfit or misspecification (aligned with prior research and theory).

Following this initial test, a structural model was specified such that leptin, dietary restraint, and hedonic hunger subscales predicted frequency and intensity of cravings, with exogenous variables freely permitted to covary (Figure 4). This was tested prospectively during pregnancy. A post-hoc power analysis was conducted using the *semPower* package (Moshagen & Erdfelder, 2016) to estimate the power to detect global model misfit (RMSEA >.10). Subsequent analyses tested dietary restraint as a potential moderator of the relationships between cravings with leptin and with hedonic hunger subscales (separately) using a latent variable interaction model as recommended by Sardeshmukh and Vandenberg (2017) and Jorgensen (2021).

To test the hypothesized interactions, product-indicator terms were constructed using the *indProd* function in *semTools* (Jorgensen et al., 2021) using the double mean centering approach to represent the interactions of dietary restraint with the “food available” factor, the “food present” factor, the “food tasted” factor, and leptin concentration. The product-indicator approach creates indicators that are the products of each combination of indicators from the two constructs hypothesized to have an interaction effect. Double mean centering calculates products from the mean-centered constituent variables, after which these product indicators are mean-centered independently, allowing them to measure the latent product term. The latent product term is treated as another latent construct, of which the indicators are all of the indicator products described above. Residual covariances are included and constrained to equality within items across their interaction with any other item (Jorgensen et al., 2021). When possible, models were estimated using robust full information maximum likelihood (FIML) methods, which have been demonstrated to be robust to non-random missingness and distributional divergences from normality (Enders, 2001a, 2001b). Full-information maximum likelihood uses all available data to contribute to estimates, omitting any cases for which no data is available. Both multiple imputation and FIML were considered as approaches to manage missingness in the data. The choice to use FIML was informed by substantive and logistical considerations (Jia, 2016; Lee & Shi, 2021), a few of which are detailed below to provide context for the decision.

From a substantive perspective, as we were simultaneously conducting work to test longitudinal measurement equivalence (Chapter 3), we could not assume this condition in order to inform a multilevel imputation model that would account for repeated measures within the data, but could not conduct simple multiple imputation due to the possible dependencies (Huque et al., 2018). FIML estimation occurred for each model, reflecting the theoretical assumptions of the researchers. From a logistical perspective, even if dependencies were assumed to be conservative, the complexity of the data (e.g., irregularly spaced, item-level) resulted in an extremely computationally intensive model with recurrent convergence issues that frequently produced implausible values (e.g., negative values). Because FIML was used in the estimation of each model separately, it was not hindered by the need to manage irregularities and dependencies across the entire dataset.

5.4 RESULTS

5.4.1 SAMPLE CHARACTERISTICS

Of the total number of enrolled participants (*N* = 458), 137 withdrew from the study (91 during pregnancy, 46 during postpartum). Reasons are detailed further in Table 5.2. Visual examination of boxplots and review of descriptive statistics did not suggest differences in distributions of sociodemographic characteristics or on the measures of interest between those who withdrew early from the study and those who continued. For those who remained in the study, the 12-month postpartum visit psychosocial measures were abbreviated during the study (after 122 participants had completed the final visit) to minimize participant burden, so fewer individuals completed measures of the focal constructs in this study than those who completed that visit (approximate *N* = 70).

Missingness on specific item-level indicators of the PFS ranged from 13% to 34% across trimesters 1-3 and 6 months postpartum, with greater rates of missingness at later time points, with the exception of one item ("Just before I taste a favorite food, I feel intense anticipation."). This item was not administered for some participants (*n* = 306 in first-trimester, *n* = 223 in second trimester, *n* = 178 in third trimester) due to an error during the creation of the online questionnaires. For the same timeframe (visits occurring prior to 12 months postpartum), missingness on specific item-level indicators of the DEBQ-R ranged from 18% to 46% across time points, missingness on leptin concentration values ranged from 2% to 21%, and missingness on craving items ranged from 17% to 62%. No consistent patterns of missingness were observed, so data were assumed to be missing at random. As no tests occur at the item level, even high levels of item-level missingness are not thought to contribute to bias within the analysis (Newman, 2014).

5.4.2 PSYCHOMETRICS OF THE FOOD CRAVINGS MEASURE

Bivariate analyses between the items within the food craving measure indicated that craving strength and frequency of different foods noted within each time point were highly correlated (*r*s = .69 - .96). Correlations between first-trimester and second-trimester craving indicators (*r*s = .28 - .42) were typically smaller than correlations between first-trimester and 12-months postpartum craving indicators (*r*s = .42 - .61). Skew and kurtosis for nearly all craving indicators were acceptable (<1.5 and >-1.5), though the strength indicator for the third indicated food item at 12 months postpartum demonstrated higher skew and kurtosis (1.87 and 2.39, respectively). Skew/kurtosis of one indicator was not thought to have a significant influence on the overall analysis so this item was retained.

The cravings measure had not been previously subjected to factor analysis, so multiple factor structures (based on theoretical/empirical predictions) were tested against one another to identify the best-fitting model. Confirmatory factor analysis ($N = 334$) indicated that although the fit of a two-factor model was superior (robust $\chi^2 = 12.68$, $df = 5$, $p < .001$; robust CFI = .995, robust RMSEA = .086[.027, .147]), the frequency and strength factors in the two-factor model were redundant ($r = .95$), thus the one-factor model was retained (robust $\chi^2 = 53.17$, $df = 6$, $p < .001$; robust CFI = .962, robust RMSEA = .211[.161, .265]). Subsequent measurement equivalence testing indicated support only for constraining the factor structure of the cravings measure over time (configural equivalence model fit: $\chi^2 = 438.65$, $df = 145$, $p < .001$; CFI = .926, RMSEA = .087[.078, .076]), because constraints on the loadings decremented model fit (ΔCFI > .01, *p* value for chi-square difference test < .001). Thus, the data does not support the critical assumption that individual craving strength and frequency for the three craved foods are equally important to measuring underlying cravings across time. Further testing modeled cravings as three separate variables during the first trimester, second trimester, and at 12 months postpartum.

5.4.3 ADDITIONAL MODELING CONSIDERATIONS

Leptin was square root-transformed, so the distribution more closely resembled that of the indicators (e.g., dietary restraint, cravings) used to scale the other latent factors. In order to facilitate model estimation and permit the calculation of modification indices to inform consideration of respecification as needed, visit 1 leptin was specified as a latent factor loading onto the single indicator of the adjusted concentration for that visit (square-root transformed). The variance of the square-root transformed variable was used along with an approximate fixed-reliability of 0.8 (Savalei, 2017, 2019) to calculate a constraint for the unique variance of leptin not attributable to the latent factor. The loading was constrained to 1 to enable scaling of the latent factor based on the single indicator as the marker item. Power to detect model misfit of RMSEA >.10 was estimated to be >99% for models described below.

5.4.4 MODEL TESTING

The initial model ($N = 407$) examined cross-sectional relationships between cravings, dietary restraint, food availability, food present, food tasted, and leptin, with the acceptable fit (robust $\chi^2 = 887.66$, $df = 447$, $p < .001$, robust CFI = .913, robust RMSEA = .051[.046, .056], SRMR = .068). None of the regression coefficients for the proposed predictors were statistically or practically significant, and the model only explained about 9% of the variance in cravings.

The next model specified second-trimester cravings as being predicted by first-trimester cravings, dietary restraint, food availability, food present, food tasted, and leptin. This model fit ($N = 407$) was adequate (robust $\chi^2 = 1333.09$, $df = 641$, $p < .001$, robust CFI = .906, robust RMSEA = .054[.050, .058], SRMR = .060). Only first-trimester cravings were uniquely associated with second-trimester cravings (β = .42, p < .001). Altogether, this model explained approximately 22.9% of the variance in second-trimester cravings. We also tested whether any of the hedonic hunger subscales had an indirect influence on second-trimester cravings, through first-trimester cravings, but none of these indirect effects were statistically or practically significant. In addition, calculated interaction terms of dietary restraint with leptin, food available, food present, and food tasted, respectively, did not improve model-explained variance in second-trimester cravings. Thus, the main effect model was retained.

The following model specified 12-months postpartum cravings as being predicted by first-trimester cravings, dietary restraint, food availability, food present, food tasted, and leptin. This model fit (N = 407) was adequate (robust χ^2 = 1304.39, df = 639, p < .001, robust CFI = .894, robust RMSEA = .051[.047, .055], SRMR = .098). Only first-trimester cravings were uniquely associated with 12-months postpartum cravings (β = .62, p < .001). Altogether, this model explained approximately 41.3% of the variance in 12-months postpartum cravings. Interaction terms of dietary restraint with leptin, food available, food present, and food tasted, respectively, did not improve variance explained by the model. Thus, the main effect model was retained.

A concurrent model specified 12-months postpartum cravings predicted by 12-months postpartum dietary restraint, food availability, food present, food tasted, and leptin. This model fit (N = 271) was adequate (robust χ^2 = 816.37, df = 447, p < .001, robust CFI = .812, robust RMSEA = .053[.047, .059], SRMR = .097). Only food availability was uniquely associated with 12-months postpartum cravings (β = .53, p = .004). Altogether, this model explained approximately 25.7% of the variance in 12-months postpartum cravings. Calculated interaction terms of dietary restraint with leptin, food available, food present, and food tasted, respectively, did not result in observable changes to the overall model, nor to the explained variance in 12 months postpartum cravings. Thus, the main effect model was retained.

Fit statistics are not provided for the interaction models because interaction terms are a function of the main effect terms and traditional evaluations of model fit are unable to account for this dependence (see Jorgensen et al., 2021). Instead, Jorgenson et al. (2021) suggest that the model fit of the main effects model be considered the "lower bound" of fit. Across all models tested as described above, model covariance residuals descriptive statistics were reviewed and stem-and-leaf plots of the residuals were visually examined for deviations from a normal distribution. Using a system of evaluation suggested by Little (2013, p.118), all model residuals appeared to be absent of platykurtosis, severe skew, or outliers, however, as described elsewhere (see Chapter 3), there were some consistent likely contributors to local misfit (e.g., cross-loadings).

5.5 DISCUSSION

The present study described a novel examination of psychophysiological influences on cravings during pregnancy and postpartum. We examined concurrent associations of leptin, hedonic hunger, and dietary restraint with cravings during the first-trimester of pregnancy, prospective first-trimester influences on second-trimester cravings, prospective first-trimester influences on 12-months postpartum cravings, and concurrent associations with 12-months postpartum cravings. First-trimester influences on appetite (hedonic hunger, leptin, dietary restraint) were not associated with first-trimester cravings, second-trimester cravings, or 12-months postpartum cravings. Only first-trimester cravings were associated with subsequent cravings (i.e., second-trimester and 12-months postpartum cravings). In contrast, a 12-months postpartum model of concurrent influences indicated a significant positive association between PFS-Available and cravings. Across all models, interaction effects were non-significant and did not appreciably improve models. Implications are discussed below in the context of the strengths and limitations of the present study. Overall, our results suggest that pregnancy cravings are not strongly associated with the appetite influences examined here, postpartum cravings are not strongly associated with pregnancy appetite influences examined here, and postpartum cravings do demonstrate some concurrent associations with hedonic hunger similar to what is observed in more broadly inclusive samples (e.g., general adult and/or college-aged individuals).

Unexpectedly, no significant associations of first-trimester pregnancy cravings with first-trimester hedonic hunger subscales, leptin concentration, or dietary restraint were observed, and this model collectively accounted for less than a tenth of the variation in first-trimester cravings (9%). This result suggests that the majority of the variability in first-trimester cravings is attributable to influences not included in this model. Similarly, first-trimester cravings, dietary restraint, hedonic hunger, and leptin were collectively associated with 23% of the variation in second-trimester cravings, but only first-trimester cravings made a statistically significant contribution to the model. Since the proportion of variance explained in second-trimester cravings was primarily due to the inclusion of first-trimester cravings as a predictor, and indirect effect models indicated that the other variables in the model did not impact second-trimester cravings through first-trimester cravings, results are consistent with the findings from the first concurrent model.

First-trimester cravings, dietary restraint, hedonic hunger, and leptin were collectively associated with just over 40% of the variance in 12-months postpartum cravings. Similar to what was found in the first to second-trimester model, only first-trimester cravings made a significant individual contribution to this model. However, in comparison to the first to second trimester model, the first trimester to 12-months postpartum model explained nearly double the variability in 12-months postpartum cravings. This finding suggests that first-trimester cravings covary more closely with 12-months postpartum cravings than with second-trimester cravings. From an appetite standpoint, second-trimester cravings may also be influenced by other aspects (not included in our models) that may be unique to that part of pregnancy (e.g., mood, growing awareness of the fetus/infant). The lack of any significant associations between appetite influences and cravings during pregnancy or from pregnancy to postpartum indicates that the majority of the variability in cravings is likely due to factors not included in our models. The proportion of explained variance (approximately 23-41%) in predictive models was likely primarily due to previously reported cravings, as this was the only significant predictor in each model.

Finally, concurrent tests of relationships of 12-months postpartum cravings with 12-months postpartum PFS-Available, PFS-Present, PFS-Tasted, leptin, and dietary restraint revealed a significant contribution of PFS-Available to this model, which collectively was associated with about a quarter (25%) of the variability in 12 months postpartum cravings. In contrast to the role of PFS-Available in the concurrent first-trimester model (not statistically or practically significant), this model showed a distinct role for PFS-Available. This result is consistent with the overall conceptualization of PFS-Available, which suggests that sensitivity to environmental stimuli such as billboards, advertisements, or awareness of nearby food, is associated with greater levels of reported cravings.

With respect to the relationship between hedonic hunger and cravings, most of our findings contrast with prior work in a sample of United States undergraduate students (Forman et al., 2007) for whom hedonic hunger (overall PFS) predicted craving frequency and intensity in the subsequent 48 hours. From a measurement perspective, our previous work (Chapter 3) indicated that a 3-factor structure (PFS-Available, PFS-Present, PFS-Tasted) was a better fit for the PFS in pregnancy and postpartum compared to a 1-factor model (general hedonic hunger). However, prior work which used a mean composite may have demonstrated significant relationships with hedonic hunger as a result of inflation of estimates due to combining across these subscales rather than a true relationship between hedonic hunger and cravings.

However, experimental research involving a craving induction in college students and commuting adults observed that engaging participants in a cognitively demanding task weakened the association between hedonic hunger and cravings (van Dillen & Andrade, 2016). Pregnancy may be demanding (cognitively or in other ways) such that expected relationships between hedonic hunger and cravings are weaker or not present during this time. Other experiences, such as thoughts/memories, physiological sensations (e.g., nausea), or emotions, may be more influential during pregnancy, though additional research would be needed to test this speculation. We did test a predictive model of the associations between 12-months postpartum cravings and first-trimester appetite influences. Still, the duration of time between these two time points may have been too long to observe an association. The concurrent model at 12-months postpartum supported a relationship between PFS-Available and cravings, which is more similar to findings outside of pregnancy and postpartum. Longitudinal work with more frequent data points within pregnancy and the first year postpartum may help to reveal possible changes in the relationship between hedonic hunger and cravings over this time.

Unexpectedly, our results also did not support a relationship between leptin and cravings during pregnancy and postpartum. While this is consistent with findings in a naturalistic community sample of US adults (Chao et al., 2017), it is inconsistent with findings in a sample of individuals in the latter phase of menstruation (luteal cycle; Yen et al., 2020), who arguably are more similar to the present sample given the hormonal changes common to menstruation, pregnancy, and postpartum. Krishnan and colleagues (2016) also reported an association between leptin and cravings during the menstrual cycle, though this was restricted to cravings for fat-rich foods. As we did not differentiate between the types of foods craved, we were not able to test this specific association; variability in the associations between leptin and specific types of cravings may have resulted in an overall null or negligible association.

First-trimester dietary restraint was not associated with cravings, nor did it modify relationships of hedonic hunger or leptin with cravings. This lack of support is not consistent with our theoretical framework (Embodied Self Model; Cook-Cottone, 2020), which would suggest that dietary restraint is an externally motivated pressure to control intake. As externally motivated pressures are thought to unbalance embodiment away from responding to internal signals, dietary restraint was expected to heighten perceived deprivation, which was expected to manifest as cravings (Schaumberg et al., 2016). As previously noted, cross-sectional analyses conducted using the same data as examined in this work supported associations between poor sleep quality and cravings during pregnancy (Betts et al., 2021), which lent empirical support to the idea that cravings may be observed in the setting of perceived deprivation, at least in pregnancy. Yet, the lack of support we observed is consistent with experimental work which found no association between induced cognitive dietary restraint and self-reported cravings in women with higher weight (Morin et al., 2018). While these prior findings did not preclude the consideration of dietary restraint as a potential modifying influence of relationships between cravings and hedonic hunger and leptin respectively, we also did not find support for this moderating role. Outside of concerns (discussed above) regarding heterogeneity in the measurement of dietary restraint, the lack of support for our theoretical expectations may have also been due to the direction of the relationships studied. Dietary restraint may not predict increased cravings during pregnancy or postpartum, but it is possible that cravings may predict postpartum dietary restraint as a result of sociocultural narratives which prescribe “tightening up” or “bouncing back” following pregnancy (Johnson & Quinlan, 2019). Future work could incorporate qualitative methods to gain a better understanding of the unique factors relevant to dietary restraint and cravings in postpartum, given the limited research thus far in this area.

5.5.1 STRENGTHS, LIMITATIONS, AND FUTURE DIRECTIONS

The present study involved a large sample of women followed over a substantial period of time spanning pregnancy through the first year postpartum. Thus results are more likely to be generalizable to women with similar demographic characteristics during this time period. The availability of data from multiple time points allowed us to adjust for the presence of prior cravings to test prospective relationships with appetite influences. Using a full structural equation model minimized the contribution of error due to measurement bias, allowing closer approximation of the relationships of interest. Future work could utilize a latent growth curve design and additional repeated measures to isolate longitudinal change from trait-level relationships by separating between-person and within-person variability.

The cravings measure demonstrated good psychometric properties separately at each time point, supporting its relevance to our research questions regarding the construct of cravings. However, this measurement was not equivalent over time. Equivalence testing conducted at periodic intervals during pregnancy and postpartum could help to identify sources of measurement variance and minimize measurement bias. Another source of measurement bias may be the measure's focus on rating cravings related to specific foods, which may not have accurately summarized overall cravings either within or between time points. Future development of the cravings measure could involve using alternative, less food-specific indicators of this construct, such as dominant taste (e.g., sweet, salty) or focusing on the impact of cravings (e.g., "My cravings distracted me from doing the things I wanted or needed to do") to support consistent operationalization over time.

Our unexpected lack of support for relationships of dietary restraint with cravings during pregnancy or postpartum could be due to limited variability in our measure of restraint. Variability observed in the DEBQ restraint scale was small relative to the mean (M = 2.48, SD = 0.67) though was not significantly different (Cohen's d = .01) than what was observed in the original validation study (M = 2.49, SD = 0.93; van Strien et al., 1986). However, individual items had more variability (M = 2.17-2.91, SD = 0.86-1.06), thus our use of structural equation modeling to incorporate individual item information may have allowed us to represent item variability which can be obscured when averaging across items to create a mean composite. Lack of evidence for relationships of cravings with dietary restraint could also indicate that items in the DEBQ are interpreted in different ways and thus have different associations for pregnant or postpartum women. Measurement revision and refinement could clarify the ways in which dietary restraint may or may not be relevant during pregnancy and postpartum. For example, qualitative work could explore how items are interpreted and their relevance or lack of such to the pregnancy/postpartum experience, or the motivations (e.g., health, baby's health) for restraint. Further, the postpartum period continues to be an understudied time period and the present analyses included only one time point during postpartum. Future research should include additional time points within the first 12 months postpartum to better understand how the studied relationships may change in presence or relevance following birth. To further test the Embodied Self Model, it may be useful to query individuals regarding awareness and/or experienced influence of common sociocultural narratives related to pregnancy and postpartum, to recognize their role within this system of influences on appetite.

5.5.2 CONCLUSION

While cravings are commonly reported during pregnancy, little research has examined cravings in postpartum. Pregnant and postpartum individuals are subjected to societal pressures regarding the moral weight of their eating and drinking choices, which may frame eating behaviors as matters of choice or effort. They may prompt dietary restraint to prevent eating in response to cravings. Instead, we hypothesized that cravings may result from attempts to manage external demands and internal signals, such as responsiveness to the food environment, signaling regarding anticipated reward, dietary restraint or an interaction among these potential influences.

The present study examined leptin, hedonic hunger, and dietary restraint as potential prospective and current influences on pregnancy and postpartum cravings.

Though their combined influence accounted for a sizable proportion of the variance in late pregnancy and 12-months postpartum cravings, results did not support a unique contribution of most of the examined factors. Notable exceptions included prior cravings as a significant predictor of late pregnancy and postpartum cravings. PFS-Available was individually associated with cravings in a model of concurrent associations at 12 months postpartum. Considered as a whole, our lack of support for these associations diverged from results of published literature examining cravings in non-pregnant individuals. Pregnancy and postpartum may be unique periods during which cravings are influenced by other aspects not studied here or a combination of influences, all of which are necessary to explain variation in cravings, but none of which are individually sufficient. This area of research could be advanced by future work incorporating more pregnancy- and/or postpartum-specific factors that may influence cravings to test their role, as well as smaller delays in time to model fluctuations within trimesters or across the first year postpartum.

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Table 5.1

Sample Characteristics (at baseline)

Sociodemographic characteristic	Mean ± SD *or* N (%)	Range
Age	30.46 ± 4.74	18-42
Education		
High school graduate or less	34 (9.26%)	-
Some college or associate's degree	70 (19.07%)	-
Bachelor's degree	108 (29.43%)	-
Master's or advanced degree	155 (42.23%)	-
Body-mass index (BMI)	27.19 ± 6.94	18.6-59.8
Race/Ethnicity		
White	264 (67.3%)	-
Black	59 (15.05%)	-
Asian	19 (4.85%)	-
Native American/Native Hawaiian	1 (<1%)	-
Hispanic/Latinx	33 (8.41%)	-
Multi-race or Something not listed	16 (4.08%)	-
Nulliparous	250 (54.5%)	-
Income to poverty ratio	3.84 ± 1.97	0.39-8.41
%WIC Eligible	24.3	-
Gestational age at delivery	39.3 ± 2.09	23 - 42.1

Sociodemographic characteristic	Mean ± SD *or* N (%)	Range
Household size	3.02 ± 1.2	1 - 10
Marital status		
Married/Partnered	333 (90.7%)	-
Single/Separated/Divorced/Widowed	34 (9.26%)	-

Note. Race/ethnicity identification categories are mutually exclusive.

Table 5.2

Reasons for Study Withdrawal

Withdrawal reason	Number of participants
Unwillingness to continue participating	48
Miscarriage, stillbirth, death of baby	29
Change in medical provider or location	17
Did not attend study visits or lost to follow up	37
Development of condition resulting in ineligibility	6

Table 5.3

Measurement Equivalence Model Fit Indices for Cravings Measure

Model	CFI	ΔCFI	χ^2	*df*	$\Delta\chi^2$	Δ*df*	RMSEA	SRMR	Sample-size adjusted BIC
Configural[a]	.932	-	332.95	123	-	-	.069	.054	9260.59
Metric[b]	.794	.138	773.01	135	289.92*	12	.114	.262	9835.71
Scalar[c]	.878	.006	1860.26	147	42.44*	12	.113	.269	9808.87

Note. [a]This model tests the degree to which the data supports the same structure of the measure over time/across groups. [b]This model retains the structural constraints and adds a test of whether the data supports the same factor loading for each item across time/groups. [c]This model retains the structural and loading constraints and adds a test of whether the data supports the same intercepts for each item across time/groups. All fit indices are calculated with robust standard errors unless indicated otherwise. CFI = robust comparative fit index; RMSEA = robust root-mean-square error of approximation; SRMR = standardized root mean residual; BIC = Bayesian Information Criterion. *Indicates change is statistically significant at $p < .05$.

Table 5.4

Model Fit Indices - Concurrent - First Trimester Cravings

Model	CFI	χ^2	*df*	RMSEA	SRMR	Cravings R^2
Main effect model	.913	887.66	447	.051 [.046, .056]	.068	.09
Model with PFS-A x DR	.446	14976.35	4056	.081 [.080,.083]	.100	.09
Model with PFS-P x DR	.576	8642.54	2448	.079 [.077, .081]	.086	.09
Model with PFS-T x DR	.442	13131.02	3202	.087 [.086, .089]	.114	.09
Model with Leptin x DR	.845	1869.19	796	.058 [.054, .061]	.071	.09

Note. *N* = 407. CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual. PFS-A = Power of Food Scale-Food Available; PFS-P = Power of Food Scale-Food Present; PFS-T = Power of Food Scale-Food Tasted; DR = Dutch Eating Behavior Questionnaire-Dietary Restraint.

Table 5.5

Parameter Estimates for Main Effect Model - Concurrent - First Trimester Cravings

	b (SE)	*p*	First Trimester Cravings R^2
Model			.09
T1 PFS-Available	.44 (.25)	.074	
T1 PFS-Present	-.03 (.21)	.877	
T1 PFS-Tasted	.19 (.27)	.877	
T1 Dietary Restraint	.04 (.17)	.794	
T1 Leptin	.08 (.05)	.129	

Note. *N* = 407. T1 = First trimester; PFS = Power of Food Scale.

Table 5.6

Model Fit Indices - Prospective - Second Trimester Cravings

Model	CFI	χ^2	*df*	RMSEA	SRMR	Cravings R^2
Main effect model	.906	1330.73	639	.054 [.050, .058]	.060	.23
Model with PFS-A x DR	.494	15887.77	4607	.078 [.076,.079]	.097	.23
Model with PFS-P x DR	.622	9346.99	2879	.074 [.073, .076]	.082	.24
Model with PFS-T x DR	.508	13453.52	3693	.081 [.079, .82]	.114	.23
Model with Leptin x DR	.864	2316.92	1047	.055 [.052, .058]	.067	.23

Note. *N* = 407. T1 = First trimester; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual. PFS-A = Power of Food Scale-Food Available; PFS-P = Power of Food Scale-Food Present; PFS-T = Power of Food Scale-Food Tasted; DR = Dutch Eating Behavior Questionnaire-Dietary Restraint.

Table 5.7

Parameter Estimates for Main Effect Model - Prospective - Second Trimester Cravings

	b (SE)	*p*	Second Trimester Cravings R^2
Model			.23
T1 Cravings	.40 (.07)	<.001	
T1 PFS-Available	-.04 (.26)	.895	
T1 PFS-Present	.01 (.19)	.970	
T1 PFS-Tasted	.33 (.28)	.251	
T1 Dietary Restraint	-.12 (.15)	.428	
T1 Leptin	-.02 (.06)	.707	

Note. N = 407. T1 = First trimester; PFS = Power of Food Scale.

Table 5.8

Model Fit Indices - Prospective - 12 Months Postpartum Cravings

Model	CFI	χ^2	*df*	RMSEA	SRMR	Cravings R^2
Main effect model	.894	1304.39	639	.051 [.047, .055]	.098	.41
Model with PFS-A x DR	.400	18751.42	4607	.087 [.086,.088]	.103	.43
Model with PFS-P x DR	.515	11408.19	2879	.085 [.084, .087]	.099	.41
Model with PFS-T x DR	.417	15544.14	3693	.089 [.087, .090]	.123	.41
Model with Leptin x DR	.827	2401.91	1047	.056 [.053, .059]	.097	.42

Note. N = 407 . T1 = First trimester; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual. PFS-A = Power of Food Scale-Food Available; PFS-P = Power of Food Scale-Food Present; PFS-T = Power of Food Scale-Food Tasted; DR = Dutch Eating Behavior Questionnaire-Dietary Restraint.

Table 5.9

Parameter Estimates for Main Effect Model - Prospective - 12 Months Postpartum Cravings

	b (SE)	*p*	12 Months Postpartum Cravings R^2
Model			.41
T1 Cravings	.55 (.12)	<.001	
T1 PFS-Available	-.03 (.62)	.965	
T1 PFS-Present	.12 (.38)	.748	
T1 PFS-Tasted	-.22 (.45)	.624	
T1 Dietary Restraint	.23 (.26)	.379	
T1 Leptin	.07 (.08)	.359	

Note. *N* = 407. T1 = First trimester; PFS = Power of Food Scale.

Table 5.10

Parameter Estimates for Main Effect Model - Concurrent - 12 Months Postpartum Cravings

	b (SE)	*p*	12 Months Postpartum Cravings R^2
Model			.26
12M PFS-Available	.64 (.22)	.004	
12M PFS-Present	-.21 (.22)	.342	
12M PFS-Tasted	.08 (.27)	.761	
12M Dietary Restraint	-.05 (.18)	.783	
12M Leptin	.09 (.09)	.310	

Note. N = 271. 12M = 12 Months Postpartum; PFS = Power of Food Scale.

Table 5.11

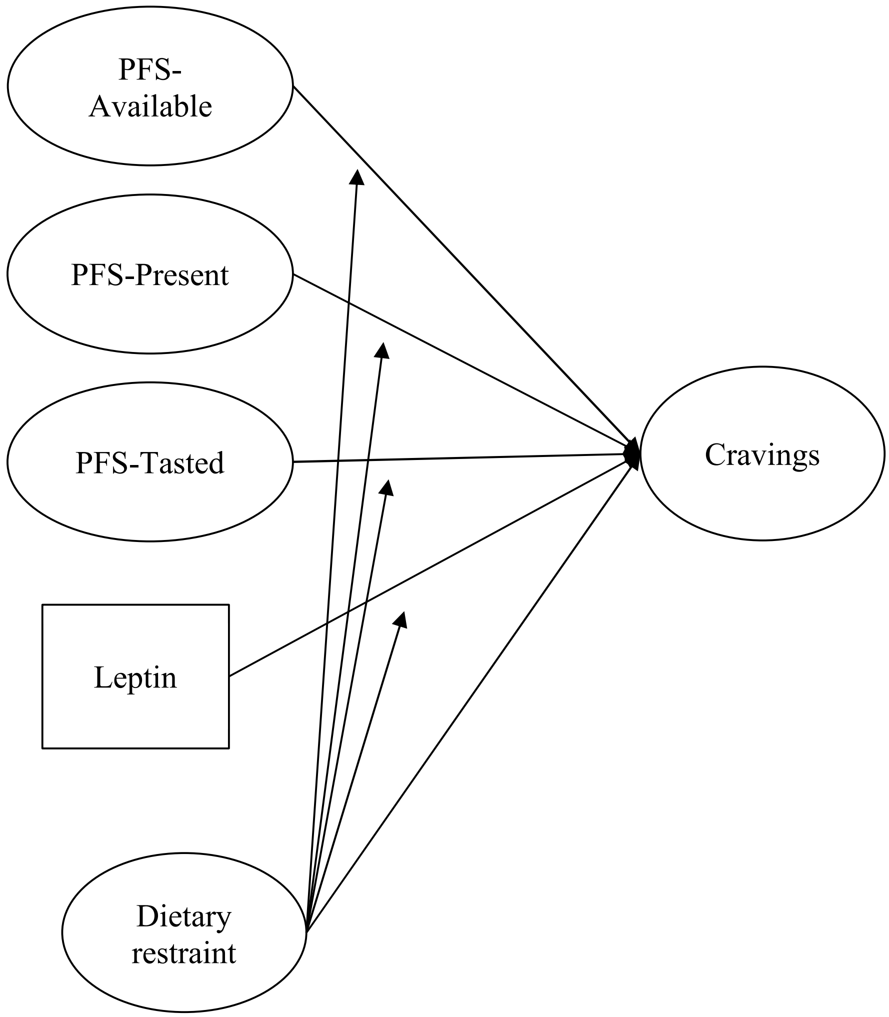
Model Fit Indices - Concurrent - 12 Months Postpartum Cravings

Model	CFI	χ^2	*df*	RMSEA	SRMR	Cravings R^2
Main effect model	.812	816.37	447	.053 [.047, .059]	.097	.26
Model with PFS-A x DR	.150	30371.96	4056	.155 [.153,.156]	.119	.26
Model with PFS-P x DR	.254	11017.19	2448	.114 [.111, .116]	.115	.25
Model with PFS-T x DR	.173	17765.72	3202	.130 [.128, .131]	.121	.25
Model with Leptin x DR	.641	1758.67	797	.067 [.063, .071]	.106	.27

Note. N = 271 . T1 = First trimester; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root mean residual. PFS-A = Power of Food Scale-Food Available; PFS-P = Power of Food Scale-Food Present; PFS-T = Power of Food Scale-Food Tasted; DR = Dutch Eating Behavior Questionnaire-Dietary Restraint.

Figure 5.1

Conceptual Model for Associations with Cravings



Note. Model is simplified for ease of view and does not illustrate individual indicators and error terms for latent factors.

CHAPTER 6: GENERAL DISCUSSION

The preceding chapters examined influences on appetite during pregnancy and postpartum from measurement, longitudinal, and predictive vantage points in a sample of adult women from the southeastern United States. PFS demonstrated measurement equivalence across pregnancy and postpartum. In comparison to data from a sample of United States young adult women, PFS exhibited structural (configural) and loading (metric) equivalence across samples, with (scalar) non-equivalence of item-level information. Though leptin exhibited fluctuation over pregnancy and into postpartum, PFS did not. Finally, leptin, PFS, and dietary restraint collectively explained minimal to moderate variation in cravings, with no consistent patterns of influence concurrently or prospectively other than prior cravings during pregnancy or postpartum. Below, each study's key findings and potential implications are summarized, along with suggestions for future work.

6.1 SUMMARY OF FINDINGS

This work is consistent with other qualitative and quantitative scholarship documenting cravings (Most et al., 2020; Orloff & Hormes, 2014) and changes in leptin during pregnancy and postpartum (Skalkidou et al., 2009), though inconsistent with previous findings of changes in PFS when diet and behavior changed (Cushing et al., 2014). Shorter assessment intervals may provide additional detail on fluctuations within trajectories or further support stability over time. The Power of Food Scale (PFS; Cappelleri et al., 2009) has been validated in various adult sub-populations (Serier et al., 2019) and is commonly reflected as an overall mean following its original scoring instructions. The PFS exhibited stable psychometric properties over pregnancy and postpartum and as expected, had strong associations with measures of emotional eating, external eating, and an inverse association with a measure of the ability to delay food-related gratification. Contrary to theoretical expectations, dietary restraint was not significantly related to PFS. Compared to a community sample of US young adult women, PFS item-level properties were different during pregnancy and postpartum, suggesting that specific items and scoring instructions may need to be explored and revised for this sub-population.

PFS was stable over time, suggesting that hedonic hunger remains a trait-level, intra-individually consistent characteristic across pregnancy and the first year postpartum. In contrast, leptin had a small positive slope and those with higher starting levels had a flatter slope over time. Although initial leptin and PFS levels were not correlated, the PFS-Present was moderately associated with leptin rate of change, indicating that those with higher sensitivity to food immediately present had a steeper change in leptin over pregnancy and postpartum. Greater initial responsiveness to food present in the environment could be associated with sharper increases in leptin as part of the negative feedback loop to regulate food intake and energy storage, which may remain active during pregnancy. However, effect sizes were modest and inconsistent relationships across PFS subscales likely indicate that leptin varies independently of PFS during pregnancy and postpartum.

Finally, cravings appear to be a complex phenomenon during pregnancy and postpartum, significantly related to previously reported cravings but not significantly influenced by dietary restraint, hedonic hunger, or leptin. While models explained a sizable proportion of the variance in cravings both concurrently and prospectively, no one influence emerged as a significant influence on cravings and tests of interactions between dietary restraint, leptin, and PFS subscales were not significant. Lack of evidence for the hypothesized associations between these variables could have been due to the focus of the cravings measure on specific foods or the distance between measurements. Other internal or environmental factors may be stronger determinants of cravings. Future work could use intensive longitudinal designs and incorporate other potential influences to examine cravings as they may be a more momentary phenomenon.

6.2 STRENGTHS, LIMITATIONS, AND FUTURE DIRECTIONS

The present body of work benefited from the repeated measures design, thorough psychometric evaluation of measures, and the use of structural equation modeling to test concurrent, prospective, and longitudinal minimize confounding influences such as measurement bias, measurement nonequivalence, and between-person differences. Yet, there were also limitations to this work, which warrant caution in interpreting the results and suggest appropriate directions for future investigation.

Though we found no evidence to suggest systematic missingness and used full-information maximum likelihood estimation, planned and unplanned missingness, particularly at the 12 months postpartum visit, contributed to estimation difficulties and may have contributed to instability of parameter estimates. Thus, future research designs could incorporate planned missingness for specific sub-groups of participants to reduce the burden and to increase stability and plausibility of estimates. In addition, while we examined measurement equivalence for both hedonic hunger and cravings, we did not conduct a full validation study for either measure. Thus we are uncertain what (if any) changes should be made to these measures to ensure they appropriately reflect the hedonic hunger and cravings of pregnant and postpartum individuals. Future research could test criterion validity for the cravings measurement by assessing whether scores predict eating behaviors during pregnancy and postpartum. Alternatively, qualitative research or cognitive interviewing (e.g., Drennan, 2003) could be useful for generating new items or revising existing items.

Similarly, this field of work will benefit from continued testing to determine which leptin-related indices (e.g., free leptin, bound leptin, leptin receptor) will be most helpful in measuring aspects related to eating behaviors, including reward signaling in the brain, satiety in the gut, and perceptions of satiety in the brain. It remains uncertain whether peripheral leptin can appropriately function as a measure of central leptin (Sáinz et al., 2015). Specifically, additional criterion validity testing (e.g., with eating behaviors, self-reported food reward perceptions, hunger, satiety, etc.) will determine the utility of measuring peripheral leptin during pregnancy and postpartum. With multiple types of leptin receptors and the contextual consideration of placental versus extra-placental leptin, it will be essential to determine what level of granularity in these indices will allow for the most accurate assessment of the influence of leptin on appetite during pregnancy and postpartum.

6.3 POTENTIAL PRACTICAL IMPLICATIONS

As we were not able to identify any specific factors with unique influences on cravings during pregnancy or postpartum, healthcare providers might be encouraged to explore influences on appetite with their patients from a qualitative standpoint (e.g., emotional or external influences, sociocultural narratives) during pregnancy and postpartum. Process-based approaches to eating, such as mindful eating (Nelson, 2017) could be helpful both in guiding this type of assessment as well as in shifting focus to more internal signals (e.g., hunger, satiety, health-related motivation) rather than external signals (e.g., sociocultural narratives, food stimuli in the environment). Our prior work demonstrated strong associations (in the present sample) between pregnancy and postpartum diet quality and autonomous (internal) motivation, which is typically guided by personal values (Mooney et al., 2021). However, the current state of the literature on the health and diet impacts of mindfulness-based eating interventions is still marked by considerable heterogeneity in design, assessment, and outcome measures, preventing firm conclusions from being drawn regarding their potential impact (Grider et al., 2021; Warren et al., 2017). In particular, our review of prior work and the limitations inherent to the research design of the present study highlight an ongoing paucity of work examining relevant processes during postpartum (Bijlholt et al., 2020). This series of projects examined influences on appetite during pregnancy and postpartum rather than on eating behaviors. Thus, although some prior research exists to guide expectations of how appetitive influences may lead to specific eating behaviors (Blau et al., 2020; Liziewski, 2020; Nansel, Lipsky, Faith, et al., 2020), our analyses did not incorporate typical endpoint behaviors or outcomes (e.g., health/well-being, distress, loss of control eating, diet quality).

6.4 OVERALL CONCLUSION

This project addressed an integrated set of specific aims to test relationships between influences on appetite during pregnancy and postpartum. From measurement, longitudinal, and predictive standpoints, the preceding work suggests that influences on appetite during this unique developmental period do not seem to interrelate. Our findings also suggest that current measurements, indicators, and constructs previously identified as relevant to appetite may not fully reflect intra- and inter-individual variability during this critically important time. Future research could build upon these findings by offering mothers opportunities to provide feedback on measurements prior to their use in this population, incorporating additional appetitive influences and/or increasing the frequency of assessments to capture fluctuations within trimesters or the first year postpartum.

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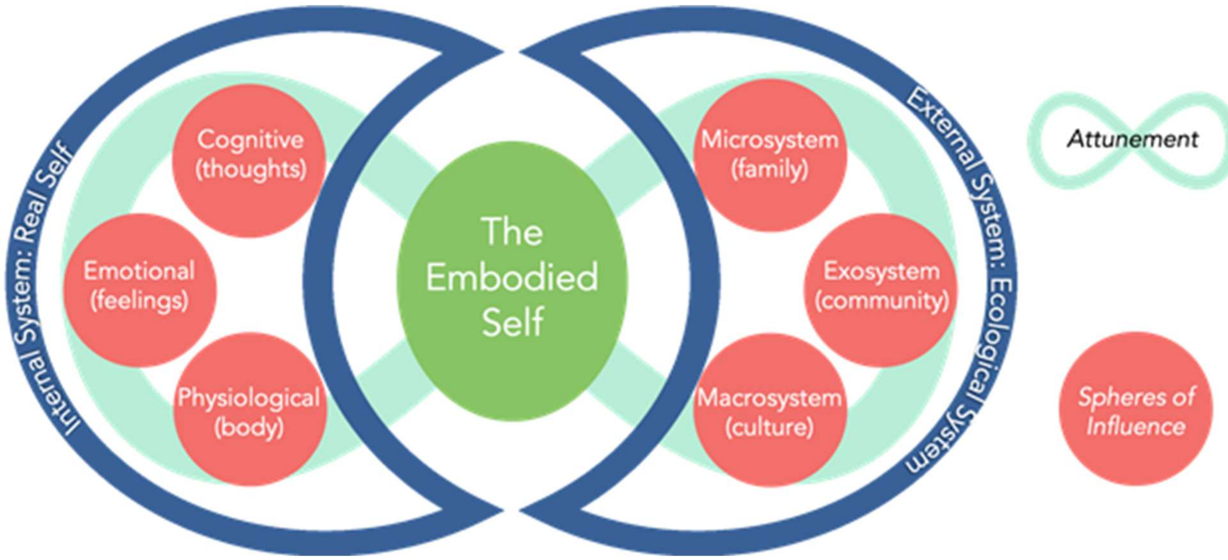
Figure 6.1

Embodied Self Model



Note. Cook-Cottone, 2006, 2015, 2020; This illustrative representation of the model was created by Erin V. Thomas and is reproduced here with permission.