Hedonic Hunger, Ultra-Processed Food Consumption, and the Moderating Effects of Impulsivity in Pregnant Individuals with BMI ≥ 25

by

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Higher hedonic hunger (preoccupation with/desire to consume food for pleasure) has been found to correlate with significantly more ultra-processed food (UPF; hyper-palatable, industrially engineered food) consumption in non-pregnant individuals with high impulsivity. It is unknown if this relationship exists during pregnancy, a period of major biopsychosocial changes that may affect these variables and how they relate. The current study tested the association between hedonic hunger and UPF consumption and the moderating effects of impulsivity in pregnant individuals with BMI≥25, who are at risk for health consequences linked to hedonic hunger and UPF. Individuals (*N*=220; *M*(*SD*)=31.6(4.8) years old) with pre-pregnancy BMI≥25 (*M*(*SD*)=32.0(6.4) kg/m^2) were recruited to a longitudinal study of perinatal health and completed the following self-reports at baseline (*M*(*SD*)=13.8(2.8) weeks' gestation): Power of Food Scale (PFS), 24-hour dietary recalls, Barratt Impulsiveness Scale (BIS-11). Participants enrolled in the ancillary study (*n*=143) also completed the Delay Discounting Task (DDT). Hedonic hunger was operationalized as PFS total score, UPF consumption as percentage of average caloric intake from UPF (defined/calculated using the Nova food classification system), and impulsivity as BIS-11 total score and DDT area under the curve value. A linear regression model tested the association between hedonic hunger and UPF consumption; interaction terms were specified to test moderating effects of self-report impulsivity and DD. Models covaried for age, gestational age, pre-pregnancy BMI, and a socioeconomic status composite variable. The association between hedonic hunger and UPF was not significant (*p*=.44), and self-report impulsivity did not significantly moderate the association (*p*=.11). DD, however, did significantly moderate the association (*p*=.01); with every one-point increase in hedonic hunger, participants with lower DD (M+1SD) consumed 7% fewer calories from UPF (*p*=.01), and those with higher DD (M-1SD) consumed 1% more calories from UPF (*p*=.58). Findings from the current study contradict those from research with non-pregnant samples and suggest that lower DD during pregnancy may serve as a protective factor, contributing to a reduction in UPF consumption at higher levels of hedonic hunger. Future research on hedonic hunger, UPF consumption, and self-report versus task impulsivity within the context of pregnancy is warranted to better understand this unique relationship.

Table of Contents

List of Tables

List of Figures

Preface

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1.0 Introduction

Excessive gestational weight gain has been shown to relate to numerous health risks, such as hypertensive disorders of pregnancy, gestational diabetes, large-for-gestational-age neonates, fetal macrosomia, increased cesarean birth rates, and increased rates of childhood obesity and asthma (McDowell et al., 2018), and pregnant individuals with BMI $\geq$ 25 are at highest risk for exceeding gestational weight gain guidelines. Although dietary intake is a modifiable, fundamental component of weight gain, there is limited understanding of the mechanisms that underlie poor prenatal diet (Parker et al., 2019). Understanding these mechanisms is crucial for developing interventions to mitigate excessive gestational weight gain and promote generational health. Accumulating evidence suggests that, across non-pregnant and pregnant samples, higher hedonic hunger and ultra-processed food (UPF) consumption negatively impact dietary intake and that greater UPF consumption relates to excess weight gain and other adverse health outcomes (X. Chen et al., 2020; Cummings et al., 2022; Espel-Huynh et al., 2018; Nansel et al., 2020, 2022). Studies have consistently found that, in the context of higher levels of impulsivity, non-pregnant individuals with higher levels of hedonic hunger consume significantly more UPF (Appelhans et al., 2011; Ely et al., 2015; Horwath et al., 2020; Stok et al., 2015), indicating that the relationship among hedonic hunger, UPF consumption, and impulsivity might help explain poor diet among non-pregnant individuals. If this relationship is replicable during pregnancy, it could represent a novel explanation for poor prenatal diet, as well as illuminate factors that can be intervened upon to mitigate excessive gestational weight gain and risk for obstetric complications.

The Nova food classification system, which the Food and Agriculture Organization of the United Nations developed to more precisely identify foods based on the nature, purpose, extent, and effects of their processing, defines UPF as food engineered using chemical modification (e.g., hydrolysis), assembly (e.g., pre-frying), additives to increase palatability (e.g., colors, flavors, emulsifiers), and packaged with synthetic materials (Monteiro et al., 2019). UPF (e.g., frozen microwave meals, fast food) is widely available, cheap, and convenient compared to unprocessed and minimally processed food (e.g., fruits, vegetables; Monteiro et al., 2019). Characteristically loaded with added fat, sugar, and/or sodium, UPF is also *extremely* palatable (de Macedo et al., 2016). Due in large part to this combination of appealing attributes, UPF makes up 71% of the packaged food products lining grocery store shelves and constitutes approximately 57% of calories consumed nationwide – and over half of energy intake among pregnant individuals (Baldridge et al., 2019; Baraldi et al., 2018; Nansel et al., 2022). However, UPF consumption is known to be detrimental to diet quality and, importantly, health (X. Chen et al., 2020; Monteiro et al., 2019). Among pregnant individuals, higher prenatal UPF intake is related to lower prenatal diet quality, including lower vegetable, fruit, whole grain, and protein intake (Nansel et al., 2022). Additionally, just one standard deviation increase in percentage of UPF intake during pregnancy has been associated with 31% greater odds of excessive gestational weight gain, 7% more postpartum weight retention, and 0.68 mg/L higher c-reactive protein, irrespective of total calorie intake, BMI, age, and income-poverty ratio (Cummings et al., 2022). Higher prenatal UPF consumption has also been shown to predict greater total body adiposity among newborns and overweight/obesity in early childhood (Hu et al., 2020; Rohatgi et al., 2017). Thus, UPF consumption increases health risk for both birthing individuals and their offspring.

Given that UPF dominates the modern food environment, is a staple in the average American diet, and has a clear, negative impact on diet quality and health, research designed to understand factors that drive its consumption has proliferated. Evidence suggests that UPF consumption over time dysregulates food reinforcement mechanisms, enhancing awareness of and attention to UPF in the environment, heightening desire to consume UPF, and increasing actual UPF intake (Temple, 2016). Neurobiological studies have shown that, likely because of its hyper-palatability, UPF elicits strong activity in the dopaminergic reward system (de Macedo et al., 2016); repeated UPF consumption, coupled with its repeated activation of the brain's reward circuitry, is thought to gradually increase the reinforcing value of UPF for, or sensitize, some individuals, such that they become more preoccupied with and likelier to consume UPF (Temple, 2016). This response has been demonstrated in mice, where prolonged exposure to a "Western" diet (i.e., comprised of food with highly palatable ingredients, mimicking the UPF that humans consume) affected many neurotransmitter systems, leading to double the dopamine release in the dorsal striatum, slower dopamine reuptake, and an overexpression of potential biomarkers of addiction that was associated with greater persistence of food seeking behavior when UPF was deprived (de Macedo et al., 2016; Fritz et al., 2018; Pérez-Ortiz et al., 2017). Relatedly, human subjects research has found that binge eating episodes (i.e., periods involving a subjective sense of loss of control and consumption of an objectively large amount of food) consist predominantly of UPF (*Mdn* = 95.36% of total calorie intake), and higher calorie intake from UPF while binge eating has been associated with more frequent binge eating episodes in the past three months (Bjorlie et al., 2022). Repeated intake of UPF may therefore heighten the incentive to consume UPF and even increase the frequency and quantity of actual UPF consumption (Temple, 2016). This phenomenon of increased salience of and motivation to consume UPF is perhaps best captured by the construct, "hedonic hunger," the psychological impact of living in UPF-abundant environments (Espel-Huynh et al., 2018).

Hedonic hunger is defined as the preoccupation with and desire to consume food for the purpose of pleasure and in the absence of physical hunger (Espel-Huynh et al., 2018). Both fasted and fed non-pregnant individuals with higher levels of hedonic hunger have been found to exhibit heightened neural responsivity to UPF-related stimuli and increased connectivity between brain regions associated with food responsivity and reward sensitivity compared to those with lower levels of hedonic hunger (Espel-Huynh et al., 2018), providing neurobiological evidence that this construct corresponds to increased salience of and motivation to consume UPF regardless of acute hunger state. Like UPF, hedonic hunger is significantly, negatively correlated with diet quality and strongly related to problematic eating behavior, including risk for the onset and maintenance of loss of control eating and the presence and severity of binge eating (Espel-Huynh et al., 2018; Nansel et al., 2020). Indeed, accumulating evidence suggests substantial overlap in the detrimental health effects of hedonic hunger and UPF consumption between non-pregnant and pregnant individuals, especially related to poor diet (Monteiro et al., 2019; Nansel et al., 2020, 2022). Despite these similarities between hedonic hunger and UPF consumption, research in non-pregnant individuals has failed to demonstrate a direct association between hedonic hunger and actual food intake (Forman et al., 2007, 2013; Nolan-Poupart et al., 2013; Thomas et al., 2011; Verhoeven et al., 2012).

Instead, research in non-pregnant individuals has shown that hedonic hunger is more likely to be associated with actual food intake when there is also a weaker ability to inhibit impulsive motivations. More specifically, studies have found that hedonic hunger is significantly, positively correlated with UPF consumption among non-pregnant individuals with higher, versus lower, levels of impulsivity (Espel-Huynh et al., 2018). Among those who score higher on impulsivity, increased hedonic hunger is associated with significantly increased UPF consumption; among those who score lower on impulsivity, however, the association is either attenuated or no longer significant. This finding has been demonstrated in samples of male and female European adolescents (*N* = 11,392), male and female Swiss adults (*N* = 4,774), and female U.S. adults with BMI ≥ 25 (*N* = 62; Appelhans et al., 2011; Horwath et al., 2020; Stok et al., 2015). This finding has also been partially replicated in female U.S. adults with lower BMIs (*N* = 78; i.e., those with higher hedonic hunger and higher impulsivity consumed the greatest amount of both UPF and non-UPF; Ely et al., 2015). Results from these studies suggest that higher impulsivity may increase susceptibility, or likelihood of "giving in," to hedonic hunger-related motivation to consume UPF, highlighting the importance of considering the role of impulsivity in the relationship between hedonic hunger and UPF consumption among pregnant individuals, too.

Impulsivity is defined as a predisposition toward rapid, unplanned reactions to stimuli without regard for the negative consequences of these reactions (Moeller et al., 2001). In other words, impulsivity reflects (1) a tendency to immediately act on urges before processing information thoroughly (i.e., motor/behavioral impulsivity) and (2) decreased sensitivity to negative consequences of behavior (i.e., cognitive/choice impulsivity; Arce & Santisteban, 2016; Moeller et al., 2001). Although impulsivity can be adaptive in some contexts (e.g., tasks requiring quick shifts in attention), it can be maladaptive in others, such as eating (Müller et al., 2015). Impulsivity is considered a hallmark feature of problematic eating behavior, including binge-eating disorder (Boswell et al., 2021; Carr et al., 2021; Lee et al., 2019). Further, extensive evidence has linked impulsivity to weight gain through the overconsumption of UPF, leading to widespread recognition of impulsivity as a meaningful risk factor for both poor diet quality and BMI ≥ 25 (Emery, 2018). Growing evidence suggests that impulsivity significantly moderates the association between hedonic hunger and UPF consumption in non-pregnant individuals, and, notably, this finding has remained significant across self-report and task measures of impulsivity. Several previous studies have observed nonsignificant correlations between the two (Reynolds et al., 2006), which is thought to reflect differences between the impulsive tendencies detected by self-reports (i.e., general, self-perceived behavioral and cognitive tendencies) and those detected by tasks (e.g., specific, objective dimensions of behavior; Emery & Levine, 2017; Reynolds et al., 2006; Waltmann et al., 2021). Nonetheless, impulsivity, whether measured by the Tempest Self-Regulation Questionnaire for Eating (Stok et al., 2015), Brief Self-Control Scale (Horwath et al., 2020), or Delay Discounting Task (Appelhans et al., 2011; Ely et al., 2015), has significantly moderated the association between hedonic hunger and UPF consumption in a variety of non-pregnant samples, across sex, age, country of origin, and weight status. This suggests that impulsive tendencies detected by both self-report and task measures influence the relationship between hedonic hunger and UPF consumption.

While evidence indicates that hedonic hunger is significantly, positively correlated with UPF consumption among non-pregnant individuals who score higher on self-report or task measures of impulsivity, no study has tested whether this relationship exists among pregnant individuals. Because pregnancy represents a period of substantial biopsychosocial change, it is particularly salient to examine how the association between hedonic hunger and UPF consumption operates in pregnancy and whether impulsivity moderates this association. For one, pregnancy-related food cravings and aversions, which are common and influence prenatal dietary intake by respectively increasing and decreasing consumption of certain foods, could impact the association between hedonic hunger and UPF consumption (Tierson et al., 2010). One study found that all pregnant participants in their sample (N = 83) had experienced and given in to at least one craving, with cravings for "sweets" and "fast foods" reported most frequently (Orloff et al., 2016), and UPF cravings during pregnancy, coupled with high levels of hedonic hunger, may increase the odds of prenatal UPF consumption. Moreover, the discrepancy in findings related to impulsivity during pregnancy creates speculation about how pregnancy-related changes in impulsivity might influence the association between hedonic hunger and UPF consumption. Impulsivity is considered an enduring personality trait that remains relatively stable across the lifespan, meaning it should not be expected to change in pregnancy, but some of the limited research on impulsivity during pregnancy has pulled this notion into question (Emery, 2018). While some data suggest that impulsivity does not change with pregnancy, other data suggest it improves (J. Chen et al., 2020; Nansel et al., 2020), indicating the possibility of pregnancy-related remissions in impulsivity that could serve as a "protective factor," lessening the susceptibility of pregnant individuals to hedonic hunger-related motivation to consume UPF.

Thus, the current study aimed to investigate the following research questions: Is hedonic hunger significantly associated with UPF consumption during pregnancy among individuals with pre-pregnancy BMI ≥ 25, and does impulsivity significantly moderate this association? In doing so, the current study sought to address several methodologic limitations of prior research with non-pregnant individuals that have hindered confidence in the validity and generalizability of findings, as well as the ability to compare results across studies. First, UPF was characterized in accordance with the current, valid Nova food classification system (Monteiro et al., 2019). Second, both self-report and task measures of impulsivity were examined as moderators within the same sample. Equally important, the current study tested the relationship among hedonic hunger, UPF consumption, and impulsivity among pregnant individuals with BMI ≥ 25, who are at highest risk for associated negative health consequences. The following aims and hypotheses were proposed:

Aim 1: Examine the association between hedonic hunger and UPF consumption in a sample of pregnant individuals with BMI ≥ 25.

Hypothesis 1: Hedonic hunger will be significantly, positively associated with UPF consumption.

Aim 2: Examine whether impulsivity significantly moderates the association between hedonic hunger and UPF consumption in a sample of pregnant individuals with BMI ≥ 25.

Hypothesis 2a: Self-report impulsivity will be a significant moderator; the association between hedonic hunger and UPF consumption will be stronger with higher total scores and attenuated with lower total scores on the Barratt Impulsiveness Scale, Version 11.

Hypothesis 2b: Task impulsivity will be a significant moderator; the association between hedonic hunger and UPF consumption will be stronger with higher delay discounting and attenuated with lower delay discounting on the Delay Discounting Task.

2.0 Method

2.1 Participants and Study Procedures

Data for the current study were drawn from a larger, longitudinal study entitled, Health and Behaviors in Transition (HABIT; R01 HL132578), and an ancillary study, iHABIT (R01 DK117358). HABIT is an ongoing sequential multiple assignment randomized trial (SMART) that follows participants from early-to-mid pregnancy until 12-months postpartum to examine the efficacy of different lifestyle intervention sequences during the perinatal period. Eligible participants who consented to HABIT were recruited to participate in the ancillary study, iHABIT, examining executive functioning and health-related outcomes. All study procedures were approved by the University of Pittsburgh Institutional Review Board (PRO16020497) and registered on ClinicalTrials.gov (NCT03069690).

Pregnant individuals were recruited in-person from women's health clinics in Pittsburgh and surrounding areas and online from research registries to participate in HABIT. Due to COVID-19, all recruitment stopped in mid-March 2020; online-only recruitment resumed in late-September 2020. Interested individuals completed phone screens with study staff to determine eligibility. Inclusion criteria included pre-pregnancy BMI ≥ 25, ≤ 17 weeks and four days of gestation, English-speaking, and singleton pregnancy. Exclusion criteria included multiple gestations, pre-existing diabetes, bariatric surgery within the past three years, use of medications known to affect weight, and/or acute psychiatric symptoms warranting immediate treatment (e.g., suicidality). Eligible participants ≥ 18 years old provided written informed consent; those < 18 years old provided verbal assent, and a parent/legal guardian provided written informed consent.

For the purposes of the current study, only relevant data from the baseline assessment, administered prior to any randomization at ≤ 16 weeks of gestation, for HABIT and HABIT + iHABIT participants were included in analyses. During the baseline assessment, HABIT and HABIT + iHABIT participants completed a self-report demographic survey, objective and self-report measures of health, self-report measures of eating, and self-report measures of executive function. HABIT + iHABIT participants also completed computerized tasks to measure executive function. Data collection for the baseline assessment began in February 2017 and concluded in December 2022.

2.2 Measures

2.2.1 Demographic Information

Participants self-reported age, gestational age, racial identity, ethnic identity, household income before taxes, number of household members, and educational background. Pre-pregnancy BMI was calculated as participants' self-reported pre-pregnancy weight (kg) divided by their collected height (m^2). Self-reported pre-pregnancy weight is commonly used in studies with pregnant samples and generally found to be reliable and valid (Shin et al., 2014). Research staff measured participants' height using a stadiometer, during which participants removed their shoes. A composite socioeconomic status (SES) variable, which produces more comprehensive estimates of the social gradient in health (Lindberg et al., 2022), was calculated by averaging household income divided by number of household members (z-scored) and educational level (z-scored; Manuck et al., 2010).

2.2.2 Ultra-Processed Food Consumption

UPF consumption was operationalized as percentage of calorie intake from UPF, calculated using dietary intake information collected from 24-hour dietary recalls and the Nova food classification system's definition and identification of UPF. 24-hour dietary recalls are structured interviews that gather detailed information on all foods and beverages consumed in the past 24 hours. Participants completed two 24-hour dietary recalls, one during the week and one during the weekend, to address intra-individual variation in dietary intake, further increasing measurement reliability (*24-Hour Dietary Recall (24HR) at a Glance*, n.d.). Trained research staff conducted 24-hour dietary recalls with participants using the Nutrition Coordinating Center's Nutrition Data System for Research (NDSR), a dietary analysis software application that collects recall data and increases the accuracy of reported information through a multiple pass approach: (1) an uninterrupted recall of dietary intake in the past 24 hours is collected before (2) asking for details on foods and beverages listed and (3) their portion sizes and recipes, followed by (4) a summary of all foods and beverages recalled (Nutrition Coordinating Center, 2023a). NDSR calculates intake estimates (e.g., calories) per ingredient, food, meal, and day (Nutrition Coordinating Center, 2023b). Reports of implausible daily energy intake based on established cutoffs adjusted for the increased energy requirements of pregnancy (< 600 kcal/day) were excluded from analysis ($n = 5$; Most et al., 2019; Rhee et al., 2015).

NDSR also assigns each food and beverage recalled by participants a unique "food ID" from the 2021 Nutrition Coordinating Center (NCC) Food and Nutrient Database (Nutrition Coordinating Center, 2023b). Food IDs were categorized into one of the four groups listed in the Nova food classification system (i.e., group 1 = unprocessed or minimally processed foods, group 2 = processed culinary ingredients, group 3 = processed foods, group 4 = ultra-processed foods;

Monteiro et al., 2019). Because the standardized code used for applying Nova to dietary recall information is only compatible with food IDs from the United States Department of Agriculture (USDA) National Nutrient Database for Standard Reference or USDA Food and Nutrient Database for Dietary Studies, the current study used validated code created by an academic group at Vanderbilt University (available from them on request) to apply Nova to NCC food IDs (Sneed et al., 2023). However, the NCC contains over 19,000 food IDs, and the Sneed et al. (2023) group coded only 3,497 NCC food IDs. Thus, an additional 1,048 NCC food IDs in the current dataset were hand-coded using the "reference approach" to apply Nova to food IDs (Steele et al., 2023). For validation purposes, 10% (n = 105) of these hand-coded food IDs were separately coded by a research specialist trained in using the reference approach; intercoder reliability was good (95% concordance). Percentage of caloric intake from UPF was calculated by dividing average caloric intake from UPF (i.e., foods categorized into Nova group 4) by average total caloric intake and multiplying by 100 (Monteiro et al., 2019). *Percentage* of caloric intake from UPF was used to reduce bias introduced by potential non-differential calorie misreporting from all foods (Martínez Steele et al., 2016).

2.2.3 Hedonic Hunger

Hedonic hunger was operationalized as total score on the Power of Food Scale (PFS; Lowe et al., 2009). The PFS is a 15-item questionnaire intended to assess appetitive responses to food at one of three levels of food proximity: (1) Availability (i.e., when food is available but not present; e.g., "I find myself thinking about food even when I'm not physically hungry"), (2) Presence (i.e., when food is present but not tasted; e.g., "If I see or smell a food I like, I get a powerful urge to have some"), and (3) Taste (i.e., when food is tasted; e.g., "When I eat delicious food, I focus a lot on how good it tastes”). Items are rated on a 5-point Likert scale from 1, “don’t agree at all,” to 5, “strongly agree.” Item-level scores are averaged to create a total score, ranging from 0-5, with higher scores indicating higher levels of hedonic hunger. The PFS demonstrates strong internal consistency and test-retest reliability and has been validated among samples with problematic eating behavior and BMI ≥ 25, as well as with respect to brain activity in response to viewing images of UPF versus control images (Appelhans et al., 2011; Yoshikawa et al., 2013).

2.2.4 Impulsivity

2.2.4.1 Self-Report

Self-report impulsivity was operationalized as total score on the Barratt Impulsiveness Scale, Version 11 (BIS-11; Patton et al., 1995). The BIS-11 is a 30-item questionnaire intended to assess both the behavioral and cognitive facets of impulsivity. Each item assesses one of six first-order factors (i.e., attention, motor, self-control, cognitive complexity, perseverance, cognitive instability), which comprise one of three second-order factors (i.e., attentional, motor, non-planning impulsiveness). Items (e.g., “I do things without thinking,” “I plan tasks carefully”) are rated on a 4-point Likert scale from 1, “rarely/never,” to 4, “almost always/always.” Item-level scores are summed to create a total score, ranging from 30-120, with higher scores indicating higher levels of impulsivity. The BIS-11 demonstrates strong internal consistency, test-retest reliability, and convergent validity with other self-report measures of impulsivity (Stanford et al., 2009); it has been used in samples with problematic eating behavior and BMI ≥ 25 (Boisseau et al., 2012; Ural et al., 2017).

2.2.4.2 Task

Task impulsivity was operationalized as the area under the curve of indifference points on the computerized version of the Delay Discounting Task (DDT; Richards et al., 1999). The DDT is intended to assess an aspect of the cognitive facet of impulsivity, the tendency to prefer smaller, immediate monetary rewards over larger, delayed monetary rewards. Participants were presented with a series of trials, in which they are asked to choose between receiving a fixed hypothetical reward of $100 at one of five delay intervals (i.e., 0, 2, 30, 180, 365 days) or a different amount of money (i.e., range: $0-100, in 50-cent increments) available "right now." Trials were administered in a randomized order with respect to both delay interval and value of the immediate reward offered. Indifference points refer to the amount of money at which immediate rewards become preferred over the delayed reward and were calculated for each participant at each delay interval (e.g., a participant who chose to receive $70 or more right now over the delayed reward of $100 after a 30-day delay, but preferred receiving the $100 over $65 or less right now, would have an indifference point of $67.50 at the 30-day delay interval).

DDT data were first examined for systematicity, and flagged if identified as nonsystematic, using the following criteria for nonsystematic DDT data (Johnson & Bickel, 2008): (1) an indifference point for the second, third, fourth, and/or fifth delay interval is greater than the preceding indifference point by a magnitude greater than 20% of the delayed reward (i.e., $20) and (2) the indifference point for the fifth/final delay interval is not less than the indifference point for the first delay interval or (if the indifference points for the first four delay intervals are all the same) not equal to the indifference points for the first four delay intervals. Consistent with previous research (Johnson & Bickel, 2008; Wongsomboon & Webster, 2023), when a participant's DDT data violated the first criterion, their first deviant indifference point was eliminated and the criterion was re-applied to their remaining indifference points. Participants were excluded from analysis if their data still met the first criterion after their first deviant indifference point was eliminated (n = 6) and/or met the second criterion (n = 30).

Area under the curve values were calculated for the remaining participants with systematic DDT data (N = 143; Reed et al., 2012). Area under the curve is an atheoretical metric of discounting that is normally distributed and commonly used in other studies (Bechara, 2005; Bickel et al., 2007; Rollins et al., 2010). Area under the curve values on the DDT (AUC_{DDT}) range from 0 to 1, with lower values indicating higher delay discounting (i.e., more impulsive decision-making). The DDT demonstrates construct validity and test-retest reliability, and it has been used in pregnant samples and in samples with problematic eating behavior and BMI ≥ 25 (Miranda-Olivos et al., 2021; Richards et al., 1999; Weafer et al., 2013; Yoon et al., 2007).

2.3 Data Analysis

The current study was preregistered (https://osf.io/xnr8c). All analyses were conducted in RStudio, Version 4.3.1 (R Core Team, 2023). Prior to testing the hypotheses, descriptive statistics for the sample were calculated, and sensitivity analyses were performed to determine whether participants with and without DDT data differed on key characteristics. Additionally, assumptions of linearity, homoscedasticity, and normality were considered, and leverage, distance, and influence were assessed for each observation. A case was considered "extreme" if above the calculated/pre-specified cutoffs of 0.049 for leverage, 3.000 for distance, and/or 1.000 for global and specific measures of influence.

In all analyses, PFS total score, BIS-11 total score, and AUC_{DDT} were mean-centered (i.e., the mean of each variable was subtracted from all observations on that variable, such that each variable's new mean was zero) to aid in the interpretation of results. To examine the association between hedonic hunger and UPF consumption, a continuous multiple linear regression model was specified with percentage of caloric intake from UPF as the dependent variable and PFS total score as the independent variable. To examine whether the association was moderated by impulsivity, two additional models were specified with BIS-11 total score and AUC_{DDT} included in interaction terms with PFS total score. Resultant coefficients were examined for statistical significance ($p < .05$), and significant interactions were probed using simple slopes analyses and graphical methods. All models covaried for age, gestational age, pre-pregnancy BMI, and SES. Racial and ethnic identities were not included as covariates since there was no reason to suspect they would influence results, and other more specific measures, for which racial/ethnic identity acts as a rough surrogate (e.g., SES), are considered to reduce bias more effectively (Kaufman, 2001).

3.0 Results

Descriptive statistics for the sample are displayed in Table 1. Participants with and without DDT data did not significantly differ from each other on any of the characteristics included in Table 1 (*p*s > .05). Assumptions of linearity, homoscedasticity, and normality were met by the data, and no case within the dataset exceeded the calculated/pre-specified cutoffs for leverage, distance, or influence. Both the PFS and BIS-11 showed excellent reliability in the current sample (α = 0.93 and 0.86; ω = 0.95 and 0.90, respectively).

3.1 Aim 1: Association between Hedonic Hunger and UPF Consumption

Hedonic hunger did not significantly relate to UPF consumption. As shown in Table 2, the association between PFS total score and percentage of caloric intake from UPF was not statistically significant. Notably, this association remained nonsignificant in an unadjusted model, b = -0.88, $t(218) = -0.71$, $p = .48$.

3.2 Aim 2: Moderating Effects of Impulsivity

Self-report impulsivity did not significantly moderate the association between hedonic hunger and UPF consumption. As shown in Table 3, the interaction between PFS total score and BIS-11 total score was not statistically significant.

However, the delay discounting did significantly moderate the association between hedonic hunger and UPF consumption. As shown in Table 4, the interaction between PFS total score and AUC_{DDT} was statistically significant, adjusted $R^2 = .06$, $F(7, 135) = 2.34$, $p = .03$, Cohen's $f^2 = 0.12$. Simple slopes analysis revealed that the association between hedonic hunger and UPF consumption was statistically significant at lower levels of delay discounting but not at higher levels of delay discounting (see Figure 1). Individuals who scored lower (*M* + 1 SD; *n* = 35) on delay discounting consumed approximately 7% less UPF as hedonic hunger increased, b = -6.99, $t(135) = -2.82$, $p = .01$. Individuals who scored higher (*M* – 1 SD; *n* = 37) on delay discounting consumed approximately 1% more UPF as hedonic hunger increased, although this increased consumption was not statistically significant, b = 1.08, $t(135) = 0.56$, $p = .58$.

3.3 Exploratory Analyses and Results

Exploratory analyses for the second aim were conducted using scores on the individual subscales comprising the PFS, rather than the PFS total score, to determine if appetitive responses at specific levels of food proximity (i.e., available, present, tasted) differentially impacted results. Prior to conducting these exploratory analyses, descriptive statistics and reliability for each PFS subscale were calculated. On average, participants scored 1.93 (*SD* = 0.96) on the Availability, 2.76 (*SD* = 1.14) on the Presence, and 2.47 (*SD* = 0.86) on the Taste subscales of the PFS (subscale score range: 0-5; higher score = greater appetitive response at that level of food proximity). PFS subscale scores for participants with and without DDT data did not significantly differ (*p*s > .05). The Availability, Presence, and Taste PFS subscales showed good reliability in the current sample ($\alpha = 0.90$, 0.90, and 0.78; $\omega = 0.90$, 0.90, and 0.78, respectively). To explore whether associations between each of these three factors of hedonic hunger and UPF consumption were moderated by self-report and task impulsivity, six models were specified with BIS-11 total score and AUC_{DDT} included in interaction terms with each PFS subscale score. Significant interactions ($p < .05$) were probed using simple slopes analyses and graphical methods. All models covaried for age, gestational age, pre-pregnancy BMI, and SES. Multiple comparisons were corrected for using the Bonferroni method.

BIS-11 total score did not significantly moderate the association between Presence, b = 0.09, $t(212) = 1.06$, $p = .29$, or Taste, b = 0.08, $t(212) = 0.86$, $p = .39$, PFS subscale scores and percentage of caloric intake from UPF; however, BIS-11 total score did significantly moderate the association between Availability PFS subscale score and percentage of caloric intake from UPF, b = 0.18, $t(211) = 2.10$, $p = .04$; adjusted $R^2 = .05$, $F(7, 211) = 2.49$, $p = .02$, Cohen's $f^2 = 0.08$. Simple slopes analysis revealed that the association between appetitive responses at the "food available" level and UPF consumption was statistically significant at lower levels of self-report impulsivity but not at higher levels of self-report impulsivity (see Figure 2). Individuals who scored lower (M – 1 SD; $n = 33$) on self-report impulsivity consumed approximately 4% less UPF as appetitive responses at the "food available" level increased, b = -4.02, $t(211) = -2.29$, $p = .02$. Individuals who scored higher (M + 1 SD; $n = 35$) on self-report impulsivity consumed approximately 0.2% less UPF as appetitive responses at the "food available" level increased, although this was not statistically significant, b = -0.16, $t(211) = -0.12$, $p = .90$. Notably, the moderating effect of self-report impulsivity was no longer statistically significant after correcting for multiple comparisons using the Bonferroni method ($p = .22$).

Similarly, AUC_{DDT} did not significantly moderate the association between the Presence, b = -6.06, $t(135) = -1.82$, $p = .07$, or Taste, b = -9.44, $t(135) = -1.89$, $p = .06$, PFS subscale scores and percentage of caloric intake from UPF but did significantly moderate the association between the Availability PFS subscale score and percentage of caloric intake from UPF, b = -10.57, *t*(134) = -2.54, *p* = .01; adjusted R^2 = .06, *F*(7, 134) = 2.35, *p* = .03, Cohen's f^2 = 0.12. Simple slopes analysis revealed that the association between appetitive responses at the "food available" level and UPF consumption was statistically significant at lower levels of delay discounting but not at higher levels of delay discounting (see Figure 3). Individuals who scored lower (*M* + 1 SD; *n* = 34) on delay discounting consumed approximately 6% less UPF as appetitive responses at the "food available" level increased, b = -6.23, *t*(134) = -2.70, *p* = .01. Individuals who scored higher (*M* – 1 SD; *n* = 37) on delay discounting consumed approximately 1% more UPF as appetitive responses at the "food available" level increased, although this was not statistically significant, b = 1.25, *t*(134) = 0.67, *p* = .50. Notably, the moderating effect of delay discounting was no longer statistically significant after correcting for multiple comparisons using the Bonferroni method (*p* = .07).

4.0 Discussion

The current study first aimed to examine the association between hedonic hunger and UPF consumption in a sample of pregnant individuals with BMI ≥ 25. We hypothesized that hedonic hunger would be positively associated with UPF consumption in early pregnancy. This hypothesis was driven by the observation that cravings for UPF (i.e., a component of hedonic hunger) are common during pregnancy and can lead to UPF consumption (Orloff et al., 2016; Tierson et al., 2010). Contrary to our hypothesis, the association between hedonic hunger and UPF consumption was not statistically significant in the current sample. That is, hedonic hunger did not significantly relate to percentage of caloric intake from UPF among pregnant individuals with BMI ≥ 25. This finding is consistent with those from studies of non-pregnant individuals, which have failed to demonstrate a reliable association between hedonic hunger and food intake alone (Forman et al., 2007, 2013; Nolan-Poupart et al., 2013; Thomas et al., 2011; Verhoeven et al., 2012), and supports the notion that hedonic hunger reflects *appetitive drive*, rather than *actual food consumption*, even within the context of pregnancy. It also supports the broader notion that, although related, the presence of factors that typically motivate a certain behavior (i.e., approach motivations) does not necessarily result in that behavior (i.e., approach behavior). For instance, cigarette craving is not clearly linked to risk for smoking relapse (Wray et al., 2013), and results are similarly mixed as to whether food craving corresponds to food intake (Boswell & Kober, 2016). Hedonic hunger, as assessed by the PFS, represents a composite of food-specific motivations to engage in eating behavior, including food cue-induced craving (e.g., "If I see or smell a food I like, I get a powerful urge to have some"). The lack of association between hedonic hunger and intake of UPF indicates that there is more to eating behavior than just experiencing inclinations to eat. Accumulating evidence, including data from the current study, suggests that eating behavior is better accounted for by a combination of food-specific approach motivations (e.g., food cue reactivity, craving, liking vs. wanting) and person-specific factors (e.g., impulsivity), which may uniquely interact to enhance or diminish an individual's motivation to eat and capture more of the variance in actual UPF consumption. Thus, future research might investigate how a wider range of person-specific factors (e.g., other components of executive function) interact with hedonic hunger to influence actual UPF consumption.

The second aim of the current study was to examine whether impulsivity significantly moderated the association between hedonic hunger and UPF consumption in a sample of pregnant individuals with BMI ≥ 25. We hypothesized that self-report and task measures of impulsivity would significantly moderate this association, such that pregnant individuals with higher BIS-11 total scores and delay discounting would consume significantly more UPF at higher levels of hedonic hunger. These hypotheses were informed by prior research that has consistently found that non-pregnant individuals with higher self-report impulsivity or delay discounting consume significantly more UPF at higher levels of hedonic hunger (Appelhans et al., 2011; Ely et al., 2015; Horwath et al., 2020; Stok et al., 2015). Results revealed that impulsivity as measured by the BIS-11 did not significantly moderate the association between hedonic hunger and UPF consumption in the current sample, but impulsivity as measured by the DDT did. Pregnant individuals who scored lower on delay discounting consumed significantly less UPF as hedonic hunger increased, whereas those who scored higher on delay discounting consumed a stable, albeit not statistically significantly so, amount of UPF across all levels of hedonic hunger. Thus, in contrast to previous studies with non-pregnant samples, we found that more impulsive decision-making did not increase risk for greater UPF consumption among pregnant individuals who experienced greater appetitive drive. Instead, we found that less impulsive decision-making served as a protective factor, contributing to less UPF consumption, among pregnant individuals who experienced greater appetitive drive.

These findings from the second aim are interesting because task measures of impulsivity, like the DDT, are assumed to be subject to state-dependent variations, while self-report measures of impulsivity, like the BIS-11, are assumed to reflect a stable trait (Meule, 2013). Given the assumption that the DDT captures state-dependent fluctuations in impulsivity, we might expect the moderating effect of the DDT to look different in pregnancy than it does outside the context of pregnancy; given the assumption that the BIS-11 captures impulsivity as a state-independent characteristic, we would expect the moderating effect of the BIS-11 to persist regardless of pregnant state (i.e., to look similar in and outside the context of pregnancy). However, despite these supposed theoretical differences between self-report and task measures of impulsivity, we found that the moderating effects of both the DDT and BIS-11 operated differently among pregnant individuals compared to non-pregnant individuals. The fact that self-reported (i.e., state-independent) and task-based (i.e., state-dependent) impulsivity both operated differently within our pregnant sample begs the question of whether these assumptions about impulsivity hold within the context of pregnancy. Should pregnancy be considered a "state," associated with small-scale changes in impulsivity, or something else (e.g., a "transitional period") that is associated with more global changes in impulsivity? Research in the area of executive function during pregnancy is extremely limited and, thus far, inconclusive (J. Chen et al., 2020; Emery, 2018; Nansel et al., 2020). Findings from the current study further underscore the importance of future work that examines the stability of this construct throughout the perinatal period.

Our finding that the relationship among hedonic hunger, UPF consumption, and impulsivity seems to operate differently in pregnant individuals than in non-pregnant individuals also prompted questions about whether appetitive drive at the three levels of food proximity (i.e., food available but not present, present but not tasted, and tasted) differentially impacted results. Previous research investigating the relationship among hedonic hunger, UPF consumption, and impulsivity has not examined the Power of Food Scale subscales separately, so there were no data available to inform a priori hypotheses about how appetitive drive for food when available, present, and tasted might interact with impulsivity to influence UPF consumption. Thus, exploratory analyses were conducted to test relationships between these three subscales of the Power of Food Scale and UPF consumption with self-report impulsivity and delay discounting as moderators. Results from the exploratory analyses revealed that both self-report impulsivity and delay discounting significantly moderated the association between appetitive drive at the "food available" level, but not the "food present" or "food tasted" levels, and UPF consumption. Pregnant individuals with lower levels of self-report impulsivity or delay discounting consumed significantly less UPF as appetitive drive for food when available increased, but those with higher levels of self-report impulsivity or delay discounting consumed roughly the same amount of UPF across levels of appetitive drive for food when available. In other words, pregnant individuals who perceived themselves to be less impulsive or engaged in less impulsive decision-making consumed significantly less UPF as appetitive drive when food was available became greater.

Although these associations from the exploratory analyses were no longer statistically significant after correcting for multiple comparisons, they tentatively signal that appetitive drive when food is available plays a particularly important role (relative to appetitive drive when food is present or tasted) in decreasing UPF consumption among pregnant individuals with lower self-report impulsivity and delay discounting. Notably, the Availability subscale of the PFS, which reflects appetitive drive for food when available, comprises items that assess preoccupation with food (e.g., "It's scary to think of the power that food has over me," "It seems like I have food on my mind a lot"). It is possible that higher scores on this subscale reflect greater general awareness of the salience of food and that pregnant individuals who are more aware of the salience of food and who are lower in self-reported impulsivity or delay discounting have self-control-related resources that allow them to mitigate UPF consumption (e.g., follow portion sizes, order groceries online as a means of stimulus control). Future studies that are adequately powered should re-examine how appetitive drive for food at the three levels of food proximity relate to UPF consumption among both pregnant and non-pregnant individuals to see whether this association re-emerges and/or differs within the context of pregnancy.

4.1 Strengths and Limitations

Results from the current study should be interpreted in the context of its strengths and limitations. Major strengths of the current study are the use of 24-hour dietary recalls to assess dietary intake and the Nova food classification system to systematically define/identify UPF. Prior research has assessed intake of variously defined "palatable" or "snack" foods via either in-laboratory experiments or food frequency questionnaires (Appelhans et al., 2011; Ely et al., 2015; Horwath et al., 2020; Stok et al., 2015), which has severely limited validity and generalizability (e.g., Appelhans et al. [2011] included salted peanuts as a "palatable" food, which the Nova food classification system does not consider an UPF). Future research should take care to conceptualize dietary intake using validated measures (e.g., Nova food classification system, Healthy Eating

Index) to ensure accurate interpretations of results across studies and facilitate reproducibility. Another strength of the current study is the concurrent measurement of self-report and task impulsivity, which tap into different aspects of the cognitive and behavioral facets of impulsivity. Prior work with pregnant and non-pregnant samples has typically only employed one or the other, which has prohibited direct comparison between general trait-level impulsivity and more specific state-dependent aspects of impulsivity both within the relationship between hedonic hunger and UPF consumption and the context of pregnancy. Discrepant results between the BIS-11 and DDT in the current study highlight the utility of including both self-report and task measures of impulsivity in future studies, especially those involving pregnant samples in which executive function is not well understood. Future studies may also consider using additional task measures (e.g., Go/No-Go Task, Stroop Color and Word Test) to explore how other specific aspects of impulsivity interact with appetitive drive to predict UPF consumption. Additionally, future studies may consider administering an alternative version of the DDT that measures discounting of food rather than money, which may approximate impulsive decision-making related to food intake more closely than money (Fazzino et al., 2022).

One limitation to the current study was the cross-sectional design. Although we were able to test *what* the relationship among hedonic hunger, UPF consumption, and impulsivity looked like among pregnant individuals, we were unable to determine *why* it looked the way it did. Given the myriad of other biopsychosocial changes that take place during pregnancy, is possible that hedonic hunger, UPF consumption, and/or impulsivity changes from pre-pregnancy to pregnancy, and even fluctuates throughout the perinatal period. For instance, diet quality has been found to decrease across trimesters (Moran et al., 2013), and UPF consumption has been shown to negatively correlate with diet quality (Nansel et al., 2022), meaning that UPF consumption may increase over the course of pregnancy. Future longitudinal research that measures hedonic hunger, UPF consumption, and impulsivity over time is needed to better understand potential changes in these variables from pre-pregnancy through the postpartum period and to examine how changes in these variables may influence how they relate to each other. Furthermore, future work is needed to test how the relationship among hedonic hunger, UPF consumption, and impulsivity impacts prenatal diet, gestational weight gain, and risk for obstetric complications.

A second limitation of the current study is that a majority of the sample identified as White (76%) and reported having high levels of education and high income. Future studies should increase representation of individuals with minoritized racial identities, lower levels of education, and lower income because individuals with these backgrounds are at significantly greater risk of adverse pregnancy and postpartum health outcomes due to structural and systemic injustices (Sheikh et al., 2022; Weck et al., 2008). Finally, the current study purposefully aimed to investigate the association between hedonic hunger and UPF consumption, and the moderating effects of impulsivity, among pregnant individuals with BMI ≥ 25 because this subgroup is at highest risk for experiencing poor prenatal diet, excessive gestational weight gain, and obstetric complications; however, results may not generalize to pregnant individuals of lower weight statuses. Future research should examine this relationship across a wider range of BMIs to tease apart potential BMI-related versus pregnancy-related influences on the association.

4.2 Conclusion

In conclusion, findings from the current sample of individuals with BMI ≥ 25 indicate that lower delay discounting, as measured by the DDT, may serve as a protective factor, contributing to a reduction in UPF consumption at higher levels of hedonic hunger. These findings contrast those from samples of non-pregnant individuals, suggesting that one or more of these variables may be subject to pregnancy-related influences. Future research on hedonic hunger, UPF consumption, and self-report versus task impulsivity during pregnancy will be important to better understand this unique relationship. Future research might also examine additional factors that could moderate the association between hedonic hunger and UPF consumption during pregnancy, including biological (e.g., pregnancy-related hormonal changes), psychological (e.g., other aspects of executive function, like cognitive flexibility), and environmental (e.g., "food deserts") factors. Indeed, more broadly, findings from the current study illustrate how the synergistic interaction among variables can influence UPF consumption in different ways in and outside the context of pregnancy.

Findings from the current study also have important implications for prenatal health. With the prevalence of elevated pre-pregnancy BMI rising (Driscoll & Gregory, 2020), research that elucidates mechanisms underlying poor prenatal diet among individuals with pre-pregnancy BMI ≥ 25, and thus modifiable factors that could mitigate excessive gestational weight gain and promote prenatal health, is imperative. Hedonic hunger and UPF consumption are two factors linked to poor prenatal diet and excessive gestational weight gain that may very well drive prenatal dietary intake when combined with other factors, and *lower* delay discounting among pregnant individuals who experience greater appetitive drive might serve as a *protective* factor against UPF consumption. Future research on whether this results in improved prenatal diet, increased odds of appropriate gestational weight gain, and decreased risk for obstetric complications is warranted.

Appendix A Tables and Figures

Table 1. Sample characteristics (*N* = 220)

Characteristic	*M*(*SD*)	Range	*n*(%)
Age (years)	31.60(4.83)	17.90-44.60	
Gestational age (weeks)	13.80(2.82)	6.29-17.40	
Pre-pregnancy BMI (kg/m^2)	32.00(6.37)	24.40-55.60	
Ethnic identity[1]			
Hispanic			9(4.10)
Non-Hispanic			210(95.50)
Racial identity[2]			
Asian			3(1.40)
Black/African American			49(22.30)
Native Hawaiian/Other Pacific Islander			1(0.50)
White			167(75.90)
Education			
Grade school/some high school			3(1.40)
High school graduate/GED			24(10.90)
Some college/technical school			52(23.60)
Four-year college degree			64(29.10)
Postgraduate degree			77(35.00)
Total family income before taxes			
< $10,000			20(9.10)
$10,000-20,000			15(6.80)
$20,001-30,000			17(7.70)
$30,001-40,000			15(6.80)
$40,001-50,000			9(4.10)
$50,001-60,000			12(5.50)
$60,001-70,000			15(6.80)
$70,001-80,000			15(6.80)
$80,001-90,000			19(8.60)
$90,001-100,000			17(7.70)
> $100,000			66(30.00)
Socioeconomic status[3]	2.77(1.67)	0.11-6.00	
Energy intake from UPF (%; range: 0-100)	62.50(16.40)	16.90-93.50	
PFS total score (range: 0-5)	2.34(0.89)	1.00-5.00	
BIS-11 total score (range: 30-120)	59.40(10.70)	35.00-98.00	

AUC_{DDT}[4] (range: 0-1)	0.71(0.27)	0.01-1.00

Note. BMI = body mass index; GED = high school equivalency degree; UPF = ultra-processed food; PFS = Power of Food Scale; BIS-11 = Barratt Impulsiveness Scale, Version 11; AUC = area under the curve; DDT = Delay Discounting Task.
[1]*n* = 1 participant missing ethnic identity data.
[2]Participants could indicate > 1 racial identity.
[3]A composite socioeconomic status variable was calculated by averaging household income divided by number of household members (z-scored) and educational level (z-scored).
[4]Calculated from the *n* = 143 participants with DDT data.

Table 2. Association between hedonic hunger and ultra-processed food consumption

Coefficient	Estimate(*SE*)	*t* value	*p*
(Intercept)	**62.53(1.09)**	**57.26**	**< .001**
PFS total score	-0.96(1.24)	-0.77	.44
Age	-0.29(0.25)	-1.19	.24
Gestational age	-0.37(0.39)	-0.95	.34
Pre-pregnancy BMI	0.16(0.18)	0.88	.38
SES	-2.28(1.35)	-1.69	.09

Note. Bolded *p*-values indicate statistical significance (*p* < .05). PFS = Power of Food Scale; BMI = body mass index; SES = socioeconomic status. PFS total score, age, gestational age, and pre-pregnancy BMI were mean-centered; the SES composite variable was z-scored.

Table 3. Moderating effect of self-report impulsivity on the association between hedonic hunger and ultra-processed food consumption

Coefficient	Estimate(*SE*)	*t* value	*p*
(Intercept)	**62.08(1.13)**	**55.13**	**< .001**
PFS total score	-1.67(1.34)	-1.25	.21
BIS-11 total score	0.03(0.11)	0.26	.80
PFS total score*BIS-11 total score	0.15(0.10)	1.59	.11
Age	-0.25(0.25)	-1.01	.31
Gestational age	-0.40(0.40)	-1.00	.35
Pre-pregnancy BMI	0.17(0.18)	0.93	.35
SES	-2.22(0.10)	-1.61	.11

Note. Bolded *p*-values indicate statistical significance (*p* < .05). PFS = Power of Food Scale; BIS-11 = Barratt Impulsiveness Scale, Version 11; BMI = body mass index; SES = socioeconomic status. PFS total score, BIS-11 total score, age, gestational age, and pre-pregnancy BMI were mean-centered; the SES composite variable was z-scored.

Table 4. Moderating effect of delay discounting on the association between hedonic hunger and ultra-processed food consumption

Coefficient	Estimate(*SE*)	*t value*	*p*
(Intercept)	**61.64(1.28)**	**48.01**	**< .001**
PFS total score	-3.00(1.59)	-1.89	.06
AUC_{DDT}	-6.18(3.88)	-1.60	.11
PFS total score*AUC_{DDT}	**-11.37(4.37)**	**-2.60**	**.01**
Age	-0.60(0.31)	-1.94	.05
Gestational age	-0.09(0.44)	-0.20	.84
Pre-pregnancy BMI	-0.04(0.21)	-0.17	.87
SES	0.56(1.63)	0.35	.73

Note. Bolded *p*-values indicate statistical significance ($p < .05$). PFS = Power of Food Scale; AUC = area under the curve; DDT = Delay Discounting Task; BMI = body mass index; SES = socioeconomic status. PFS total score, AUC_{DDT}, age, gestational age, and pre-pregnancy BMI were mean-centered; the SES composite variable was z-scored.

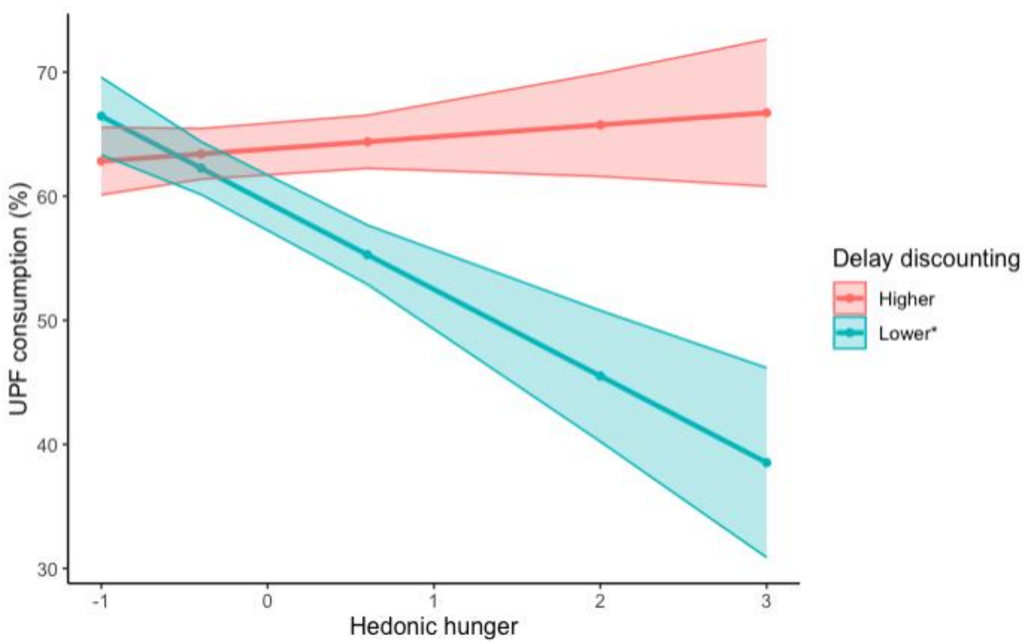

Figure 1. Moderating effect of delay discounting on the association between hedonic hunger and ultra-processed food (UPF) consumption

*** indicates statistical significance ($p < .05$). Hedonic hunger (PFS total score) and delay discounting (AUC_{DDT}) were mean-centered. "Higher" ($n = 37$) and "lower" ($n = 35$) delay discounting were determined by respectively subtracting and adding 1 standard deviation ($SD = 0.35$) from and to the adjusted mean ($M = 0.00$).**

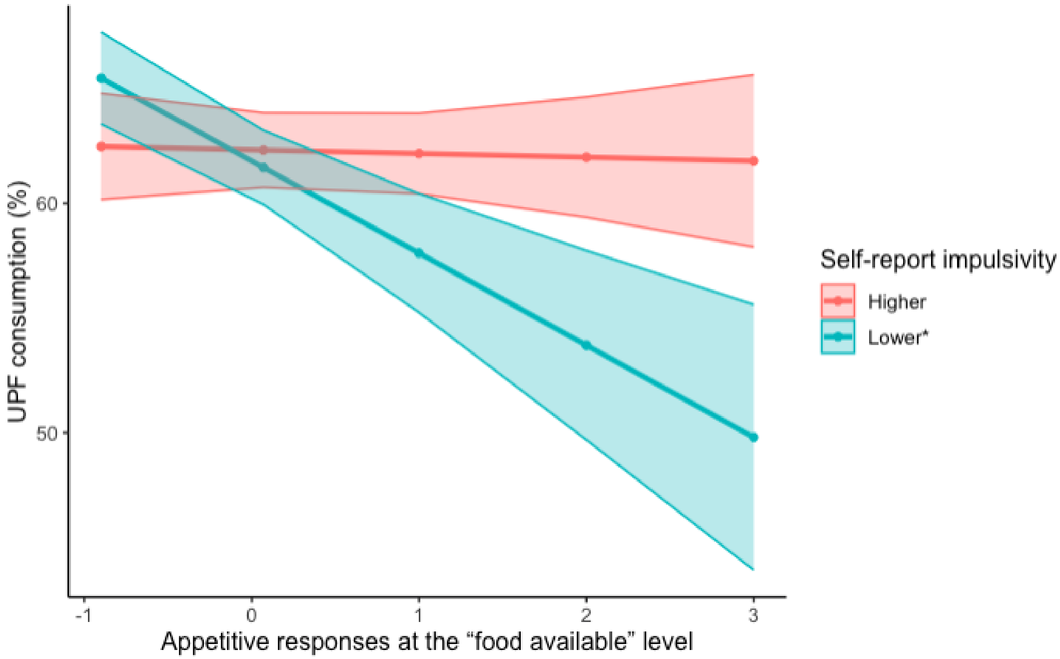

Figure 2. Moderating effect of self-report impulsivity on the association between appetitive responses at the "food available" level and ultra-processed food (UPF) consumption

*** indicates statistical significance (*p* < .05). Appetitive responses at the "food available" level (Power of Food Scale's Availability subscale score) and self-report impulsivity (BIS-11 total score) were mean-centered. "Higher" (*n* = 35) and "lower" (*n* = 33) self-report impulsivity were determined by respectively adding and subtracting 1 standard deviation (*SD* = 10.71) to and from the adjusted mean (*M* = 0.00).**

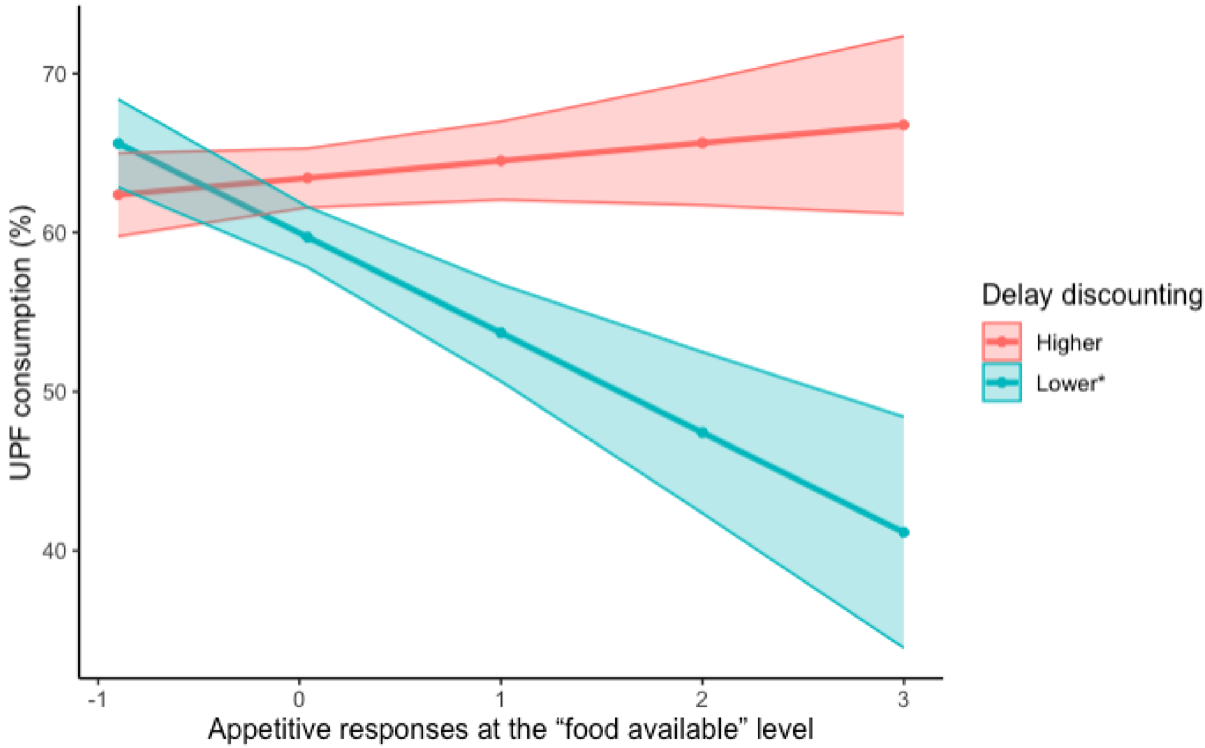

Figure 3. Moderating effect of delay discounting on the association between appetitive responses at the “food available” level and ultra-processed food (UPF) consumption

*** indicates statistical significance (*p* < .05). Appetitive responses at the “food available” level (Power of Food Scale’s Availability subscale score) and delay discounting (AUC_{DDT}) were mean-centered. “Higher” (*n* = 37) and “lower” (*n* = 34) delay discounting were determined by respectively subtracting and adding 1 standard deviation (*SD* = 0.35) from and to the adjusted mean (*M* = 0.00).**

Bibliography

24-hour Dietary Recall (24HR) at a glance. (n.d.). National Cancer Institute. https://dietassessmentprimer.cancer.gov/profiles/recall/

Appelhans, B. M., Woolf, K., Pagoto, S. L., Schneider, K. L., Whited, M. C., & Liebman, R. (2011). Inhibiting food reward: Delay discounting, food reward sensitivity, and palatable food intake in overweight and obese women. *Obesity*, *19*(11), 2175–2182. https://doi.org/10.1038/oby.2011.57

Arce, E., & Santisteban, C. (2016). *Impulsivity: A review*. *18*(2), 213–220.

Baldridge, A. S., Huffman, M. D., Taylor, F., Xavier, D., Bright, B., Van Horn, L. V., Neal, B., & Dunford, E. (2019). The Healthfulness of the US Packaged Food and Beverage Supply: A Cross-Sectional Study. *Nutrients*, *11*(8), 1704. https://doi.org/10.3390/nu11081704

Baraldi, L. G., Martinez Steele, E., Canella, D. S., & Monteiro, C. A. (2018). Consumption of ultra-processed foods and associated sociodemographic factors in the USA between 2007 and 2012: Evidence from a nationally representative cross-sectional study. *BMJ Open*, *8*(3), e020574. https://doi.org/10.1136/bmjopen-2017-020574

Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nature Neuroscience*, *8*(11), 1458–1463. https://doi.org/10.1038/nn1584

Bickel, W. K., Miller, M. L., Yi, R., Kowal, B. P., Lindquist, D. M., & Pitcock, J. A. (2007). Behavioral and neuroeconomics of drug addiction: Competing neural systems and temporal discounting processes. *Drug and Alcohol Dependence*, *90*, S85–S91. https://doi.org/10.1016/j.drugalcdep.2006.09.016

Bjorlie, K., Forbush, K. T., Chapa, D. A. N., Richson, B. N., Johnson, S. N., & Fazzino, T. L. (2022). Hyper-palatable food consumption during binge-eating episodes: A comparison of intake during binge eating and restricting. *International Journal of Eating Disorders*, *55*(5), 688–696. https://doi.org/10.1002/eat.23692

Boisseau, C. L., Thompson-Brenner, H., Caldwell-Harris, C., Pratt, E., Farchione, T., & Harrison Barlow, D. (2012). Behavioral and cognitive impulsivity in obsessive–compulsive disorder and eating disorders. *Psychiatry Research*, *200*(2–3), 1062–1066. https://doi.org/10.1016/j.psychres.2012.06.010

Boswell, R. G., & Kober, H. (2016). Food cue reactivity and craving predict eating and weight gain: A meta-analytic review. *Obesity Reviews*, *17*(2), 159–177. https://doi.org/10.1111/obr.12354

Boswell, R. G., Potenza, M. N., & Grilo, C. M. (2021). The neurobiology of binge-eating disorder compared with obesity: Implications for differential therapeutics. *Clinical Therapeutics*, *43*(1), 50–69. https://doi.org/10.1016/j.clinthera.2020.10.014

Carr, M. M., Wiedemann, A. A., Macdonald-Gagnon, G., & Potenza, M. N. (2021). Impulsivity and compulsivity in binge eating disorder: A systematic review of behavioral studies. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *110*, 110318. https://doi.org/10.1016/j.pnpbp.2021.110318

Chen, J., Guo, Y., Liao, Z., Xia, W., & She, S. (2020). Does pregnancy make women more cautious and calm? The impact of pregnancy on risk decision-making. *Judgment and Decision Making*, *15*(5), 807–822. https://doi.org/10.1017/S1930297500007944

Chen, X., Zhang, Z., Yang, H., Qiu, P., Wang, H., Wang, F., Zhao, Q., Fang, J., & Nie, J. (2020). Consumption of ultra-processed foods and health outcomes: A systematic review of epidemiological studies. *Nutrition Journal*, *19*(1), 86. https://doi.org/10.1186/s12937-020-00604-1

Cummings, J. R., Lipsky, L. M., Schwedhelm, C., Liu, A., & Nansel, T. R. (2022). Associations of ultra-processed food intake with maternal weight change and cardiometabolic health and infant growth. *International Journal of Behavioral Nutrition and Physical Activity*, *19*(1), 61. https://doi.org/10.1186/s12966-022-01298-w

de Macedo, I. C., de Freitas, J. S., & da Silva Torres, I. L. (2016). The influence of palatable diets in reward system activation: A mini review. *Advances in Pharmacological Sciences*, *2016*, 1–7. https://doi.org/10.1155/2016/7238679

Driscoll, A. K., & Gregory, E. C. W. (2020). *Increases in prepregnancy obesity: United States, 2016–2019* (392).

Ely, A. V., Howard, J., & Lowe, M. R. (2015). Delayed discounting and hedonic hunger in the prediction of lab-based eating behavior. *Eating Behaviors*, *19*, 72–75. https://doi.org/10.1016/j.eatbeh.2015.06.015

Emery, R. L. (2018). A perspective on the potential associations among impulsivity, palatable food intake, and weight gain in pregnancy: Arguing a need for future research. *Current Addiction Reports*, *5*(2), 251–256. https://doi.org/10.1007/s40429-018-0201-3

Emery, R. L., & Levine, M. D. (2017). Questionnaire and behavioral task measures of impulsivity are differentially associated with body mass index: A comprehensive meta-analysis. *Psychological Bulletin*, *143*(8), 868–902. https://doi.org/10.1037/bul0000105

Espel-Huynh, H. M., Muratore, A. F., & Lowe, M. R. (2018). A narrative review of the construct of hedonic hunger and its measurement by the Power of Food Scale. *Obesity Science & Practice*, *4*(3), 238–249. https://doi.org/10.1002/osp4.161

Fazzino, T. L., Bjorlie, K., Rohde, K., Smith, A., & Yi, R. (2022). Choices between money and hyper-palatable food: Choice impulsivity and eating behavior. *Health Psychology*, *41*(8), 538–548. https://doi.org/10.1037/hea0001185

Forman, E. M., Hoffman, K. L., Juarascio, A. S., Butryn, M. L., & Herbert, J. D. (2013). Comparison of acceptance-based and standard cognitive-based coping strategies for craving sweets in overweight and obese women. *Eating Behaviors*, *14*(1), 64–68. https://doi.org/10.1016/j.eatbeh.2012.10.016

Forman, E. M., Hoffman, K. L., McGrath, K. B., Herbert, J. D., Brandsma, L. L., & Lowe, M. R. (2007). A comparison of acceptance- and control-based strategies for coping with food cravings: An analog study. *Behaviour Research and Therapy*, *45*(10), 2372–2386. https://doi.org/10.1016/j.brat.2007.04.004

Fritz, B. M., Muñoz, B., Yin, F., Bauchle, C., & Atwood, B. K. (2018). A high-fat, high-sugar 'Western' diet alters dorsal striatal glutamate, opioid, and dopamine transmission in mice. *Neuroscience*, *372*, 1–15. https://doi.org/10.1016/j.neuroscience.2017.12.036

Horwath, C. C., Hagmann, D., & Hartmann, C. (2020). The Power of Food: Self-control moderates the association of hedonic hunger with overeating, snacking frequency and palatable food intake. *Eating Behaviors*, *38*, 101393. https://doi.org/10.1016/j.eatbeh.2020.101393

Hu, Z., Tylavsky, F. A., Kocak, M., Fowke, J. H., Han, J. C., Davis, R. L., LeWinn, K. Z., Bush, N. R., Sathyanarayana, S., Karr, C. J., & Zhao, Q. (2020). Effects of maternal dietary patterns during pregnancy on early childhood growth trajectories and obesity risk: The CANDLE study. *Nutrients*, *12*(2), 465. https://doi.org/10.3390/nu12020465

Johnson, M. W., & Bickel, W. K. (2008). An algorithm for identifying nonsystematic delay-discounting data. *Experimental and Clinical Psychopharmacology*, *16*(3), 264–274. https://doi.org/10.1037/1064-1297.16.3.264

Kaufman, J. S. (2001). Commentary: Considerations for use of racial/ethnic classification in etiologic research. *American Journal of Epidemiology*, *154*(4), 291–298. https://doi.org/10.1093/aje/154.4.291

Lee, R. S. C., Hoppenbrouwers, S., & Franken, I. (2019). A systematic meta-review of impulsivity and compulsivity in addictive behaviors. *Neuropsychology Review*, *29*(1), 14–26. https://doi.org/10.1007/s11065-019-09402-x

Lindberg, M. H., Chen, G., Olsen, J. A., & Abelsen, B. (2022). Combining education and income into a socioeconomic position score for use in studies of health inequalities. *BMC Public Health*, *22*(1), 969. https://doi.org/10.1186/s12889-022-13366-8

Lowe, M. R., Butryn, M. L., Didie, E. R., Annunziato, R. A., Thomas, J. G., Crerand, C. E., Ochner, C. N., Coletta, M. C., Bellace, D., Wallaert, M., & Halford, J. (2009). The Power of Food Scale. A new measure of the psychological influence of the food environment. *Appetite*, *53*(1), 114–118. https://doi.org/10.1016/j.appet.2009.05.016

Manuck, S. B., Phillips, J. E., Gianaros, P. J., Flory, J. D., & Muldoon, M. F. (2010). Subjective socioeconomic status and presence of the metabolic syndrome in midlife community volunteers. *Psychosomatic Medicine*, *72*(1), 35–45. https://doi.org/10.1097/PSY.0b013e3181c484dc

Martínez Steele, E., Baraldi, L. G., Louzada, M. L. D. C., Moubarac, J.-C., Mozaffarian, D., & Monteiro, C. A. (2016). Ultra-processed foods and added sugars in the US diet: Evidence from a nationally representative cross-sectional study. *BMJ Open*, *6*(3), e009892. https://doi.org/10.1136/bmjopen-2015-009892

McDowell, M., Cain, M. A., & Brumley, J. (2018). Excessive gestational weight gain. *Journal of Midwifery & Women's Health*, jmwh.12927. https://doi.org/10.1111/jmwh.12927

Meule, A. (2013). Impulsivity and overeating: A closer look at the subscales of the Barratt Impulsiveness Scale. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00177

Miranda-Olivos, R., Steward, T., Martínez-Zalacaín, I., Mestre-Bach, G., Juaneda-Seguí, A., Jiménez-Murcia, S., Fernández-Formoso, J. A., Vilarrasa, N., Veciana de las Heras, M., Custal, N., Virgili, N., Lopez-Urdiales, R., Menchón, J. M., Granero, R., Soriano-Mas, C., & Fernandez-Aranda, F. (2021). The neural correlates of delay discounting in obesity and binge eating disorder. *Journal of Behavioral Addictions*, *10*(3), 498–507. https://doi.org/10.1556/2006.2021.00023

Moeller, F. G., Barratt, E. S., Dougherty, D. M., Schmitz, J. M., & Swann, A. C. (2001). Psychiatric aspects of impulsivity. *American Journal of Psychiatry*, *158*(11), 1783–1793. https://doi.org/10.1176/appi.ajp.158.11.1783

Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J.-C., Louzada, M. L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: What they are and how to identify them. *Public Health Nutrition*, *22*(5), 936–941. https://doi.org/10.1017/S1368980018003762

Moran, L. J., Sui, Z., Cramp, C. S., & Dodd, J. M. (2013). A decrease in diet quality occurs during pregnancy in overweight and obese women which is maintained post-partum. *International Journal of Obesity*, *37*(5), 704–711. https://doi.org/10.1038/ijo.2012.129

Most, J., Dervis, S., Haman, F., Adamo, K. B., & Redman, L. M. (2019). Energy intake requirements in pregnancy. *Nutrients*, *11*(8), 1812. https://doi.org/10.3390/nu11081812

Müller, V. I., Langner, R., Cieslik, E. C., Rottschy, C., & Eickhoff, S. B. (2015). Interindividual differences in cognitive flexibility: Influence of gray matter volume, functional connectivity and trait impulsivity. *Brain Structure and Function*, *220*(4), 2401–2414. https://doi.org/10.1007/s00429-014-0797-6

Nansel, T. R., Cummings, J. R., Burger, K., Siega-Riz, A. M., & Lipsky, L. M. (2022). Greater ultra-processed food intake during pregnancy and postpartum Is associated with multiple aspects of lower diet quality. *Nutrients*, *14*(19), 3933. https://doi.org/10.3390/nu14193933

Nansel, T. R., Lipsky, L. M., Faith, M., Liu, A., & Siega-Riz, A. M. (2020). The accelerator, the brake, and the terrain: Associations of reward-related eating, self-regulation, and the home food environment with diet quality during pregnancy and postpartum in the pregnancy eating attributes study (PEAS) cohort. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 149. https://doi.org/10.1186/s12966-020-01047-x

Nolan-Poupart, S., Veldhuizen, M. G., Geha, P., & Small, D. M. (2013). Midbrain response to milkshake correlates with ad libitum milkshake intake in the absence of hunger. *Appetite*, *60*, 168–174. https://doi.org/10.1016/j.appet.2012.09.032

Nutrition Coordinating Center. (2023a). *24-hr dietary recall collection*. University of Minnesota. http://www.ncc.umn.edu/24-hr-dietary-recall-collection/

Nutrition Coordinating Center. (2023b). *Features*. University of Minnesota. http://www.ncc.umn.edu/products/features/

Orloff, N. C., Flammer, A., Hartnett, J., Liquorman, S., Samelson, R., & Hormes, J. M. (2016). Food cravings in pregnancy: Preliminary evidence for a role in excess gestational weight gain. *Appetite*, *105*, 259–265. https://doi.org/10.1016/j.appet.2016.04.040

Parker, H. W., Tovar, A., McCurdy, K., & Vadiveloo, M. (2019). Associations between pre-pregnancy BMI, gestational weight gain, and prenatal diet quality in a national sample. *PLOS ONE*, *14*(10), e0224034. https://doi.org/10.1371/journal.pone.0224034

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology*, *51*(6), 768–774. https://doi.org/10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Pérez-Ortiz, J. M., Galiana-Simal, A., Salas, E., González-Martín, C., García-Rojo, M., & Alguacil, L. F. (2017). A high-fat diet combined with food deprivation increases food seeking and the expression of candidate biomarkers of addiction. *Addiction Biology*, *22*(4), 1002–1009. https://doi.org/10.1111/adb.12389

R Core Team. (2023). *R: A Language and environment for statistical computing* [Mac]. R Foundation for Statistical Computing. https://www.R-project.org/

Reed, D. D., Kaplan, B. A., & Brewer, A. T. (2012). A tutorial on the use of Excel 2010 and Excel for Mac 2011 for conducting delay-discounting analyses. *Journal of Applied Behavior Analysis*, *45*(2), 375–386. https://doi.org/10.1901/jaba.2012.45-375

Reynolds, B., Ortengren, A., Richards, J. B., & de Wit, H. (2006). Dimensions of impulsive behavior: Personality and behavioral measures. *Personality and Individual Differences*, *40*(2), 305–315. https://doi.org/10.1016/j.paid.2005.03.024

Rhee, J. J., Sampson, L., Cho, E., Hughes, M. D., Hu, F. B., & Willett, W. C. (2015). Comparison of methods to account for implausible reporting of energy intake in epidemiologic studies. *American Journal of Epidemiology*, *181*(4), 225–233. https://doi.org/10.1093/aje/kwu308

Richards, J. B., Zhang, L., Mitchell, S. H., & de Wit, H. (1999). Delay or probability discounting in a model of impulsive behavior: Effect of alcohol. *Journal of the Experimental Analysis of Behavior*, *71*(2), 121–143. https://doi.org/10.1901/jeab.1999.71-121

Rohatgi, K. W., Tinius, R. A., Cade, W. T., Steele, E. M., Cahill, A. G., & Parra, D. C. (2017). Relationships between consumption of ultra-processed foods, gestational weight gain and neonatal outcomes in a sample of US pregnant women. *PeerJ*, *5*, e4091. https://doi.org/10.7717/peerj.4091

Rollins, B. Y., Dearing, K. K., & Epstein, L. H. (2010). Delay discounting moderates the effect of food reinforcement on energy intake among non-obese women. *Appetite*, *55*(3), 420–425. https://doi.org/10.1016/j.appet.2010.07.014

Sheikh, J., Allotey, J., Kew, T., Fernández-Félix, B. M., Zamora, J., Khalil, A., Thangaratinam, S., Abdollahain, M., Savitri, A. I., Salvesen, K. Å., Bhattacharya, S., Uiterwaal, C. S. P. M., Staff, A. C., Andersen, L. B., Olive, E. L., Daskalakis, G., Macleod, M., Thilaganathan, B., Ramírez, J. A., … Van Gelder, M. (2022). Effects of race and ethnicity on perinatal outcomes in high-income and upper-middle-income countries: An individual participant data meta-analysis of 2 198 655 pregnancies. *The Lancet*, *400*(10368), 2049–2062. https://doi.org/10.1016/S0140-6736(22)01191-6

Shin, D., Chung, H., Weatherspoon, L., & Song, W. O. (2014). Validity of prepregnancy weight status estimated from self-reported height and weight. *Maternal and Child Health Journal*, *18*(7), 1667–1674. https://doi.org/10.1007/s10995-013-1407-6

Sneed, N. M., Ukwuani, S., Sommer, E. C., Samuels, L. R., Truesdale, K. P., Matheson, D., Noerper, T. E., Barkin, S. L., & Heerman, W. J. (2023). Reliability and validity of assigning ultraprocessed food categories to 24-h dietary recall data. *The American Journal of Clinical Nutrition*, *117*(1), 182–190. https://doi.org/10.1016/j.ajcnut.2022.10.016

Stanford, M. S., Mathias, C. W., Dougherty, D. M., Lake, S. L., Anderson, N. E., & Patton, J. H. (2009). Fifty years of the Barratt Impulsiveness Scale: An update and review. *Personality and Individual Differences*, *47*(5), 385–395. https://doi.org/10.1016/j.paid.2009.04.008

Steele, E. M., O'Connor, L. E., Juul, F., Khandpur, N., Galastri Baraldi, L., Monteiro, C. A., Parekh, N., & Herrick, K. A. (2023). Identifying and estimating ultraprocessed food intake in the US NHANES according to the Nova Classification System of Food Processing. *The Journal of Nutrition*, *153*(1), 225–241. https://doi.org/10.1016/j.tjnut.2022.09.001

Stok, F. M., De Vet, E., Wardle, J., Chu, M. T., De Wit, J., & De Ridder, D. T. D. (2015). Navigating the obesogenic environment: How psychological sensitivity to the food environment and self-regulatory competence are associated with adolescent unhealthy snacking. *Eating Behaviors*, *17*, 19–22. https://doi.org/10.1016/j.eatbeh.2014.12.003

Temple, J. L. (2016). Behavioral sensitization of the reinforcing value of food: What food and drugs have in common. *Preventive Medicine*, *92*, 90–99. https://doi.org/10.1016/j.ypmed.2016.06.022

Thomas, J. G., Doshi, S., Crosby, R. D., & Lowe, M. R. (2011). Ecological momentary assessment of obesogenic eating behavior: Combining person-specific and environmental predictors. *Obesity*, *19*(8), 1574–1579. https://doi.org/10.1038/oby.2010.335

Tierson, F. D., Olsen, C. L., & Hook, E. B. (2010). Influence of cravings and aversions on diet in pregnancy. *Ecology of Food and Nutrition*, *17*(2), 117–129. https://doi.org/10.1080/03670244.1985.9990886

Ural, C., Belli, H., Akbudak, M., Solmaz, A., Bektas, Z. D., & Celebi, F. (2017). Relation of binge eating disorder with impulsiveness in obese individuals. *World Journal of Psychiatry*, *7*(2), 114. https://doi.org/10.5498/wjp.v7.i2.114

Verhoeven, A. A. C., Adriaanse, M. A., Evers, C., & De Ridder, D. T. D. (2012). The power of habits: Unhealthy snacking behaviour is primarily predicted by habit strength. *British Journal of Health Psychology*, *17*(4), 758–770. https://doi.org/10.1111/j.2044-8287.2012.02070.x

Waltmann, M., Herzog, N., Horstmann, A., & Deserno, L. (2021). Loss of control over eating: A systematic review of task based research into impulsive and compulsive processes in binge eating. *Neuroscience & Biobehavioral Reviews*, *129*, 330–350. https://doi.org/10.1016/j.neubiorev.2021.07.016

Weafer, J., Baggott, M. J., & de Wit, H. (2013). Test–retest reliability of behavioral measures of impulsive choice, impulsive action, and inattention. *Experimental and Clinical Psychopharmacology*, *21*(6), 475–481. https://doi.org/10.1037/a0033659

Weck, R. L., Paulose, T., & Flaws, J. A. (2008). Impact of environmental factors and poverty on pregnancy outcomes. *Clinical Obstetrics & Gynecology*, *51*(2), 349–359. https://doi.org/10.1097/GRF.0b013e31816f276e

Wongsomboon, V., & Webster, G. D. (2023). Delay discounting for HIV/STI testing. *Sexuality Research and Social Policy*. https://doi.org/10.1007/s13178-023-00819-x

Wray, J. M., Gass, J. C., & Tiffany, S. T. (2013). A systematic review of the relationships between craving and smoking cessation. *Nicotine & Tobacco Research*, *15*(7), 1167–1182. https://doi.org/10.1093/ntr/nts268

Yoon, J. H., Higgins, S. T., Heil, S. H., Sugarbaker, R. J., Thomas, C. S., & Badger, G. J. (2007). Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. *Experimental and Clinical Psychopharmacology*, *15*(2), 176–186. https://doi.org/10.1037/1064-1297.15.2.186

Yoshikawa, T., Tanaka, M., Ishii, A., & Watanabe, Y. (2013). Immediate neural responses of appetitive motives and its relationship with hedonic appetite and body weight as revealed by magnetoencephalography. *Medical Science Monitor*, *19*, 631–640. https://doi.org/10.12659/MSM.889234